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Full Length Research Paper

Effect of zinc and phosphorus fertilizers application on yield and yield components of faba bean (V*icia faba L.)* grown in calcaric cambisol of semi-arid northern Ethiopia

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A pot experiment under greenhouse conditions to evaluate the effect of P and Zn nutrients on yield and yield components of faba bean (*Vicia faba L.* CS20DK) was conducted in P and Zn deficient alkaline soil at Mekelle Agricultural Research Center in 2009. A factorial combination of P and Zn fertilization with three levels of P (0, 30, and 60 kgPha^{-1}) and with three levels of Zn (0, 15, and 25 kg Zn ha^{-1}) was laid in randomized complete block design in with three blocks. Triple super phosphate (46% P), urea (46% N), KCl and $ZnSO_4$ $7H_2O$ (22.75% Zn) were used as source of fertilizers for the greenhouse experiment. The results showed that P fertilization significantly increased ($p<0.05$) yield and yield components and attributes in faba bean plant. Similarly, Zn fertilization significantly increased ($p<0.05$) pods per plant and above ground biomass at maturity stage of faba bean plant, but, it did not significantly affect biomass at 50% flowering, root weight at 50% flowering, grain yield, yield components and attributes. Combined fertilization of P and Zn had significant effect on pods per plant, seeds per pod and plant height at maturity stages, while, it had no significant affect on yield and other yield attributes. Furthermore, there was positive correlation between yield and yield components. This study concludes that grain yield and biomass yield increased with the increase in phosphorus fertilizer. Application of 60 kg P/ha gave statistically higher grain yield than 0 and 30 kg P/ha. Interaction effect of P and Zn shows significant effect on pods per plant, seeds/pod, and plant height at maturity stage. However, there was no significant effect on yield and some yield attributes of faba bean.

Key words: Faba bean, zinc, phosphorus, yield, yield component.

INTRODUCTION

Ethiopia is the largest producer of cool-season food legumes (CSFL) in Africa (Yamane and Skjelvg, 2003). Among the CSFL, a faba bean variety *(Vicia faba L.*) is grown by subsistence farmers in Ethiopia, during the cool main rainy season (June to September). Faba bean is the most important pulse crop in Ethiopia, occupying about 34% of the total land area under pulses (CSA, 2007).

The dry grains of this legume have been an important protein source for human diet for centuries, in which animal protein is expensive or not sufficiently available. The straw of the crop is also used as animal feed and soil fertility restorer (El Tinay et al., 1993; Amanuel et al., 2000; and Habtegebriel et al., 2007). Yield of faba bean is very low, mainly limited by poor soil fertility (Tsigie and Woldeab, 1994), as it is cultivated in inherently poor soils often without fertilization.

Phosphorous is the major potentially yield limiting nutrient in the high lands of Ethiopia, in which most soils are dominantly deficient in it (Miressa and Roborge, 1999), and among the micronutrients, Zn is widely reported to limit crop production and about 30 to 50% of world

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cultivated soils are considered deficient in Zn (Sillanpää, 1982; Mendel et al., 2000). The deficiency of these nutrients becomes even more serious in alkaline calcareous dry soils. In these soils, P and Zn are mainly found as insoluble or plant unavailable forms, P fixed in apatite calcium minerals and Zn existing as insoluble zinc hydroxides and adsorbed strongly to carbonate minerals, such as calcite and dolomite (Cakmak et al., 1996).

The other important aspect of P and Zn nutrition is the interaction effect between them, especially in soils marginally deficient in P and Zn. If P and Zn are fertilized together, to such soils crop yields are reported to increase with positive interaction of P and Zn (Havlin et al., 2005). The requirement of P and Zn by faba bean is relatively high. Faba bean may require P and Zn fertilization in the range of 20 to 30 kg P ha^{-1} and 10 to 25 kg Zn ha^{-1} (Prasad and Power, 1997; FAO, 2000).

Use of mineral fertilizers to increase crop productivity by Ethiopian farmers is low and the use of micronutrient fertilization is uncommon. Limited studies on the effect of P on yield (Tsigie and Woldeab 1994; Yamane and Skjelvg, 2003) are reported for Ethiopian conditions. However, studies on the effect of P and Zn fertilization to CSFL on soils deficient in P and Zn are generally missing in Ethiopia. Thus, this study was conducted in greenhouse pot experiments to assess the effect of combined fertilization of different rates of P and Zn on yield and yield components of faba bean plants using a calcareous alkaline soil that is deficient in P and Zn nutrients.

Highland soils of Ethiopia are low in soil organic matter, and dominantly deficient in major nutrients. The availability of P and micronutrients in alkaline calcareous soils is curtailed mainly by the fixing potential of these soils to nutrients like P and Zn; hence, limiting their plant available concentrations. The effect of P and Zn and their interaction on plants is known, but the extent of limiting the yield potential of grain legumes is little known in calcareous dry land soils of Northern Ethiopia. Thus, it is important to study the effect of P and Zn nutrients and their interaction on yield components and yield potential of one of the common grain legumes- faba bean (*V. faba L.*). A preliminary greenhouse study on the effect of the combined fertilization of different rates of P and Zn on yield components and yield of faba bean will be conducted using an alkaline soil deficient in both nutrients. This will logically lead to a similar study at field-scale, which may be possible to recommend the rates needed to optimize the yield of faba bean on these soils. Thus, the objective of this study was to examine the effect of Zn and P fertilization and their interaction on yield and yield components of faba bean plants.

MATERIAL AND METHODS

General description of the experimental area

The greenhouse pot experiment was conducted at the Mekelle Research Institute, Tigray- Northern Ethiopia at 13°14'N and 39°32'E, and at 2100 meter above sea level from October first to the end of December of 2009 G.C. This is located 3 km to the north from the center of Mekelle town. The soil was collected from Elala from nearby farmers' fields.

Soils and climate

The area has a bimodal rainfall with an annual average rainfall of 453.3 mm. The minimum and maximum temperature of the area is 12.3 and 27.1°C, respectively (Tigray Agricultural Research Institute, 2009). Rainfall is distributed between the short rainfall season (March to April) and the main rainy season (June to September). This pattern is, however, extremely variable with high probability of no rainfall during the short rainfall season. The soil from which the pot experiment was conducted is classified as Cambisol according to FAO/UNESCO (1984).

Soil extraction and plant sampling and analysis

Cambisols were used to conduct a pot experiment in the greenhouse. Soil medium for the greenhouse experiments were taken from 0 to 50 cm depth with the help of a spade during October 17/2009. The soil was air dried under shade and ground with a wooden roller and then passed through a 2 mm sieve. The soils were used to fill plastic pots having 20 cm diameter, depth of 30 cm and capacity of 10 kg.

For the analysis of some soil physical and chemical properties, a composite soil sample was collected using auger from the field at 0 to 50 cm soil depth, before planting. The collected soil samples were bulked to make a composite sample. The sample was air-dried, ground, sieved to pass 2 mm size screen and stored in sealed plastic for laboratory analysis. The composite soil sample was analyzed for some soil parameters at Mekelle Agricultural Research Center Soil Laboratory.

Soil pH was measured in a suspension of a 1:2.5 soil to water ratio as described by Jackson (1958), organic carbon was determined by the method described by Wakley and Black (1934) and CEC was determined by ammonium acetate method. Available soil phosphorus was analyzed using Olsen method (Olsen et al., 1954). To determine the available potassium in the soil, the sample was extracted with Morgan solution and K in the extract was measured by flame photometer. Total nitrogen was determined by Kjeldehal method (Sahlemedhin and Taye, 2000) and calcium carbonate was determined by the method described by Jackson (1970). Available Zn was determined by using diethylene triamine penta acetic acid (DTPA) extraction, a procedure developed by Lindsay and Norvell as outlined by Sahlemedhin and Taye (2000). Particle size was determined by international pipette method (Sahlemedhin and Taye, 2000).These all above mentioned parameters were analyzed at the soil laboratory of Tigray Agricultural Research Center.

Experimental design and treatments

A factorial combination of two factors, P and Zn, P with three levels0, 30 and 60 kg P ha^{-1}) and Zn with three levels (0, 15 and 25 kg Zn ha^{-1}) laid in randomized complete block design (RCBD) with six replication. 23 kg N ha^{-1} and 60 kg K ha^{-1} were applied to all pots as (starter-N and basal dressing, respectively. Triple super (46% P), Urea (46% N), KCl and $ZnSO_4$ $7H_2O$ (22.75% Zn) were used as source of fertilizers for the greenhouse experiment.

Faba bean (*V. faba L.* CS20DK) was obtained from the Ethiopian Seed Agency (ESA). Four faba bean seeds were planted for every pot which was later thinned to three plants after 10 days of

Table 1. Some selected physical and chemical properties for the Cambisol soil from site at Elala.

Soil parameter	Measured value
pH (1:2.5 soil water suspension)	8.3
Electrical conductivity (dSm^{-1} at 25°C)	0.12
Organic carbon (%)	1.23
Available P ($mg.kg^{-1}$)	4
Available K ($mg.kg^{-1}$)	180
Total Nitrogen (%)	0.14
Calcium carbonate equivalent (%)	17
Cation exchange capacity [$Cmol_c\ kg^{-1}$]	38.6
DTPA Zn ($mg.kg^{-1}$soil)	0.47
Particle size analysis	
Clay (%)	40
Silt (%)	41
Sand (%)	19

emergence. The actual rates of treatments (P and Zn), starter-N and basal dressing-KCl were calculated one plant per pot basis by taking 50 plants m^{-2} density of field experiments into consideration (Yamane and Skjelvg, 2003). Combined fertilizers (P + Zn + N + K) were placed 5 × 5 cm to the side and below the seed at planting. The date of sowing was October 17 of 2009.

Experimental under greenhouse condition

The maximum and minimum average temperature recorded during the greenhouse experiment was 24°C and 13°C respectively. The pots were arranged with a distance of 20 cm between pots of a block and 20 cm between blocks. The crop was kept free of weeds by hand picking every week after emergence.

For the first 14 days after sowing, soils were maintained at 75% of field capacity, using deionized water. Thereafter, the pots were maintained at field capacity by frequent watering to weight. The pots were randomized in the greenhouse after each watering to eliminate any environmental effects, especially solar radiation.

Yield, yield component and nodulation

The following yield components and attributes were measured for the effect of P and Zn fertilization on:

1. Plant height: This was measured at 50% flowering and physiological maturity by measuring the main stem height from the ground up to the canopy height using a ruler and average height per plant was recorded. Number of branches $plant^{-1}$: This was determined by counting the number of branches of each plant in a pot and the average number of branches per plant was recorded. Number of seeds pod^{-1}: This was determined by counting number of seeds in pod and the average seed per pod was recorded.
Number of pods $plant^{-1}$: Number of pods $plant^{-1}$ of faba bean was obtained by collecting all pods from each plant and the average number per plant for each pot.
2. Seed yield: This was measured per plant for the different treatment combinations, from the air-dried seeds adjusted at 12.5% seed moisture content.

Statistical analysis

Greenhouse from randomized complete block design data were analyzed using GenStat Discovery Edition 3. Two factor analyses of variance (ANOVA) were performed to evaluate the main and interaction effects of treatments (P and Zn-fertilization), on yield and yield components of faba bean. Pearson correlation product moment coefficients (r) and the significance of the correlations between yield and yield component were conducted. LSD was used to compare treatment means and the probability significance level of a treatment effects and correlations were evaluated at α=0.05.

RESULT AND DISCUSSION

Physical and chemical analysis of the soil

The results of analysis for some selected physical and chemical properties of the soil used in the pot experiment are given in Table 1. The soil is silt clay in texture, alkaline in pH and calcareous with calcium carbonate content of 17% (Havlin et al., 2005). The soil is non-saline with low organic matter content (<5%) and deficient in total N content, typical for semiarid soils (Landon, 1991; Brady and Weil, 2002). The alkaline pH and high $CaCO_3$ content of the soil indicate the fixing potential of the soil of P, Zn and other micronutrient metal ions. This could also be seen from the analysis concentration values for the available P and Zn in which the available P and Zn contents place the soil in the deficient P (4 to 7 ppm of Olsen-P) and deficient Zn (0 to 0.5 ppm) categories that are in low range or deficient content category (Landon, 1991; Havlin et al., 2005).

Yield, yield components and attributes

As a measure of yield, above-ground biomass, root weight at 50% flowering and total above-ground biomass at maturity and grain yield were measured. Pods $plant^{-1}$, and seeds pod^{-1} were measured as yield components (Fageria, 2009); branches $plant^{-1}$ at maturity, plant height both at 50% flowering and maturity were measured as yield attributes.

Phosphorus fertilization showed significant differences ($P≤0.05$) in pods per plant, seeds per pod, and number of branches per plant at maturity, and plant height both at 50% flowering and maturity stage (Table 2). This may probably be due to the cumulative effect of phosphorus in the processes of cell division and balanced nutrition (Zafar, 2003). The yield advantage of faba bean by applying P could be attributed to an increase in the number of productive nodes and number of pods per plant. In fact, the number of pods per faba bean plant was found to correlate strongly with grain yield in this experiment (Yemane and Skjelvg, 2003).

Similarly, zinc fertilization did significantly affect ($P≤0.05$) the number of pods per plant. However, it had no significant effect on plant height at 50% flowering, seeds per pod and plant height at maturity stages. Although it is not significant, an increasing trend in these parameters was observed with zinc fertilization. This may be due to

Table 2. Main effect of Zn and P fertilization on number of branches (nbs), pods $plant^{-1}$ (ppp), seeds pod^{-1}(spp), plant height 50% flowering (phf) and maturity stage (phm) of faba bean.

Source of variation	Phf	nbs	ppp	spp	Phm
Phosphorus (kg P/ha)					
0	39.8^{b}	0.22^{b}	4.22a^{b}	2.78^{b}	52.98^{c}
30	41.79^{b}	0.67^{b}	4.00^{b}	2.22^{b}	60.83^{b}
60	47.5^{a}	1.4^{a}	5.00^{a}	3.89^{a}	75.44^{a}
SE	1.46	0.23	0.345	0.474	0.155
LSD	3.1	0.48	0.732	1.004	4.411
CV (%)	7.2	62.5	16.6	33.9	24.00
Zinc (kg Zn/ha)					
0	41.69	0.89	3.89^{b}	2.89	62.22
15	43.13	0.67	4.56^{ab}	3.00	65.61
25	44.27	0.78	4.78^{a}	3.00	61.42
SE	1.46	0.23	0.345	0.474	0.155
LSD	Ns	ns	0.732	ns	Ns
CV (%)	7.2	62.5	16.6	33.9	24.00

Means not connected by the same letters are significantly different at alpha 0.05;, ns non-significant.

Table 3. Interaction effect of Zn and P fertilization on pods per plant (ppp), seeds per pod (spp),number of branches (nbr), plant height at 50% flowering (phf) and plant height at maturity stage (phm).

Treatment combination	ppp	spp	nbr	phf	phm
P_0Zn_0	3.67^{c}	3.67^{ab}	0.33	40.17	52.50^{e}
P_0Zn_{15}	5.33^{ab}	2.67^{bc}	0.67	39.20	62.85^{cde}
P_0Zn_{25}	3.67^{c}	2.00^{de}	0.00	40.03	43.60^{f}
$P_{30}Zn_0$	3.00^{cd}	1.00^{e}	1.00	41.43	66.70^{bc}
$P_{30}Zn_{15}$	4.00^{bc}	2.33^{cd}	0.67	40.37	56.50^{e}
$P_{30}Zn_{25}$	5.00^{ab}	3.33^{abc}	0.33	43.57	64.33^{cd}
$P_{60}Zn_0$	5.00^{ab}	4.00^{a}	1.00	43.47	72.50^{ab}
$P_{60}Zn_{15}$	4.33^{bc}	4.00^{a}	1.00	49.83	77.50^{a}
$P_{60}Zn_{25}$	5.67^{a}	3.67^{ab}	1.67	49.20	76.33^{a}
SE	0.598	0.474	0.397	2.5	3.6
LSD	1.268	1.001	ns	ns	7.64
CV(%)	16.6	33.9	62.5	7.2	7

Means not connected by the same letters are significantly different at alpha 0.05; ns, non-significant.

the fact that zinc is important in fruiting, growth and metabolism of crop plants (Fageria, 2009).

The interaction effect of Zn and P fertilization had also significant effect ($P \leq 0.05$) on the number of pods per plant, seeds per pod and plant height at maturity stage (Table 3). However, the combined effect of these nutrients did not significantly affect plant height at 50% flowering, and number of branches of faba bean. Though the height at 50% flowering and number of branches at maturity of faba bean plants were not significant, highest plant height at 50% flowering at fertilization combination of $P_{60}Zn_{15}$ and $P_{60}Zn_{25}$, and number of branches at $P_{60}Zn_{25}$ were observed. When P and Zn were fertilized together at rates of P_1 (30 $kgPha^{-1}$) and Zn_1 (15 kg Zn ha^{-1}), the height of faba bean plants at maturity stage increased significantly ($P<0.05$) by 27% compared to the control (P_0Zn_0). In contrast, when P was fertilized to the highest rate (60 kg P ha^{-1}) the height at maturity stage of faba bean plant increased significantly ($P<0.05$) from 66.7 cm ($P_{30}Zn_{15}$) to 77.5 cm ($P_{60}Zn_{15}$) accounting an increase of 17%. Fertilization of P and Zn together at a rate of P_2 (60 kg P ha^{-1}) and Zn_2 (25 kg Zn ha^{-1}), the number of pods per plant significantly increased from3.67 [P_0Zn_0 (P=0 kg P ha^{-1} and 0 kg Zn ha^{-1})] and 4 ($P_{30}Zn_{15}$) to 5.67 ($P_{60}Zn_{25}$). Phosphorus is involved in photosynthetic energy transfer. Similarly, Zn is also involved in photosynthetic enzymatic process, which are both important for growth of plants (Jakobsen, 1985;

Table 4. Main effect of P and Zn fertilization on root weight at 50% flowering (g plant^{-1}), aboveground biomass yield at 50% flowering and at maturity (g plant^{-1}) and grain yield (g plant^{-1}) of faba bean plant.

Source of variation	Root weight at 50% flowering	Biomass yield at 50% flowering	Biomass yield at maturity stage	Grain yield
Phosphorus (kg P/ha)				
0	0.752^{c}	1.076^{b}	2.09^{c}	0.98^{b}
30	1.140^{a}	1.328^{ab}	2.45^{b}	0.85^{b}
60	1.262^{a}	1.695^{a}	3.76^{a}	1.48^{a}
SE	0.177	0.155	0.327	0.222
LSD	0.375	0.328	0.694	0.47
CV (%)	35.7	24	25.1	42.7
Zinc (kg Zn/ha)				
0	0.91	1.217	2.38^{b}	1.094
15	0.993	1.342	2.65^{ab}	1.001
25	1.25	1.541	3.26^{a}	1.211
SE	0.177	0.155	0.327	0.222
LSD	ns	ns	0.694	Ns
CV (%)	35.7	24	25.1	42.7

Means not connected by the same letters are significantly different at alpha 0.05, ns non-significant.

Fageria, 2009).

Data regarding above ground biomass yield, grain yield, root weight is presented in Table 4. Phosphorus fertilization showed significant differences (P≤ 0.05) in grain yield, root weight at 50% flowering, above ground biomass yield both at 50% flowering and at maturity stages. The application of 60 kg P ha^{-1} resulted in significant (P≤ 0.05) higher grain yield, aboveground biomass yield both at 50% flowering and maturity stages, root weight at 50% flowering than 30kg P ha^{-1} and the control treatments (P_0) (Table 4). The application of 60 kg P ha^{-1} increased the biomass yield by approximately 57% compared with control treatment. This may probably be due to stimulated biological activities in the presence of balanced nutrient supply (Zafar, 2003). The increment in yield due to phosphorus fertilizer may be attributed to the activation of metabolic processes, where P is important nutrient that increases the leaf area and improve the rate of photosynthetic assimilation. Furthermore, its ability to increase productive pods per plant enhances the biomass and grain yield of legumes (Marschner, 1986; Yemane and Skjelvg, 2003). These results are in agreement with the recent findings of (Habtegebriel et al., 2007) that dry matter of pea were significantly improved by P fertilization, increasing the yield by 48% relative to the control. Result is also in accordance with the result obtained by SrARC (Sirinka Agricultural Research Center, 2002) who reported that application of phosphorus fertilizer had significant effect on plant height, root weight and biomass yield of faba bean.

However, the results revealed that zinc fertilization did not have a significant effect on aboveground biomass yield at 50% flowering, root weight at 50% flowering and grain yield at maturity stage (Table 4). Though this was not statistically significant (P≤ 0.05), the results showed an increasing trend with increasing zinc fertilization. The mean values of the levels of zinc presented in Table 4 showed that the increase in of zinc from 0 to 25 kg Zn ha^{-1} levels increases the root weight from 0.91 to 1.25 g plant^{-1} at 50% flowering, aboveground biomass yield from 1.217 to 1.541 g plant^{-1} at 50% flowering and grain yield from 1.1 to 1.2 g plant^{-1} at maturity stage. This might be because Zn improves root development, fruiting, growth and development of crop plants (Fageria, 2009). However, zinc fertilization had significant effect (P≤ 0.05) in above ground biomass yield at maturity stage. Haluk et al. (1999) also reported the same results in rice.

Correlation of some important yield, yield components and attributes of faba bean

Biomass yield had significant, strong and positive correlation with average plant height and average number of branches could also had strong (r=0.65), positive and significant (P=0.06) correlation with number of seeds per pod (Table 5). Number of pods per plant was positively and mildly correlated. This indicates that biomass yield significantly increases with an increase of average plant height and average number of branches per plant and these attributes contribute to the majority on the biomass yield of the crop.

Number of seeds/pod had highly significant, very strong and positive correlation with grain yield of faba bean which means that when this yield component increase, grain yield increase significantly (Table 5). But average

Table 5. Correlation between some yield, yield components and attributes of faba bean.

Variable	By variable	r-Value	P-Value
Biomass yield (g plant^{-1})	Average plant height (cm)	0.7815	0.0129
Biomass yield (g plant^{-1})	Average number of branches	0.7232	0.0277
Biomass yield (g plant^{-1})	Number of pods/plant	0.4108	0.2720
Biomass yield (g plant^{-1})	Number of seeds/pod	0.6504	0.0579
Grain yield (g plant^{-1})	Average plant height (cm)	0.5453	0.1289
Grain yield (g plant^{-1})	Average number of branches	0.2820	0.4623
Grain yield (g plant^{-1})	Number of pods/plant	0.7654	0.0162
Grain yield (g plant^{-1})	Number of seeds/pod	0.9510	0.0001
Grain yield (g plant^{-1})	Biomass yield (g plant^{-1})	0.6182	0.076

r = Correlation coefficient with values <0.2 and >-0.2 indicating very weak correlation; 0.2 to 0.4 and -0.2 to -0.4 weak correlation; 0.4 to 0.6 and -0.4 to -0.6 mild correlation; and 0.6 to 0.8 and -0.6 to -0.8 strongly correlated and >0.8 and <-0.8 very strongly correlated, P-value= highly significantly correlated 0.01; P-value= significantly correlated at 0.05 probability.

pods per plant were correlated significantly, strongly and positively but biomass yield had no significant, strong, and positive correlation with grain yield plant. Furthermore, number of branches was weakly, positively but not significant correlated with grain yield. Generally, numbers of seeds per pod and number pods per plant are major contributors to the increment of grain yield during faba bean production.

CONCLUSION AND RECOMMENDATION

From this study it was possible to conclude that phosphorus fertilization has brought a significant effect in the faba bean yield, yield components and attributes. Grain yield and biomass yield increased with the increase in phosphorus fertilizer. Application of 60 kg P/ha gave statistically higher grain yield than 0 and 30 kg P/ha.

Zinc fertilization significantly increased pods per plant, aboveground biomass yield at maturity stage of faba bean, while it had not significantly affected grain yield and other yield attributes.

Combined fertilization of P and Zn had no significant effect on the number of branches, plant height at 50% flowering, grain yield, biomass yield at maturity and at 50% flowering, root weight at 50% flowering of faba bean, however, the combined fertilization of these nutrients had significant effect on the other yield attributes. Furthermore, there was a positive correlation between grain yield and biomass yields, plant height at maturity stages, seeds per pod, and pods per plant were found. Biomass yield was also positively correlated with plant height, number of branches, seeds per pod, pods per plant and grain yield at maturity stages were found.

Finally, this study recommends that the application of combined fertilization of zinc and phosphorus have significant increase in seeds pod^{-1}, pods plant^{-1} and plant height at maturity stage. These parameters are highly associated with yield of faba bean. Therefore researchers can use this finding for further study.

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