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Inoculation, phosphorous and zinc fertilization effects on nodulation, yield and nutrient uptake of Faba bean (*Vicia faba* L.) grown on calcaric cambisol of semiarid Ethiopia

Yohannes Desta, Kiros Habtegebrial* and Yirga Weldu

Department of Land Resource Management and Environmental Protection, Mekelle University, P. O. Box 231, Mekelle, Ethiopia.

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A field experiment was conducted in 2010 crop season with three factors: Inoculation (U = no inoculums and I = with inoculums), three levels of P (0, 20, 40kgPha^{-1}) and three levels of Zn (0, 15, 25kgZnha^{-1}) fertilizations. The experiments were laid in randomized complete blocks in three replications on calcaric cambisols to study effects of inoculation, P and Zn fertilizations on nodulation, yield, yield components, and the uptake N, P and Zn by the plant. Composite soil samples were collected one month before sowing and plant samples were taken both at 50% flowering and plant maturity. Findings showed that, the main and interaction effects of inoculation, P and Zn fertilization were found to affect significantly (P < 0.05) the root distribution and mass of nodules, the concentration of N, P and Zn in nodule, root and leaf tissues at 50% flowering, At maturity, P and Zn were found to significantly increase the root length, root fresh weight of the plant, and inoculation significantly affected the root fresh weight. Phosphorous and Zn fertilization improved the grain yield, pods plant^{-1}, grain pod^{-1}, number of branches, and the grain uptake of N, P and Zn nutrients. The combined application of inoculation, P and Zn fertilization increased the grain yield on average by 1.3 Mg ha^{-1}. Phosphorous and Zn fertilization alone increased the grain P and Zn uptake by 1.1 and 2.7 × 10^{-2} kg ha^{-1}, respectively, and the combined application of inoculation, P and Zn improved the N uptake of the faba bean grains on average by 40 kg ha^{-1}. Thus, inoculating the legume with efficient and compatible rhizobium, and fertilizing it with P and Zn should be recommended to soils deficient in P and Zn, especially in alkaline calcareous soils.

Key words: Semiarid, nodulation, inoculation, zinc, phosphorus, yield, nutrient uptake, faba bean.

INTRODUCTION

Ethiopia is one of the largest faba bean (*Vacia faba* L.) producing country in Africa and the world (Hawitin and Hebblewaite, 1993). Faba bean is a cool-season food legume (CSFL), grown in Ethiopian highlands and occupies about 34% of the total cultivated land under pulses (CSA, 2012). The grain of faba bean is an

*Corresponding author. E-mail: rabkir2@gmail.com, Tel: +251-0914-701152. Fax: + 251-0344-409304.

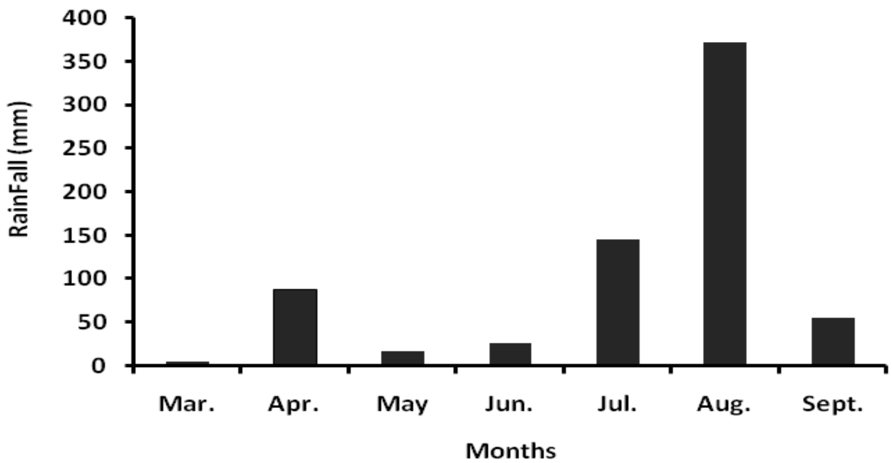

Figure 1. Monthly rainfall (mm) distribution for 2010 at MU.

important source of proteins and its straw serves as animal feed and soil fertility restorer. In addition to being an important food crop, faba bean also plays an important role in legume-cereal cropping system because of its high N_2 fixing ability. Furthermore, grain legumes, such as faba bean could serve as alternative to fallow and in turn increase land use, weed control and reduce the need for inorganic fertilizers (Carlos and Minguez, 2001).

The yield of faba bean is low, mainly limited by mineral nutrient availability and lack of efficient and compatible strains of rhizobium in the soil (Habtegebrial et al., 2007). However, faba bean, among the grain legumes is reported to derive the highest percentage of N from the atmosphere (Hardarson et al., 1987), and the yield, protein content, nodulation and amount of N_2 fixed are reported to increase with rhizobium inoculation and mineral nutrient applications (Elsiddig and Abudlhafize, 1997; Shibru and Mitiku, 2000; Habtegebrial et al., 2007). Therefore, accumulation of enough N by the legume and the subsequent yield effects depend on the number, efficiency and compatibility of rhizobia and nutrient constraints that affect nodulation and N-fixation (Aynabeba et al., 2001).

Phosphorous and Zinc are the major yield limiting nutrients in the highlands of Ethiopia (Bereket et al., 2011), and their effect is severe in alkaline calcareous soils, where P is fixed in apatite Ca minerals and Zn is precipitated as insoluble oxides and hydroxides, and adsorbed strongly to carbonate mineral surfaces (Alloway, 2004). Phosphorous and Zn are important mineral nutrients to the growth and biological N_2 fixation (BNF) of legumes, and the requirement of P and Zn by faba bean is relatively high, which is 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). Phosphorous is needed in relatively large amount by legumes and in addition to promoting the host legume growth; it has specific roles on N_2 fixation and nodule initiation, growth and development (Leidi and Rodiguez-Navarro, 2000). Zinc is also an important micronutrient for BNF and likely involved in leghaemoglobin synthesis. Deficiency of Zn in legumes is found to reduce the number and size of nodules (Marsh and Waters, 1985). The other important aspect of P and Zn nutrition is the interaction effect between them, especially in soils marginally deficient in both nutrients, where a positive interaction is reported when fertilized together in these soils (Havlin et al., 2005).

Few studies on the effect of inoculation and P fertilization on the yield, nodulation and N_2 fixation of legumes exist (Shibru and Mitiku, 2000; Amanuel et al., 2000; Habtegebrial and Singh, 2006), but studies on the combined effect of inoculation, P and Zn fertilization to grain legumes, grown on alkaline calcareous soils are generally scarce. Prior to this study, Weldu et al. (2012) was conducted a greenhouse pot experiment in 2009 to determine the effect of P and Zn fertilization on the response of faba bean. The current study, in continuation of the greenhouse experiment, intended to further evaluate at field level the effects of inoculums with P and Zn fertilization on yield, yield components, nodulation and nutrient uptake of faba bean on soils deficient in P and Zn under rainfed conditions.

MATERIALS AND METHODS

Site description

The experiment was conducted at Mekelle University (MU) Campus, Tigray-northern Ethiopia at 13°14'N and 39°32'E, and at 2100 m.a.s.l in the 2010 crop season. The site is located in a semi-arid agroecological zone with annual rainfall, ranging between 200 and 700 mm. The rainfall distribution is bimodal with short rain season (March-April) and main rain season (June-September) (Figure 1). The pattern, however, is extremely variable with high probability of no rain during the short rain season. The annual rainfall at Mekelle for the 2010 crop season was 711 mm. The average minimum and maximum temperature for the same season (June to October) were 11.8 and 24.3°C respectively. The soil type of the study site is Cambisol (UNESCO, 1994). The surface of the soil (0-0.2 m) is clay-loam in texture and contains 40% clay, 32% silt and 28% sand.

The soil had a pH of 7.7, electrical conductivity of 2.1 dS m^{-1} and CEC of 37 $cmol_c$ kg^{-1}. It contained 27% of $CaCO_3$, 1.42% soil organic matter, 0.14% total N, 5.5 mg kg^{-1} available-P, 0.48 mg kg^{-1} DTPA extractable-Zn, and 188 mg kg^{-1} extractable-K.

Experimental design and treatments

The experiment was laid out in randomized complete block design with three replications. A factorial combination of three factors: P with three levels (0, 20, kg P ha^{-1}), Zn with three levels (0, 15, 25 kg Zn ha^{-1}) and inoculation with two levels (U = no inoculums and I= with inoculums) were applied in 6.3 m^2 (2.1 m × 3 m) plots. Triple super phosphate (TSP) and zinc oxide (ZnO) were used as the source of P and Zn treatments. 23 kg N ha^{-1} and 40 kg K ha^{-1} in the form of urea (46% N) and Potassium chloride (52.5% K) respectively, were used as starter-N and basal dressing. The mixture of the treatment elements, the starter-N and basal-K were banded 5 cm to the side and 3 cm below the seeds at sowing.

The faba bean seeds (*Vicia faba* cv. CS20DK) were obtained from the Ethiopian Seed Agency (ESA). The inoculant used was *Rhizobium leguminosarum* biovar *vacia* strain EAL-110, obtained from the National Soil Research Laboratories (Addis Ababa, Ethiopia). The legume seeds were inoculated at the time of sowing with a powder containing an equivalent of 10^8 viable bacteria cells g^{-1}.

Prior to inoculation, the seeds were surface sterilized as follows: Washed with 70% (v/v) ethanol for 5 min, rinsed twice with sterilized water, shaken by hand for 15 min in 30% (v/v) H_2O_2, and rinsed four times with sterilized water. The surface unharmed faba bean seeds were then soaked overnight in distilled water and made ready for inoculation and sowing the next morning. The legume seeds were sown by hand with spacing between plants and rows of 7 and 30 cm respectively, as recommended by ESA in the 20th of July, 2010. Thinning of the faba bean seedlings was carried out to make the final plant density to 50 plants m^{-2}. Hand weeding of faba bean plots was carried out three times before pod filling.

Soil sampling and analysis

Composite soil samples from 0 to 20 cm depths were collected one month before sowing. Soil samples after drying and sieving were analyzed for pH (1:2.5 soil: water ratio), and EC_e of the saturated paste extract. Cation exchange capacity (CEC) was determined by the ammonium acetate method and the calcium carbonate content of the soil was determined by the method outlined in Sahlemedhin and Taye (2000). Soil organic carbon (SOC) was analyzed by Walkley and Black method (Nelson and Sommers, 1982). Total soil N (TN) was determined as total kjeldahal N (Bremer and Mulvaney, 1982), available-P was extracted using 0.5 M $NaHCO_3$ at pH 8.5 and determined as described in Olsen and Sommers (1982), and extractable K was analyzed as given in Knudsen et al. (1982). Available Zn was extracted using the diethylene triamine penta acetic acid (DTPA) chelate complex and determined using the method developed by Lindsay and Novell (1978).

Plant sampling and analysis

Nodulation was assessed at 50% flowering stage of the plants. Ten randomly selected plants from each plot were uprooted. Soil adhering to the roots was removed by washing with tap water. Nodules from the crown and lateral root portions were removed separately and spread on a sieve for some minutes until the water had drained from the surface of the nodules. The crown region was defined as that part of the root extending 3 cm in all directions from the stem base, whereas the lateral roots were those parts of the root system extending beyond 3 cm from the stem base (CIAT, 1988). The total number of nodules, number of nodules in the crown and lateral portion of the root, fresh weight and volume of the nodules were recorded.

Measurements on the length and fresh weight of roots were obtained from the plants obtained at 50% flowering. Newest top matured leaves and roots were collected from ten faba bean plants for nutrient analysis. At maturity, grain samples were collected from each plot for similar nutrient analyses. All the plant samples were then oven dried at 70°C for 48 h. The samples were ground to pass through a 1-mm sieve and the N, P and Zn content of these plant tissues were determined from their dry ash and wet digested samples (Sahlemedhin and Taye, 2000).

At physiological maturity, plants harvested from 1-m^2 inner row areas of each plot were used to record yield and yield components. Grain yield and number of pods m^{-2} were obtained by collecting all pods from these plants. The number of seeds pod^{-1} was then counted from 20 randomly picked pods. Number of branches $plant^{-1}$ and plant height was determined from the 10 randomly picked plants of each plot.

Statistical analysis

Field data were analyzed using SAS (version 9.1) (SAS Institute, 2003). Three-factor analysis of variance was performed to evaluate the main and interaction effect of inoculation, P and Zn fertilization on yield, yield components, nodulation, and nutrient uptake. LSD was used to compare treatment means and the probability significance level of a treatment effects and correlations were evaluated at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Nodulation and root growth

During the assessment, the nodule color across all inoculated treatments was invariably pink, indicating rhizobium infection of the roots.

Inoculation, P and Zn fertilization have significantly affected the distribution and total number of nodules, their dry mass and volume; although inoculation only affected the root crown nodules and not the lateral and total number of nodules (Table 1). In this experiment, P and Zn were found to significantly increase the root length of faba bean plant and its fresh weight, while inoculation only affected the root fresh weight and not its length (Table 1). Strong and positive two-way interactions between inoculation, P and Zn were also observed, affecting significantly the same parameters, shown in Table 1.

Inoculation, P and Zn treatments alone increased the average dry mass of nodules by 83, 109, and 13%, respectively. In turn, the combined effect of inoculation, P and Zn fertilization increased the average number and mass of nodules by 34 and 0.34g, compared to the control, corresponding to 53 and 151% increase.

Table 1. Distribution, total number, dry weight (g) and volume (cm^3) of nodules, and root growth at 50% flowering of the faba bean plant.

Treatment	Number of nodule $plant^{-1}$			Nodule dry wt. (g $plant^{-1}$)	Nodule volume ($cm^3 plant^{-1}$)	Root length (cm)	Root fresh wt. (g)
	Crown	Lateral	Total				
UP_0Zn_0	42.2	22.1	64.3	0.21	0.21	10.3	14.4
IP_0Zn_0	58.5	30.7	89.2	0.36	0.34	11.5	16.0
UP_0Zn_1	56.3	29.5	85.8	0.22	0.22	13.8	17.7
IP_0Zn_1	63.7	33.4	97.1	0.37	0.36	13.9	19.7
UP_0Zn_2	64.4	33.7	98.1	0.23	0.22	12.7	19.0
IP_0Zn_2	66.7	28.8	95.5	0.38	0.37	11.3	21.1
UP_1Zn_0	59.3	31.8	91.1	0.38	0.37	16.3	16.9
IP_1Zn_0	65.9	31.1	97.0	0.53	0.49	12.4	18.7
UP_1Zn_1	67.4	34.5	101.9	0.39	0.38	13.8	18.9
IP_1Zn_1	68.9	35.5	104.4	0.66	0.58	13.1	21.0
UP_1Zn_2	68.1	36.1	104.2	0.45	0.43	11.4	19.4
IP_1Zn_2	62.2	35.7	97.9	0.77	0.68	11.9	22.0
UP_2Zn_0	65.2	32.6	97.8	0.45	0.44	18.7	17.8
IP_2Zn_0	68.2	34.2	102.4	0.89	0.77	18.8	19.8
UP_2Zn_1	70.4	35.7	106.1	0.41	0.39	14.6	19.2
IP_2Zn_1	71.9	36.9	108.8	0.79	0.72	15.4	21.3
UP_2Zn_2	63.0	37.6	100.6	0.51	0.48	10.9	19.8
IP_2Zn_2	65.2	33.0	98.2	1.16	0.98	14.5	21.6
LSD_I	2.44	ns	ns	0.034	0.031	ns	0.81
LSD_P	2.99	2.90	5.64	0.041	0.037	1.07	0.99
LSD_{Zn}	2.99	2.90	5.64	0.041	0.037	1.07	0.99
R^2	0.77	0.51	0.67	0.96	0.95	0.97	0.98

ns = Not significant at P = 0.05, U= uninoculated, I= inoculated; P_0 = 0 kg P ha^{-1}, P_1 = 20 kg P ha^{-1}, P_2 = 40 kg P ha^{-1}; Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 15 kg Zn ha^{-1}, and Zn_2 = 25 kg Zn ha^{-1}.

Interaction plots indicate that the highest nodule mass was obtained when the plant was fertilized with P_2 and Zn_2.

Inoculating grain legumes with efficient strains of rhizobium is widely reported to increase the number, mass and volume of nodules (Shibru and Mitiku, 2000; Nuruzzaman et al., 2005), and the corresponding grain and total dry matter yield of faba bean. However, nodule mass is reported to be more reliable measure of nodulation than nodule number, which is also found to strongly correlate with the total amount of N_2 fixed and dry matter accumulation (Fawz et al., 2002). The nodules most affected by inoculation were found to be those in the faba bean root crown, as similarly found by Amanuel et al. (2000). The crown nodules are the first to be formed and more likely to originate from the inoculated strains (CIAT, 1988).

Phosphorous is involved in nodule metabolism, stimulating their growth and development (Leidi and Rodiguez-Navarro, 2000; Giller, 2001). Adequate fertilization of Zn was found to increase the number and size of nodules, as it might be possibly involved in the synthesis of leghaemoglobin (Marsh and Waters, 1985), while addition of sufficient P and Zn nutrients were associated with the increase of root growth and development (Havlin et al., 2005; Fageria, 2009).

Nutrient concentrations in the plant tissues

Main effects of inoculation, P and Zn fertilization, and their interactions have significantly ($P < 0.05$) affected the concentration of N, P and Zn in nodule, leaf and root tissues of the faba bean plant (Table 2).

Combined effects of inoculation, P and Zn fertilization increased the N concentration of the nodule, leaf and root tissues by 0.4, 2.7 and 0.6%, respectively, compared to the control. Phosphorous fertilization improved the P content of the nodule, leaf and root by 0.04, 0.06 and 0.16%, and Zn fertilization increased the Zn concentration of the nodule and leaf by 0.76 and 31 mg kg^{-1}.

The increase in the concentration of N and P in nodules, roots and shoots of faba bean and other grain legume with inoculation and P fertilization was similarly reported by many authors (Nuruzzaman et al., 2005; Yamane and Skjelvåg, 2003; and Habtegebrial and Singh, 2006). Increasing the supply of P to legume plants, such as pea and faba bean was found to considerably increase the concentration N and P in their

Table 2. The N, P and Zn contents of the nodule, root and shoot parts of the faba bean plant.

Treatment	Nodule	Leaf	Root	Nodule	Leaf	Root	Nodule	Leaf
		%N			%P		Zn (mg kg^{-1})	
UP_0Zn_0	7.3	2.9	2.1	0.43	0.66	0.16	1.42	56.8
IP_0Zn_0	6.4	3.8	2.2	0.38	0.59	0.18	1.96	78.7
UP_0Zn_1	8.2	4.3	2.4	0.49	0.76	0.43	1.89	75.8
IP_0Zn_1	6.9	5.7	2.6	0.41	0.63	0.18	2.14	86.4
UP_0Zn_2	8.3	5.4	2.9	0.50	0.77	0.41	2.16	87.3
IP_0Zn_2	7.0	6.2	2.6	0.42	0.65	0.19	2.23	89.9
UP_1Zn_0	8.0	4.3	2.3	0.48	0.74	0.24	1.99	80.1
IP_1Zn_0	6.8	6.1	2.3	0.41	0.63	0.19	2.21	88.8
UP_1Zn_1	8.1	5.5	2.5	0.49	0.76	0.29	2.25	91.2
IP_1Zn_1	7.0	6.4	2.5	0.43	0.67	0.23	2.43	93.3
UP_1Zn_2	8.3	6.3	3.0	0.51	0.79	0.30	2.28	92.0
IP_1Zn_2	7.2	6.6	2.9	0.44	0.68	0.33	2.09	84.1
UP_2Zn_0	8.0	4.9	2.4	0.49	0.76	0.26	2.18	87.9
IP_2Zn_0	7.1	6.1	2.5	0.43	0.67	0.88	2.29	91.8
UP_2Zn_1	8.4	6.1	3.0	0.51	0.79	0.31	2.37	94.7
IP_2Zn_1	8.0	6.8	3.2	0.49	0.76	0.33	2.31	97.3
UP_2Zn_2	8.4	4.5	3.0	0.52	0.80	0.32	2.14	85.4
IP_2Zn_2	8.4	6.9	3.3	0.52	0.80	0.35	2.21	88.0
LSD_I	0.213	0.099	ns	0.017	0.023	ns	0.07	1.73
LSD_P	0.261	0.121	0.022	0.021	0.029	0.022	0.09	2.12
LSD_{Zn}	0.261	0.121	0.157	0.021	0.029	0.022	0.09	2.12
R^2	0.81	0.99	0.77	0.75	0.79	0.97	0.82	0.93

ns = Not significant at P = 0.05, U= uninoculated, I= inoculated; P_0 = 0 kg P ha^{-1}, P_1 = 20 kg P ha^{-1}, P_2 = 40 kg P ha^{-1}; Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 15 kg Zn ha^{-1}, and Zn_2 = 25 kg Zn ha^{-1}.

shoots, enhancing the assimilation of reduced carbon and increasing the supply of photosynthase to nodules and roots (Jakobsen, 1985). Zinc is an important plant nutrient with specific roles in nodule metabolism, plant and root growth, synthesis of chlorophyll, N-metabolism, and enzymatic processes. Thus the requirement of Zn in legumes is relatively high. Hence, the adequate concentration of Zn in the upper matured leaves and grains of legumes could reach 25 to 100 and 40 mg kg^{-1}, respectively (Fageria and Baligar, 1997).

Yield, yield components and nutrient-uptake

Significant main and interaction effects of inoculation, P and Zn fertilization were observed in this experiment, improving the grain yield, pods $plant^{-1}$, grain pod^{-1}, number of branches, and the grain uptake of N, P and Zn by the faba bean crop (Table 3).

Inoculation alone increased the grain yield, pods and branches $plant^{-1}$ by 6.3, 23 and 6. 3%, and phosphorous fertilization respectively increased by 15, 27.6 and 14.8%, while zinc increased the same parameters in the same order by 10.9, 36.2 and 10.8%. Phosphorous and Zn fertilization alone increased the grain P and Zn uptake by 1.1 and 2.7 × 10^{-2} kg ha^{-1}, respectively. The combined application of inoculation, P and Zn fertilization improved the grain yield on average by 1.3 Mg ha^{-1}, which is a 54.2% increase, compared to the control. Furthermore, the combined application of the three factors increased the N. P and Zn uptake of the faba bean crop on average by 39.8, 0.54, and 9.5 × 10^{-2} kg ha^{-1}, respectively, corresponding to 102, 54 and 138% increase, compared to the control (UP_0Zn_0). The highest grain yield was obtained when Zn_1 (15 kg ha^{-1}) was fertilized with P_2 (40 kg ha^{-1}).

Similar significant improvement of grain yield, the total above-ground dry matter, pods and branches $plant^{-1}$ of faba bean (Shibru and Mitiku, 2000; Weldu et al., 2012) and other grain legumes (Yamane and Skjelvåg, 2003; Habtegebrial and Singh, 2006) were reported by the application of P and Zn.

Phosphorous and Zn have a positive yield advantage when both are added together to soils deficient to them than adding high level of P to soils that are marginally deficient to Zn (Havlin et al., 2005). Phosphorous and Zn are found to enlarge the leaf area and improve the rate of assimilate production per unit leaf area of legumes (Yamane and Skjelvåg, 2003; Fageria, 2009), improving the yield of the crops, as they are involved in the

Table 3. Grain yield, yield components and grain nutrient uptake of faba bean.

Treatment	Grain yield (Mg ha^{-1})	Pods plant^{-1}	Grain pod^{-1}	Plant length (cm)	No. branches	Grain Nutrient uptake (kg ha^{-1})		
						N	P	Zn (x 10^{-2})
UP_0Zn_0	2.4	5.0	2.4	86.0	2.3	39.2	6.2	6.9
IP_0Zn_0	3.3	6.6	3.2	74.9	3.2	51.5	8.6	13.3
UP_0Zn_1	3.2	7.4	3.6	95.6	3.1	58.0	8.3	12.4
IP_0Zn_1	3.6	10.0	4.9	79.7	3.5	78.2	9.4	15.8
UP_0Zn_2	3.7	11.8	5.7	97.1	3.5	92.3	9.5	16.1
IP_0Zn_2	3.8	9.4	4.5	81.5	3.6	73.4	9.8	17.2
UP_1Zn_0	3.4	7.4	3.6	92.9	3.2	58.3	8.7	13.6
IP_1Zn_0	3.8	10.6	5.1	79.1	3.6	83.3	9.7	16.8
UP_1Zn_1	3.8	9.6	4.7	94.4	3.7	75.5	9.8	17.3
IP_1Zn_1	3.9	11.1	5.4	82.1	3.7	87.3	10.1	18.3
UP_1Zn_2	3.9	10.9	5.3	96.7	3.7	85.5	9.9	17.7
IP_1Zn_2	3.5	12.5	6.0	83.9	3.4	98.2	9.1	14.9
UP_2Zn_0	3.7	8.6	4.1	93.1	3.5	67.2	9.5	16.2
IP_2Zn_0	3.9	10.6	5.1	82.3	3.7	83.3	10.0	17.9
UP_2Zn_1	4.0	10.6	5.1	97.6	3.8	82.9	10.3	19.2
IP_2Zn_1	4.1	12.3	5.9	93.4	3.9	96.1	10.6	20.2
UP_2Zn_2	3.6	7.8	3.7	98.2	3.4	60.8	9.3	15.6
IP_2Zn_2	3.7	14.2	6.9	98.8	3.5	111.7	9.6	16.6
LSD_I	0.14	0.56	0.29	2.59	0.15	3.34	0.44	0.24
LSD_P	0.17	0.68	0.35	3.17	0.18	4.09	0.53	0.29
LSD_{Zn}	0.17	0.68	0.35	3.17	0.18	4.09	0.53	0.29
R^2	0.78	0.88	0.87	0.80	0.72	0.93	0.68	0.99

U = Uninoculated, I = inoculated; P_0 = 0 kg P ha^{-1}, P_1 = 20 kg P ha^{-1}, P_2 = 40 kg P ha^{-1}; Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 15 kg Zn ha^{-1}, and Zn_2 = 25 kg Zn ha^{-1}.

Table 4. Correlation analysis between grain yield and yield attributes of the plant.

Variable	By variable	*r*-Value	*P*-Value
Grain yield (g plant^{-1})	Number of pods plant^{-1}	0.72	0.0008
Grain yield (g plant^{-1})	Number of grains pod^{-1}	0.72	0.0009
Grain yield (g plant^{-1})	Number of branches plant^{-1}	0.99	<0.0001
Grain yield (g plant^{-1})	Plant height (cm)	0.16	0.52

production of chlorophyll and growth phytohormones, and photosynthetic energy transfer processes. In this experiment, the yield advantage of faba bean produced by the applied P and Zn could be attributed to an increase in the number of branches, which in turn increased the number of productive nodes and number of pods m^{-2}. The number of branches and pods plant^{-1} and the number of grains pod^{-1} of the plant, were found to strongly correlate with the grain yield (Table 4), which is consistent with the definition of yield components for legumes that determine their grain yields (Fageria, 2009).

Conclusion

Faba bean is an important source of protein and can serve as an alternative to fallow, especially in areas affected by high farmland pressure, benefiting farmers with additional income and improving or maintaining the soil's N status as the grain legume is the highest N_2-fixing crop. It is apparent in study, the N content and yield formation of faba bean was highly influenced by inoculation, P and Zn nutrition. Thus, inoculating the legume in soils devoid of efficient and compatible rhizobium, as well fertilizing with P and Zn nutrients should be recommended to soils deficient in them, especially in high alkaline calcareous semiarid soils.

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Conflict of Interest

The authors have not declared any conflict of interest.

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