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The Effects of Different Nitrogen and Phosphorus Doses and Bacteria Inoculation (*Rhizobium phaseoli*) on the Yield and Yield Components of Field Bean (*Phaseolus vulgaris* L.)

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Abstract: The aim of the research was to find out the effects of bacteria inoculation, four different nitrogen (0, 20, 40, 60 kg ha^{-1} N) and four different phosphorus doses (0, 40, 60, 80 kg ha^{-1} P_2O_5) on field bean in Van-Turkey ecological condition. Although the effects of the applications showed differences depending on years, nitrogen application exerted a significant and positive effect on pod number, grain yield and raw protein proportion, whereas no significant effect was seen on seed number per pod and weight of thousand seeds. As for the effects of phosphorous doses, they weren't found to be significant for all of the factors. On the other hand, bacteria inoculation exerted a significant and positive effect on pod number per plant and grain yield, whereas no effect of this application was seen on weight of thousand seeds and raw protein rate.

Key words: *Phaseolus vulgaris*, bean, fertilization, bacteria, *Rhizobium*, nitrogen, phosphorous, yield, yield components

INTRODUCTION

In order to maintain their livelihood human beings should take sufficient and balanced supplements. The increase in the burgeoning population of the world and the shortage of the resources to meet the requirements for food have increased the need for protein sources. Proteins are known to be derivative of animal and plant by products. Proteins based on animal by-products are constituted and compounded of plants. Therefore, the enhancement of nutritional sources necessitates a direct or indirect proliferation of plant sources. The global protein requirement constitutes 70.0% of the plant sources, 66.0% of the plant proteins, 18.5% of them constitutes grain beans for meals and 15.5% of them constitutes the other herbal sources. Beans play an important role in the enhancement of the level of nourishment in developing countries due to the fact that this plant is rich in elements like potassium, calcium, iron and phosphor and it contains 18-32% of protein in every grain averagely[1]. The plant is also rich in A, B and D vitamins[2].

According to the statistical data obtained by Food and Agriculture Organization (FAO), a total 54.691.000 ha of agricultural land for the growing of this crop are used by the global populations in the world. Bean comes foremost with 27.086.000 ha and with a yield of 729 kg ha^{-1}. Its volume of production is 19.745.694.000 tons[3].

In a 176.000 ha of agricultural land in Turkey, bean farming is made in 1403 kg ha^{-1} yield and an approximate 247.000.000 kg of the product is harvested[3]. The cultivating area of beans in Van city is 373.0 ha, its production 273.4 tons and its yield is 733 kg ha^{-1}[4]. A great part of bean-cultivated areas in Van is within the domains of Gevaş town. As it is quite evident from the above parameters, the grain yield obtained from bean plant in Van is quite below the average of our country (1403 kg ha^{-1}), the grain yield of bean plant in Van being 733 kg ha^{-1}. The underlying causes of this insufficiency could be cited as the failure to use appropriate cultivars and the lack of the suitable techniques to be applied for the harnessing of this crop. Therefore, the amount of the crop to be harvested from the field's per unit should be increased in Van, a region which is feasible for bean farming. In order to conduct an adequate agriculture of this crop in this region bean cultivars of higher yielding quality which are well-adapted to the region should be used as well as investigations to be made about fertiliser and inoculation. The preferred cultivar, effective *Rhizobium* strain, the applied fertiliser, the fertilization time and the amount of useful nutrient in the soil affect the grain yield[5].

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Phosphor is one of the most important nutritional components in the nourishment of the plant[6]. Fertilisers containing phosphor have proved to be effective in terms of root development in the first stages of growth and after the growth stage they have also a positive effect on grain yield an quality on the point of the bean plant[7].

The nitrogen requirement in bean is quite high due to the emergence of nodules and build-up of the symbiotic nitrogen fixation in the first stage of development[6]. In the later stages of development the plant fulfills its nitrogen requirement from the bacteria, thus it does not need any fertilization based on nitrogen however, fertilisers in the scale 20-60 kg ha^{-1} and containing nitrogen were found to be positively affecting yield. Whereas nitrogen in greater amounts were found to be decreasing nodule weight, nodule number and nodule size, nitrogen given in 22 kg ha^{-1} of scale increased nodulation[2].

The importance of symbiotic nitrogen fixation is has been overemphasized due to the fact that the protein requirement worldwide has been on a rise and serious environmental problems have emerged during the production and use of fertilisers based on minerals and nitrogen. Given the requirement for a 20.000 kcal energy in order to produce 1 kg of fertiliser containing nitrogen and the solar energy was used for binding of nitrogen biologically (microorganism-plant photosynthesis-N fixation), the importance of biological nitrogen fixation could much more clearly be understood. It is estimated that the amount of biologically obtained nitrogen is approximately $175x10^6$ tons. This amount is expected to be the binding nitrogen symbiotically[8]. The amount of nitrogen, which is symbiotically bound, changes depending on the kind of the plant, the efficiency of bacteria inoculated, soil properties and the existence of necessary plant supplements. Of all these factors, bacteria inoculation, the efficacy of inoculation take on special importance[9].

It is known that the symbiotic bacteria like *Rhizobium phaseoli* in the roots of bean, which is a plant within the family of leguminosae, leave a nitrogen-rich soil to the post-grown plants as a result of the fixation of nitrogen freely found in the air. Grained leguminosae plants leave 5-20% of nitrogen through their roots and straws to the soil after they are harvested. In the previous investigations conducted on these phenomena, leguminosae roots approximating 13:1 in terms of their C:N under favourable conditions were found to have been split in 1-2 weeks of period, whereas the cereal roots whos C:N is 80:1 were found to have been split in 4-8 weeks of period[2,10].

This investigation was conducted (in order) to determine the urgency of fertilisers containing nitrogen and phosphor in Van environs. Therefore, four distinct doses of nitrogen (0, 20, 40, 60 kg $ha^{-1}N$) and four distinct doses of phosphorous (0, 40, 60, 80 kg ha^{-1} P_2O_5) were applied to dried bean cultivars within the context of bacteria inoculation. So, in our investigation, the effect of nitrogen, phosphor and bacteria on the grain yield and some other productivity components were studied.

MATERIALS AND METHODS

The trials were carried out under the watery conditions around lake Van basin in the East. Anatolian Region of Turkey between the years of 2001 and 2002.

The proportionate humidity rate on a biennial average pertaining to the vegetation period of the plant in the this region is 57.1%, precipitation 170.9 mm and the average temperature is 16.7°C. The average temperatures of 2001 and 2002 are 11.1 and 17.4°C, respectively. The average proportion of humidity was 45.7% in the first year, whereas it was 51.5% in the second year. The amount of precipitation during the vegetation period between the years of 2001 and 2002, in which the investigation was carried out, was found to be 137.5 and 158.7 mm, respectively[11]. The data of soil analysis of trial field and the texture of soil samples revealed sandy-loamy-clayed and slightly alkali soil reaction property (pH=7.35), poor in organic substance (2.48%), sufficient in proper potassium (586.0 kg ha^{-1}) but under the sufficient level in terms of usable phosphorous (67.9 kg ha^{-1}). According to the results of soil analysis, the soil samples of tested area were found to be moderately calcareous (7.61%) and salt less in terms of salination (0.046%).

In the investigation, sugar bean in the property of dwarf and belonging to *Phaseolus vulgaris* L. species was used as plant material[11].

Rhizobium phaseoli mixed peat culture was used as inoculation material, within the context of bean nodusity bacteria. Ammonium sulfate [$(NH_4)_2SO_2$] 21% was used as nitrogen containing fertiliser and 42% of tripled super phosphate [10 CaH_4 $(PO_4)_2$. H_2O] was used as fertiliser containing phosphor. In the selection of the commercial fertiliser material, solubility rate, application period and the method applied in the trials essentially taken into consideration[6].

The trial was based on three replications according to Factorial Test Pattern in Random Blocks[12] and it was composed of a total of 32 different applications with and without bacteria inoculation together with four different

nitrogen doses and four different phosphor doses. Parcel size in sawing was 2x4 m = 8 m^2 and 0.5 m from the top of each parcel and one raw from the margins were omitted and all the procedures were conducted on 1x3 m =3 m^2 of area. Two meter of distance were maintained between parcels and blocks in order to prevent the applied fertilisers and *Rhizobium* bacteria to be infected into parcels[13].

Both of the trial fields were ploughed in the previous autumn before sawing and were thus left for winter season to pass and after the month of April were made to be ready for sawing after they were processed by rotatiller and discaro. Sawing process was made in the first week of May. The distance between the rows was maintained as 40 with 10 cm of the tops omitted and each parcel consisted of 5 rows. As for the sawing depth, it was arranged as 6-8 cm[13].

In the trial a total of 16 different combinations of fertiliser dose, based on four nitrogen and four phosphorous doses were used. Before cultivation, fertilisers based on 42% of Triple Super Phosphate (TSP) which comprises 0(P_0), 40(P_4), 60(P_6), 80(P_8) kg phosphor (P_2O_5) for each hectare, 21% of Ammonium Sulfate which comprises 0(N_0), 20(N_2), 40(N_4), 60(N_6) kg pure nitrogen (N) for each hectare were over sprinkled onto the plots by hand and scratched. In order to prevent any possible mixture of the applied fertilisers with the other parcels, distance of 2 m was maintained between the blocks and plots[13]. Depending on the need, occasional irrigation and weed controls were conducted. When the plants had harvesting, 20 samples were taken from each plot. The number of pod per plant, the number of the seeds per pod were determined; then, grain yield, 1000 seeds weight and raw protein rate for each plot were found. After yields were transformed into the yield pertained to the hectare.

RESULTS AND DISCUSSION

The number of pods per plant: In the trial, the fertiliser applications based on nitrogen were found to be effective on the pods number per plant for both of the years (Table 1). As it is shown in Table 1 increasing nitrogen doses up to 60 kg ha^{-1} increased the number of pods per plant. In the applications of N_0, N_2 N_4 and N_6 on a biennial average the legume number in the plant were found to be 17.87, 19.69, 20.37 and 20.84, respectively. In an investigation conducted by Ukkelberg *et al.*[14] and related with this type of research, 6-12 kg of nitrogen application significantly increased pod number per plant. Also, in an investigation conducted by Şehirali *et al.*[13] a nitrogen application up to 50 kg ha^{-1} was reported to have increased the number of pods compared with the controls.

The effect of the applications based on phosphorous fertiliser on the number of pods per plant was statistically significant (Table 1). The number of the pods per plant was respectively found as thus: 18.33 per plant in P_0 application; 19.21 per plant in P_4 dose; 18.32 per plant in P_6 dose, 20.58 per plant in P_8 dose. Similarly Gates and Wilson[15], Alvino *et al.*[16] reported that phosphor increased the number of pods per plant.

Bacteria-based application, too, was found to have increased the number of pods per plant in a statistically significant way throughout the course of biennial trials. Coherent with this finding, the number of pod in bacteria-inoculated plots was 20.72, whereas it was 18.66 in the plots with no bacteria inoculation. In studies conducted by Graham and Halliday[17], Karuç[18], Popescu[19], Thakur *et al.*[20] and Shisanya[21] inoculation based on *Rhizobium* increased the number of pods per plant compared with the controls.

Number of seed per pod: As it is shown in Table 2, nitrogen, phosphor and bacteria applications were found to be insignificant in terms of their effect on the seed number per pod. Similarly, the seed number per pod in different nitrogen applications and as the average value of the years was found to be 2.86/pod in N_0 dose, 2.82/pod in N_2 dose, 2.77/pod in N_4 dose and 2.75/pod in N_6 dose. This number in different phosphor application was found to be 2.77/pod in P_0 dose, 2.78/pod in P_4 dose, 2.82/pod in P_6 dose and 2.81/pod in P_8 dose. On the other hand, in the plots with no bacteria application the seed number per pod was found to be 2.78/pod; as for the plots with bacteria inoculation, the number was 2.82/pod. The seed number per pod is related with the genetic structure of the plant this parameter is to be evaluated with little correlation with environmental conditions in field bean[22]. In an investigation conducted by Yılmaz and Çiftçi[23] under the conditions prevailing in Van city about field bean and related with seed number (3.0-5.0/pod), the findings were in agreement with those in our study.

Weight of thousand seeds (g): The trial factors were found to have shown no difference in regard with their effects on thousand seeds weight depending on the years. The average thousand seeds weight was found to be 466.54 g.

As shown in Table 3, nitrogen, phosphorous and bacteria applications were found to be statistically insignificant in terms of their effects on weight of

Table 1: Average values of the number of pods per plant studied for nitrogen, phosphorus doses and bacteria inoculation*

		2001				2002				2001-02 year average			
Nitro.	Phosp.	Un inocul.	Inoculat.			Un inocul.	Inoculated			Un inocul.	Inoculat		
		B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N
N_0	P_0	13.76e-j	10.03k	11.90		15.25h	26.23a-e	20.74d		14.50	18.13	16.32g	
	P_4	12.03ı-k	12.73h-k	12.38		19.80f-h	24.26d-f	22.03bd		15.92	18.50	17.21fg	
	P_6	13.30f-j	10.26k	11.78	12.24b	22.93e-g	26.73a-e	24.83ad	23.49b	18.12	18.50	18.31c-g	17.87b
	P_8	12.20h-k	13.66e-j	12.93		23.00e-g	29.76a-c	26.38ab		17.60	21.71	19.66b-f	
	NxB Ave.	12.82 cd	11.67d			20.24c	26.75a			16.53	19.21		
N_2	P_0	12.46h-k	20.66a	16.57		24.46c-f	26.93a-e	25.70ad		18.46	23.80	21.14a-c	
	P_4	16.30c-f	11.23j-k	13.76		23.66d-f	30.73a	27.20ab		19.98	20.98	20.48a-e	
	P_6	13.30f-j	15.93c-g	14.61	14.79a	18.20g-h	23.20e-g	20.80d	24.61b	15.75	19.57	17.66e-g	19.69ab
	P_8	12.50h-k	15.96c-f	14.23		26.10a-e	23.26e-g	24.68ad		19.30	19.61	19.46b-f	
	NxB Ave.	13.64 b-d	15.95ab			23.10b-c	26.03a-b			18.42	20.99		
N_4	P_0	17.46b-d	13.70e-j	15.58		24.80a-d	25.13a-d	24.96d		21.13	19.41	20.27a-f	
	P_4	12.30h-k	18.56a-c	15.43		30.13a	28.86d-f	29.46a		21.21	23.71	22.46a	
	P_6	15.20d-h	12.90g-k	14.05	15.02a	20.54f-h	23.21e-g	21.85bd	25.72a	17.87	18.05	17.94d-g	20.37a
	P_8	13.46f-j	16.60c-e	15.03		22.96e-g	30.23a	26.60ab		18.21	23.40	20.80a-d	
	NxB Ave.	14.60a-c	15.44a-c			24.60b-c	26.85a			19.60	21.14		
N_6	P_0	15.90c-g	16.26c-f	16.08		30.80a	24.41c-f	27.60a		23.35	20.33	21.84ab	
	P_4	13.30f-j	19.66a-b	16.48		27.46a-e	24.73b-f	26.10ac		20.38	22.20	21.29a-c	
	P_6	16.96b-d	16.56c-e	16.76	16.32a	17.26h	26.86a-e	22.07bd	25.37a	17.11	21.71	19.42b-f	20.84a
	P_8	15.10k	16.83k	15.96		24.16d-f	27.26a-e	25.71ad		19.63	22.05	20.84a-d	
	NxB Ave.	15.31a-c	17.33a			24.92b-c	25.81b			20.12	21.57		
	Bacteria Ave.	14.09b	15.10a			23.21b	26.36a			18.66b	20.72a		
	Year Ave.	14.59B				24.67A				19.69			
Ave. (PxB)				Ave. (P)				Ave. (P)				Ave. (P)	
	P_0	13.31c	15.16ab	14.24		24.90	26.92	25.81		17.21	19.46	18.33b	
	P_4	13.48c	15.55a	14.51		21.88	25.95	23.91		17.68	20.75	19.21ab	
	P_6	14.69abc	13.91bc	14.30		19.72	25.00	22.36		17.20	19.45	18.32b	
	P_8	14.90ab	15.76a	15.33		24.05	27.63	25.84		19.47	21.69	20.58a	

* Differences between the means pointed out different letter(s) are significant at 5% probability level

Table 2: Average values of the number of seeds per pod studied for nitrogen, phosphorus doses and bacteria inoculation*

		2001				2002				2001-02 year average			
Nitro.	Phosp.	Un inocul.	Inoculat.			Un inocul.	Inoculated			Un inocul.	Inoculat		
		B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N
N_0	P_0	2.67	2.66	2.67		3.19	3.01	3.10 ab		2.93	2.84	2.89	
	P_4	2.51	2.55	2.53		2.61	3.11	2.86 ab		2.56	2.83	2.70	
	P_6	2.84	2.59	2.71	2.62	3.07	2.86	2.97 ab	3.10	2.96	2.73	2.84	2.86
	P_8	2.82	2.34	2.58		3.42	3.52	3.47 a		3.12	2.93	3.03	
	NxB Ave.	2.71	2.53			3.07	3.12			2.89	2.83		
N_2	P_0	2.53	2.46	2.49		3.24	3.00	3.12 ab		2.89	2.73	2.81	
	P_4	2.54	2.44	2.49		3.22	3.27	3.24 ab		2.88	2.86	2.87	
	P_6	2.47	2.46	2.47	2.50	2.66	3.27	2.96 ab	3.14	2.57	2.87	2.72	2.82
	P_8	2.43	2.69	2.56		3.37	3.11	3.24 ab		2.90	2.90	2.90	
	NxB Ave.	2.49	2.51			3.12	3.16			2.81	2.84		
N_4	P_0	2.85	2.63	2.73		2.59	2.85	2.72b		2.72	2.74	2.73	
	P_4	2.55	2.77	2.66		2.89	3.13	3.01 ab		2.72	2.95	2.84	
	P_6	2.55	2.54	2.55	2.58	3.48	3.00	3.24 ab	2.96	3.01	2.77	2.89	2.77
	P_8	2.40	2.40	2.40		2.77	2.88	2.83 ab		2.59	2.64	2.62	
	NxB Ave.	2.58	2.58			2.93	2.97			2.76	2.78		
N_6	P_0	2.51	2.50	2.50		2.72	3.10	2.91ab		2.62	2.80	2.71	
	P_4	2.39	2.47	2.43		2.82	3.16	2.99 ab		2.61	2.82	2.71	
	P_6	2.49	2.55	2.52	2.48	3.06	3.46	3.27 ab	3.01	2.78	3.01	2.90	2.75
	P_8	2.35	2.65	2.50		2.93	2.85	2.89 ab		2.64	2.75	2.70	
	NxB Ave.	2.43	2.54			2.88	3.14			2.66	2.84		
	Bacteria Ave.	2.55	2.54			3.01	3.10			2.78	2.82		
	Year Ave.	2.54				3.05				2.80			
Ave. (PxB)				Ave. (P)				Ave. (P)				Ave. (P)	
	P_0	2.64	2.56	2.60		2.93	2.99	2.96		2.75	2.78	2.77	
	P_4	2.50	2.55	2.53		2.88	3.17	3.03		2.69	2.86	2.78	
	P_6	2.58	2.53	2.56		3.07	3.15	3.11		2.79	2.84	2.82	
	P_8	2.50	2.52	2.51		3.12	3.09	3.11		2.81	2.81	2.81	

* Differences between the means pointed out different letter(s) are significant at 5% probability level

Table 3: Average values of the weight of 1000 seeds studied for nitrogen, phosphorus doses and bacteria inoculation (g)*

		2001				2002				2001-02 year average			
Nitro.	Phosp.	Un inocul.	Inoculat.			Un inocul.	Inoculated			Un inocul.	Inoculat.		
		B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N
N_0	P_0	454.63	472.50	463.56		469.43	445.83	457.63		462.03	459.17	460.60	
	P_4	445.43	425.33	435.38		491.66	468.66	480.16		468.55	446.99	457.77	
	P_6	446.96	500.66	473.81	462.89	468.66	452.76	460.71	461.08	457.81	476.71	467.26	461.98
	P_8	457.76	499.86	478.81		450.00	441.66	445.83		453.88	470.76	462.32	
	NxB Ave.	451.20	474.59			469.94	452.23			460.56	463.41		
N_2	P_0	466.93	489.33	478.13		445.83	461.10	453.46		456.38	475.22	465.80	
	P_4	493.16	468.00	480.58		436.10	500.00	468.05		464.63	484.00	474.31	
	P_6	481.67	510.53	496.10	480.55	437.50	440.26	438.88	463.71	459.58	475.39	467.48	472.13
	P_8	495.80	438.97	467.38		508.33	480.56	494.45		502.06	459.76	480.91	
	NxB Ave.	484.39	476.71			456.94	470.48			470.67	473.60		
N_4	P_0	461.03	449.63	455.33		479.16	472.23	475.70		470.10	460.93	465.51	
	P_4	412.00	457.77	434.88		452.76	444.43	448.60		432.38	451.10	441.74	
	P_6	472.53	475.53	474.03	456.83	431.93	477.80	454.86	470.31	452.23	476.66	464.44	463.53
	P_8	463.10	463.00	463.10		516.67	487.50	502.08		489.59	475.25	482.42	
	NxB Ave.	452.16	461.50			470.13	470.49			461.15	466.00		
N_6	P_0	441.36	422.73	432.05		420.83	491.67	456.25		431.10	457.20	444.15	
	P_4	482.00	469.83	475.91		458.33	488.90	473.61		470.17	479.36	474.76	
	P_6	510.26	481.83	496.04	468.39	477.76	487.50	482.63	468.58	494.01	484.66	489.33	468.48
	P_8	454.10	485.00	469.55		445.83	477.80	461.81		449.96	481.40	465.68	
	NxB Ave.	471.93	464.85			450.69	486.47			461.31	475.66		
	Bacteria Ave.	464.92	469.41			461.92	469.91			463.42	469.66		
	Year Ave.	467.16				465.91				466.54			
Ave. (PxB)				Ave.(P)				Ave. (P)				Ave.(P)	
	P_0	455.27	458.55	456.91		453.81	467.70	460.76		454.54	463.13	458.84	
	P_4	458.15	455.23	456.69		459.71	475.50	467.61		458.93	465.37	462.15	
	P_6	477.85	492.14	485.00		453.97	464.58	459.28		465.91	478.36	472.14	
	P_8	467.69	471.73	469.71		480.20	471.88	476.04		473.95	471.81	472.88	

* Differences between the means pointed out different letter(s) are significant at 5% probability level

thousand seeds. Components of bean were not found to be statistically significant; similarly parameters of average related with thousand seeds weight in different nitrogen applications were respectively found to be 461.98 g in N_0 dose, 472.13 g in N_2 dose, 463.52 g in N_4 dose and 468.48 g in N_6 dose; also, in phosphor applications, thousand seeds weight was found to be 458.84 g in P_0 dose, 462.15 g in P_4 dose, 472.14 g in P_6 dose and 472.88 g in P_8 dose. On the other hand, thousand seeds weight in the parcels undergoing no bacteria applications was found to be 463.42 g. In the plots to which bacteria were applied, this figure was 469.66 g.

The heredity rate of thousand seeds weight in the bean is very high. It is very slightly effected by the environment and technical applications[24,25]. Due to such peculiarity, nitrogen and phosphorous fertilisers and bacteria applications were not found to have changed one-thousand grain weight in bean similarly, in an investigation conducted by Budak[26] nitrogen and phosphorous fertilization increased the amount of the product but was not effective in thousand seeds weight.

Grain yield (kg ha^{-1}): The grain yield per hectare has shown significant differences depending on the years. The grain yield per hectare based on the average of all of the factors was determined as 3202 kg ha^{-1} in 2001 and 3796 kg ha^{-1} in 2002 (Table 4). Such difference in yield components seen on a biennial basis is believed to be caused by climatologic factors. Because, the temperatures showed differences in the trial years, the average of 2001 being 11.1°C; this average was 17.4°C for 2002. The precipitation was 137.5 mm during the vegetation period for 2001 and 158.7 mm for 2002. On the other hand, the average relative humidity rate in 2001 was 45.7 and 51.5% in 2002. Thus, it is much more tempting to say that the higher rates of the total relative humidity and average temperature in 2002 increased the grain yield in this plant.

The effects of nitrogen fertiliser applications in the trial on the grain yield per hectare have been statistically significant in both of the trial years. The increased doses of nitrogen increased the grain yield per hectare compared with the control plots. Therefore, taking into consideration as the biennial average, the grain yields according to the increased doses of nitrogen were found to be 3151, 3587.9, 3604 and 3654 kg ha^{-1} in N_0, N_2, N_4 and N_6, respectively. In the investigations conducted about this subject by Şehirali *et al.*[13] nitrogen application in 50 kg ha^{-1} increased the grain yield compared with the controls. On the other hand, Asif and Greig[27], reported that 67 kg ha^{-1} nitrogen application in bean increased

Table 4: Average values of the grain yield studied for nitrogen, phosphorus doses and bacteria inoculation (kg ha^{-1})*

		2001				2002				2001-02 year average			
Nitro.	Phosp.	Un inocul.	Inoculat.			Un inocul.	Inoculated			Un inocul.	Inoculat.		
		B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N
N_0	P_0	1984l	3480c-g	2732f		2200l	2825ı-l	2513c		2092l	3152h-j	2622c	
	P_4	2847ı-j	2341k-l	2594f		5142a-b	3809c-k	4476a-b		3994b-c	3075ı-j	3534a-b	
	P_6	2994g-j	3163d-ı	3079d-f	285.7b	2677j-l	4288b-h	3482b-c	3445b	2835j-m	3725c-d	3280b-c	3151b
	P_8	2604j-k	3449c-g	3026d-f		3275f-l	3343f-l	3309b-c		2939j-k	3396d-h	3167b-c	
	NxB Ave.	2607	3108			3323b	3566a-b			2965	3337		
N_2	P_0	3440c-g	3197d-ı	3318c-e		2961h-l	4325b-g	3643a-c		3200h-j	3761c-d	3480a-b	
	P_4	2866h-j	2992g-j	2929e-f		4015b-j	4078b-ı	4047a-b		3440d-h	3535c-g	3487a-b	
	P_6	2285k-l	4417a	3351b-e	333.5a	5248a-b	3317f-l	4283a-b	3840ab	3766c-d	3867b-d	3816a	3587ab
	P_8	2996g-j	4491a	3743a-c		2479k-l	4300b-h	3390b-c		2737k-l	4395a	3566a-b	
	NxB Ave.	2896	3774			3676 a-b	4005a-b			3286	3889		
N_4	P_0	3024f-j	3910b-c	3467b-d		3291f-l	4691b-e	3991a-b		3157h-j	4300a-b	3729a-b	
	P_4	3586c-e	3937b-c	3761a-c		3223g-l	3257f-l	3240b-c		3404d-h	3597c-e	3500a-b	
	P_6	3240d-ı	3552c-e	3396b-e	331.8a	3505d-l	4585b-f	4045a-b	3890ab	3372d-f	4068b-c	3720a-b	3604ab
	P_8	2978g-j	2321k-l	2650f		3738c-k	4831b-d	4285a-b		3358e-f	3576c-f	3467a-b	
	NxB Ave.	3206	3430			3439 b	4341 a			3322	3885		
N_6	P_0	2970g-j	3102e-j	3036d-f		3479e-l	4990a-c	4235a-b		3224g-j	4046b-c	3635a-b	
	P_4	2905h-j	3670c-d	3287c-e		3604d-k	5369a	4496a		3254g-h	4519a	3887a	
	P_6	3520c-f	2598j-k	3059d-f	329.8a	3665d-k	4227b-h	3946a-b	4009a	3592c-e	3412d-h	3502a-b	3654a
	P_8	3374d-h	4251a-b	3813a-b		3071g-l	3669d-k	3370b-c		3222g-j	3960b-c	3591a-b	
	NxB Ave.	3192	340			3455b	4564a			3323	3984		
	Bacteria Ave.	2975b	3429a			3473b	4119a			3224b	3774a		
	Year Ave.	3202B				3796A				3499			
Ave.	(PxB)			Ave.(P)				Ave.(P)				Ave.(P)	
	P_0	2854b	3422a	3138		4207	2982	3595b		3531	3202	3366	
	P_4	3051a-b	3235a-b	3143		3681	4432	4056a		3366	3833	3599	
	P_6	3010a-b	3433a	3221		4104	3773	3939a		3557	3603	3580	
	P_8	3460a	3157a-b	3308		4035	3141	3588b		3748	3149	3448	

* Differences between the means pointed out different letter(s) are significant at 5% probability level

Table 5: Average values of protein content in grain studied for nitrogen, phosphorus doses and bacteria inoculation (%)*

		2001				2002				2001-02 year average			
Nitro.	Phosp.	Un inocul.		Inoculat.		Un inocul.	Inoculated			Un inocul.	Inoculat		
		B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N	B_0	B_1	Ave.(NxP)	Ave. N
N_0	P_0	19.62	18.86	19.24		20.00	25.03	22.51a-b		19.81	21.95	20.87	
	P_4	18.22	20.51	19.36		23.18	24.03	23.60a		20.70	22.27	21.48	
	P_6	19.97	19.95	19.96	19.46c	22.87	23.52	23.20a-b	22.90a-b	21.42	21.74	21.58	21.18b
	P_8	19.55	18.98	19.26		21.93	22.68	22.30 a-b		20.74	20.83	20.78	
	NxB Ave.	19.34	19.58			21.99	23.82			20.66	21.70		
N_2	P_0	21.21	21.04	21.12		23.54	24.13	23.83a		22.38	22.58	22.48	
	P_4	19.63	21.62	20.62		22.80	23.38	23.09a-b		21.22	22.50	21.86	
	P_6	22.20	20.75	21.47	21.01b	21.53	21.70	21.61b	23.10a	21.87	21.23	21.54	22.05b
	P_8	20.98	20.69	20.83		23.85	23.89	23.87a		22.41	22.29	22.35	
	NxB Ave.	21.01	21.03			22.93	23.27			21.97	22.15		
N_4	P_0	23.86	25.03	24.44		23.25	21.98	22.61 a-b		23.56	23.51	23.53	
	P_4	23.98	24.97	24.47		22.62	22.03	22.32 a-b		23.30	23.50	23.40	
	P_6	24.50	24.09	24.30	24.48a	21.95	20.98	21.47b	22.02b	23.23	22.54	22.89	23.26a
	P_8	23.98	25.38	24.68		21.45	21.98	21.71b		22.72	23.68	23.20	
	NxB Ave.	24.08	24.87			22.31	21.74			23.20	23.31		
N_6	P_0	25.49	24.97	25.23		23.07	22.08	22.58a-b		24.28	23.53	23.91	
	P_4	22.87	24.80	23.83		22.61	21.32	21.96a-b		22.74	23.06	22.90	
	P_6	27.09	22.98	25.04	24.39a	22.95	23.09	23.02a-b	22.19b	25.02	23.04	24.03	23.29a
	P_8	23.92	22.99	23.45		21.70	20.76	21.23b		22.81	21.88	22.34	
	NxB Ave.	24.84	23.93			22.58	21.81			23.71	22.88		
	Bacteria Ave.	22.32	22.35			22.45	22.66			22.38	22.51		
	Years Ave.	22.33				22.55				22.45			
Ave.	(PxB)			Ave.(P)				Ave.(P)				Ave.(P)	
	P_0	22.54a-b	22.47a-b	22.50		23.12	23.21	23.17		22.83	22.84	22.84	
	P_4	21.17b	22.97a-b	22.07		22.15	22.79	22.47		21.66	22.88	22.27	
	P_6	23.44a	21.95a-b	22.69		22.34	22.33	22.34		22.89	22.14	22.52	
	P_8	22.11a-b	22.01a-b	22.06		22.10	22.25	22.18		22.11	22.13	22.12	

* Differences between the means pointed out different letter(s) are significant at 5 % probability level

the grain yield. Similarly in a study reported by Ukkelberg *et al.*[14] 60-120 kg ha^{-1} nitrogen application significantly increased the yield.

Whereas the effect of phosphorous fertiliser application on grain yield per hectare was insignificant in 2001, it was statistically significant in 2002 (Table 4). When Table 4 is evaluated, the highest grain yield per hectare in 2002 were 4056 and 3939 kg ha^{-1} from P_4 and P_6 doses, respectively, whereas the lowest grain yield per hectare were 3595 and 3588 kg ha^{-1}, respectively, from P_0 and P_8 applications, respectively. The grain yield per hectare in 40 kg ha^{-1} increased the productivity up to the phosphorous doses compared with the controls, but in the increased phosphorous doses in the later stages a decrease was seen in the yield. In the investigations conducted previously, the highest grain yield per hectare was obtained by Steward and Mack[28,29] in 50 kg ha^{-1} P_2O_5 doses and by Güvenç and Zülfikar[30] in 75 kg ha^{-1} P_2O_5 doses. The difference between the results of the investigations is supposed to be caused by climatologic and soil conditions.

The effect of bacteria application on grain yield per hectare was observed to be significant both in 2001 and 2002 (Table 4). The highest grain yield per hectare in both years was found to be 3429 and 4119 kg ha^{-1} in bacteria applied plots, which shows agreement that in the previous investigations bacteria inoculation was reported to increase the grain yield per hectare[13,17,20,21,31-34].

As for the effects of nitrogen, phosphor and bacteria on grain yield in combination (N x P x B interaction) were found to be significant in both trial years (Table 4). As it is observed in Table 4, the highest grain yield per hectare in 2001 was found to be 4491 kg ha^{-1} in N_2 x P_8 x B_1 applications and the lowest value 1984 kg ha^{-1} in N_0 x P_0 x B_0 control applications. The highest value of this component in 2002 was 5369 kg ha^{-1} in N_6 x P_4 x B_1 application, whereas the lowest value was 2200 kg ha^{-1} in N_0 x P_0 x B_0 application. In both trial years, nitrogen x phosphor x bacteria applications increased grain yield per hectare compared with the controls. Investigations conducted about such components showed that phosphor application increased symbiotic nitrogen fixation; and the nitrogen application decreased the bacterial activity and preferred the available nitrogen instead of nitrogen fixation. However the effects of N x P x B interaction were found to increase the yield[15,18,35,36-40].

Raw protein rate: Raw protein rate showed significant differences depending on the years. The average raw protein rate was found to be 22.45%. The protein rate in bean grain is quite changeable based on genotype, environmental conditions and methods of growing[41]. Similarly, in the investigations conducted about protein rate in bean environmental factors were found to be effective on a wide range of scale[42] (Table 5).

Whereas the effect of nitrogen application on raw protein rate in our investigation was found to be significant, phosphor and bacteria applications were insignificant. The highest protein rate based on biennial average was 23.29% in N_6 application, whereas the lowest raw protein rate was 21.18% in N_0 control application. Also, in phosphor applications, raw protein rate was respectively found to be 22.84, 22.27, 22.52 and 22.12% in P_0 , P_4, P_6 and P_8 application, respectively. On the other hand, in the plots where no bacteria inoculation was conducted, raw protein rate was 22.38%; this rate was 22.51% in bacteria-applied plots. Ayanoğlu and Engin[41] reported that highest protein rate (20.31%) was obtained in nitrogen applied in 50 kg of proportion per hectare in their investigations conducted under Mersin-Erdemli environments.

In this investigation conducted in Lake Van basin in East Anatolia Region in the years 2001 and 2002, nitrogen applications were found to be effective and significantly increase number of pod per plant, grain yield and raw protein rate, though showing differences depending on years, whereas no significant effect was seen in grain number per pod and thousand seeds weight. As for the effect of phosphor, it was not significant for all of the factors investigated. On the other hand, whereas bacteria inoculation was found to be positively effective on a significant range for increasing number of pod per plant and grain yield, no effect was seen on number of seeds per pod, thousand seeds weight and raw protein rate.

Taken into consideration generally, the highest grain yield based on the biennial average was obtained as 4519 kg ha^{-1} from 60 kg of nitrogen (N), 40 kg phosphor (P_2O_5) and bacteria applications.

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