Growth and Yield of Common Bean (*Phaseolus Vulgaris* L.) in Response to *Rhizobium* Inoculation, Nitrogen and Molybdenum Fertilization

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ABSTRACT

Two field trials were carried out in two successive growing seasons of 2006 and 2007 at Elbehara Governerate - Faculty of Agriculture to study the combination effects of seed inoculation (with *Rhizobium* and without), nitrogen fertilization with (0, 48, 96 kg N/ha) and foliar molybdenum application(0 and 30 µg Mo/l as sodium molybdate) on plant height, branch number, plant fresh weight, plant dry weight, average number of green pods per plant and green pods yield ha^{-1} as well as nitrogen and molybdenum contents in leaves of bean plants Giza3.

The highest values of all investigated parameters were obtained with a combination of seed inoculation, molybdenum application and nitrogen fertilization of 96 kg N/ha. Polynomial quadratic models were developed and used to describe green pods yield responses. Four polynomial equations were established to express the relationship among green pods yield and application rate of N fertilizer, molybdenum fertilization and Rhizobium inoculation for each season. The calculated yields in the two seasons closely approximate experimental yields as evidenced by the highly significant value of coefficient of determination (R^2).

INTRODUCTION

Legume crops are not only used as human diet but also for improving soil fertility through biological nitrogen fixation. Among the grain legumes, common bean (*Phaseolus vulgaris*) is the most important pulse crop in the world .It is an important source of calories, proteins, dietary fibers, minerals and vitamins for millions of people in both developing and developed countries (Consideine, 1992). Egypt is the main exporter of green beans; therefore the expansion in green bean cultivation has exhibited impressive growth during the past several years with a cultivated area of 21.3 thousand hectare with a production of 215 thousand tones of green beans (FAO Statistics, 2007). Beans are capable of fixing atmospheric nitrogen through *Rhizobium* species living in root nodules. However, poor nodulation of beans under Egyptian agro-ecological conditions is considered the major cause of its lower yield. Inoculation of beans with *Rhizobium* increased plant height, leaf area, photosynthetic rate and dry matter production (Thakur and Panwar, 1995). Brar and Lal (1991) found an increase yield of mungbean with inoculation of *Rhizobium*. Also Srivastava et al. (1998) reported that inoculation of pea seeds with *Rhizobium leguminosarum* gave maximum pod yield of pea. On the other hand Solaiman and Khondaker (2002) stated that maximum green pod yield of 30.78 g/plant (111% increases over uninoculated control) of pea was obtained when plants were inoculated with *Rhizobium* strains.

Molybdenum (Mo) is an essential micronutrient for plants, bacteria and animals. Molybdenum is directly related to metabolic function of nitrogen in the plant through nitrate reductase enzyme that reduces the nitrate to nitrite, and this the first step of the incorporation of nitrogen to proteins (Marschner 1995). Molybdenum also participates as co - factor of nitrogenase, responsible for biological nitrogen fixation. Jongruaysup et al. (1993) stated that crops developing symbiosis with rhizobium bacteria had increased molybdenum requirements. Deficiency of this element causes a reduction of nodulation and nitrogen fixation. Chahal and Chahal (1991) claimed that foliar applications of molybdenum stimulated nodulation and biological nitrogen fixation, thus increasing the legume yield.

These investigations aimed to study the effect of seed inoculation with Rhizobium, nitrogen fertilization and foliar nutrition with molybdenum on growth and yield of common bean.

MATERIAL AND METHODS

Two experiments were conducted in two successive growing seasons of 2006 and 2007 at Elbehara Governerate - Faculty of Agriculture, Alexandria University. Soil chemical and physical properties of the experimental soil were determined according to the methods reported by Page et al. (1982).The main chemical characteristics of the two soils are summarized as follows : N 0.17 and 0.15 %, P 0.06 and 0.065%, K 0.13and 0.12%, pH 7.8 and 7.85 and, Mo 0.142 and 0.134 ppm in the seasons of 2006 and 2007 respectively.

The experimental layout was a split- split plot system in a randomized complete blocks design with three replications. Rhizobium inoculations were

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arranged in the main plots, Inorganic nitrogen rates were assigned to sub-plots and molybdenum rates were

distributed in the sub-sub plots. The plots were formed by three rows of 5m length, and 0.7 m width. Common bean (*Phaseolus vulgaris* L.) Giza-3 cultivar was used in both years of investigations (summer of 2006 and 2007 seasons).

Each experiment was established with 12 variants represented the combinations among; seed inoculation (with and without nitrogen fixing bacteria of genus *Rhizobium*), three inorganic nitrogen fertilizer rates (0, 48 and 96 kg N ha^{-1} and two molybdenum rates (0 and 30 µg Mo/l) as sodium molybdate.

Bean seed inoculations were done with the symbiotic N-fixing bacteria of genus *Rhizobium* by coating the seeds at the rate of 20gms of Oqadin /kg of seeds using staking substance (Arabic gum 5%) just before sowing and then were directly sown on one side of the row at 15 cm intra-raw spacing. Nitrogen was applied by hand as ammonium sulphate (20.5%N) at two equal doses; 3 and 5 weeks after sowing. Molybdenum foliar fertilization was applied at 15 and 25 days after plant emergence as sodium molybdate (30 µg Mo/l as sodium molybdate ($Na_2MoO_4 \cdot 2\ H_2O$). Phosphorus and potassium fertilizations were also applied in doses of 72 kg P_2O_5/ha and 115kg K_2O /ha as calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) respectively.

The data of vegetative growth characters were recorded using five random chosen plants from each treatment, 60 days after seed sowing. The following measurements were recorded: Plant height, Number of branches $plant^{-1}$, Plant fresh and dry weight, and leaf area $plant^{-1}$

Green pods yield and its components:

At harvesting time plants of the second row was allocated to measure the following data: number of green pods $plant^{-1}$ and green pods yield $ha.^{-1}$

Chemical analysis of leaves:

Wet digestion was performed on leaves according to Chapman and Pratt (1978). Molybdenum concentration (µg/g dry wt.) was estimated by using Atomic Absorption Spectrophotometer according to Villora, et al. (2002). Total Nitrogen was determined using micro- kjeldahl method according to Ling (1963).

Statistical analysis

The obtained data were statistically analyzed using SAS Software program (1996). Comparisons among the means of different treatments were conducted using the Least Significant Difference Procedure at P=0.05 level as illustrated by Al-Rawy and Khalf-Allah (1980).

RESULTS AND DISCUSSION

The main effects of *Rhizobium*, nitrogen and molybdenum

Tables (1and 4) showed that *Rhizobium* inoculation treatments significantly, increased all the vegetative growth of bean plants in both seasons compared to uninoculated control. Meanwhile, branch number in the first season and plant height in the second season reflected a similar trend though the differences were insignificant. *Rhizobium* inoculation significantly increased plant fresh and dry weights and green pods yield by 9.45, 6.27 and 15.37 %; 15.17, 7.23 and 19.7 % in the first and second seasons respectively. The beneficial effects of these bacteria have been attributed to their ability to produce various compounds including phytohormones, organic acids and fixation of atmospheric nitrogen (Lazarovits and Nowak, 1997 and Noel et al., 1996). These findings agree with the results of Solaiman and Khondaker (2002) who reported that peas green pods yield increased by 111% over uninoculated control when plants were inoculated with *Rhizobium* strains. Kanaujia et al. (1998) obtained similar result with pea crop. Also it can be noticed from the data of Table(4) that Rhizobium inoculation significantly increased N and Mo contents of leaves as compared to the control in both seasons. This inspection was confirmed by Moawad et al. (2004), who mentioned that Rhizobia inoculation showed a positive response due to enhanced plant growth and N values compared to control.

Nitrogen application rates (Tables1 and 4) had significant effects on the plant height, number of branches, plant fresh and dry weight, and number of green pods as well as green pods yield in the two growing seasons compared to the control treatment. Increasing nitrogen levels up to 96 kg N ha^{-1} reflected positive effects on vegetative growth characters and green pods yield. Nitrogen treatments of 48 and 96 Kg Nha^{-1} increased leaves area by 17.11 and 31.65; 21.73 and 33.47 % whereas green pods yield increased by 61 .91 and 97.3; 60.27 and 106.4 % over the control in the first and the second seasons respectively. The obtained results are in accord with those of Arisha and Bardisi (1999) who reported that the number and yield of green pods $plant^{-1}$ as well as the total green pods yield were significantly increased with increasing the applied nitrogen up to 192 kg N ha^{-1}. Ismail (2002) indicated that addition of 216 Kg N ha^{-1}., to the growing pea plants, was sufficient for the plants to express their best performance on the green pods yield and its components. Similar trends were reported by several researchers such as Solieman et al. (2003), and gabr et al (2007) on pea plants.

Table 1. The main effects of Rhizobium, nitrogen fertilization and molybdenum foliar application on vegetative growth parameters of common bean plants during 2006 and 2007 seasons.

seasons	2006					2007				
Treatment	Plant height	Branch number	Plant fresh wt. (g)	Plant dry wt. (g)	Leaves area (cm^2)	Plant height	Branch number	Plant fresh wt. (g)	Plant dry wt. (g)	Leaves area (cm^2)
Rhizobium										
R_0	38.18 B	3.78 A	74.67 B	15.16 B	699.91 B	33.35 A	3.28 B	63.82 B	14.09 B	782.2 A
R_1	39.19 A	3.72 A	81.73 A	16.11 A	753.66A	35.47 A	3.77 A	73.5 A	15.11 A	782.2 B
Nitrogen rates										
N_0	36.49 C	2.5 C	66.76 C	12.93C	625.19 C	31.65 C	2.5 C	57.51 C	12.44 C	634.54 C
N_1	38.78 B	3.9 B	78.38 B	16.01B	732.15 B	34.23 B	3.5 B	68.55 B	14.71 B	772.43 B
N_2	40.78 A	4.8 A	89.45A	17.97 A	823.08 A	37.36 A	4.6 A	79.92A	16.67 A	846.95A
Molybdenum										
M_0	38.25 B	3.72 A	75.91 B	15.63 B	735.34 B	33.63 B	3.33 B	66.44 B	14.33 B	773.10 B
M_1	39.12 A	3.78 A	80.49 A	15.92 A	718.22 A	35.19 A	3.72 A	70.89 A	14.89A	729.51A

Rhizobium inoculation rates: R0 = uninoculated (control) and R1 = inoculated with Rhizobium.
Mineral nitrogen rates (kg N ha^{-1}) : No = without nitrogen (control),N1= 48 and N2= 96 kg N ha^{-1}.
Molybdenum rates : Mo = without molybdenum (control) and M1= 30 μg Mo/l as sodium molybdate

Table 2. The first order interaction effects of Rhizobium, nitrogen fertilization and molybdenum foliar application on vegetative growth parameters of common bean plants during 2006 and 2007 seasons

Treatments	2006					2007				
	Plant height (cm)	Branch number	Plant fresh wt. (g)	Plant dry wt. (g)	Leaves area (cm^2)	Plant height (cm)	Branch numbers	Plant fresh wt. (g)	Plant dry wt. (g)	Leaves area (cm^2)
Rhizobium +Nitrogen										
R0+ N0	36.44 e	2.5 c	63.43 e	12.27 d	612.33 c	30.58 d	2.33 e	52.48d	11.92 e	619.22 d
R0+ N1	38.27 d	4.0 b	74.72 c	15.49 b	694.67 bc	33.37 c	3.17 cd	64.37 c	14.12 c	731.37bc
R0+ N2	39.83 b	4.8 a	85.87 b	17.74 a	792.72 a	36.1 ab	4.33 ab	74.62 b	16.25 a	810.67 ab
R1+ N0	36.55 e	2.5 c	70.10 e	13.61 c	637.92 c	32.72 cd	2.66 de	62.55 c	12.96 d	649.87 cd
R1+ N1	39.30 c	3.8 b	88.38 d	16.52 b	769.63 b	35.0 bc	3.83 bc	72.73 b	15.30 b	813.5 ab
R1+ N2	41.72 a	4.8 a	93.05 a	18.09 a	853.43 a	38.62 a	4.83 a	85.23 a	17.09 a	883.23 a
Rhizobium + Molybdenum										
R0+ M0	37.78 c	3.67 a	72.56 c	14.91c	693.47 b	32.54 b	3.11 b	61.41 d	13.78 c	704.48 b
R0+ M1	38.58 b	3.89 a	76..79 b	15.41 bc	706.34 ab	34.16 ab	3.44 ab	66.23 c	14.41 bc	736.36 ab
R1+ M0	38.71 b	3.88 a	79.26 b	15.81ab	742.98 ab	34.71 a	3.56 ab	71.47 b	14.87 ab	754.54 ab
R1+ M1	39.67 a	3.55 a	84.2 a	16.42a	764.34 a	36.23 a	4.0 a	75.54 a	15.36 a	809.86 a
Nitrogen + Molybdenum										
N_0+ M0	36.31 e	2.5 c	64.58 f	12.46 c	619.1 d	30.95 d	2.17 d	55.55 d	11.98 d	614.80 d
N_0 + M1	36.68 e	2.5 c	68.95 e	13.41 c	631.15 d	32.35 cd	2.83 cd	59.48 d	12.9 c	654.28 cd
N_1 + M0	38.28 c	4.0 b	75.87 d	15.93 b	722.4 c	33.7 bc	3.33 bc	65.5 c	14.52 b	742.23 bc
N_1 + M1	39.28 c	3.8 b	80.9 c	16.08 b	741.9 bc	34.75 bc	3.67 b	71.59 c	14.90 b	802.63 ab
N_2+ M0	40.15 b	4.83 a	87.29 b	17.69 ab	813.17 ab	36.23 ab	4.5 a	78.27 a	16.47 a	831.5 ab
N_2 + M1	41.40 a	4.83 a	91.63 a	18.15 a	832.98 a	38.48 a	4.67 a	81.58 a	16.86 a	862.4 a

Rizobium inoculation rates: R0 = uninoculated (control) and R1 = inoculated with Rizobium.
Mineral nitrogen rates (kg N ha^{-1}) : N0 = without nitrogen (control),N1= 48 and N2= 96 kg N ha^{-1}.
Molybdenum rates: M0 – without molybdenum (control) and M1= 30 µg Mo/l as sodium molybdate

Table 3. The second order interaction effects of Rhizobium, nitrogen fertilization and molybdenum foliar application on vegetative growth parameters of common bean plants during 2006 and 2007 seasons.

Seasons	2006					2007				
Treatments	Plant height (cm)	Branch number	Plant fresh wt. (g)	Plant dry wt. (g)	Leaves area (cm^2)	Plant height (cm)	Branch number	Plant fresh wt. (g)	Plant dry wt. (g)	Leaves area (cm^2)
Rhizobium+ Nitrogen +Molybdenum										
R0 + N0 + M0	36.28 g	2.33 d	61.37 i	11.88 e	608.87 d	29.9 e	2.0 g	49.83 g	11.42 g	600.43 e
R0 + N0 + M1	36.6 g	2.67 cd	65. hi	12.65 fg	615.8 d	31.27 de	2.67 efg	55.13 fg	12.41 fg	638.00 de
R0 + N1 + M0	37.7 f	4.0 ab	72.37fg	15.47 de	689.67bc d	32.7 cde	3.0 defg	61.47 e	13.96 de	713.97bcde
R0 + N 1+ M1	36.28 g	2.33 d	77.07 ef	15.5 de	699.67 bcd	34.03 bcd	3.33 cdef	67.27 cde	14.28 de	748.77bcde
R0 + N2 + M0	39.37de	4.67 ab	83.93cd	17.38 abc	781.87 ab	35.03 bc	4.33 abc	72.93 bc	15.95 abc	799.03 abc
R0 + N2 + M1	40.3 bc	5.0 a	87.8 bc	18.09 ab	803.57 ab	37.17 ab	4.33 abc	76.3 b	16.54 ab	822.3 abc
R1 + N0 + M0	36.33 g	2.67 cd	67.8 gh	13.04 fg	629.33 d	31.0 cde	2.33 fg	61.27 ef	12.53 fg	629.17 de
R1 + N0 + M1	36.77 g	2.33 d	72.4 fg	14.18 ef	646.5 cd	33.43 cde	3.00 defg	63.83 de	13.39 ef	670.57cde
R1+ N1 + M0	38.87e	4.0 ab	79.37de	16.39 cd	755.13 abc	34.7 bcd	3.67 bcde	69.53 cd	15.08 cd	770.50 abcd
R1 + N1 + M1	39.73 cd	3.67 bc	84.73cd	16.65 bcd	784.13 ab	35.46 bc	4.0 abcd	75.93 b	15.53 bc	856.5 ab
R1 + N2 + M0	40.93 b	5.0 a	90.63ab	17.99 ab	862.4 a	37.43 ab	4.67 ab	83.60 a	17.0 a	863.97 ab
R1 + N2 + M1	42.5 a	4.67 ab	95.47 a	18.42 a	844.47a	39.8 a	5.0 a	86.87 a	17.18 a	902.5 a

Rizobium inoculation rates: R0 = uninoculated (control) and R1 = inoculated with Rhizobium.
Mineral nitrogen rates (kg N ha^{-1}) : N0 = without nitrogen (control).N1= 48 and N2= 96 kg N ha^{-1}.
Molybdenum rates: M0 = without molybdenum (control) and M1= 30 µg Mo/l as sodium molybdate

Table 4 . Main effects of Rhizobium, nitrogen fertilization and molybdenum foliar application on yield and mineral contents of common bean plants during 2006 and 2007 seasons

seasons	2006				2007			
Treatment	No of green pod plant $^{-1}$	Green pod yield ha $^{-1}$ (ton)	N%	Mo	No of green pod plant $^{-1}$	Green pod yield ha $^{-1}$ (ton)	N %	Mo
Rhizobium								
R_0	18.05 B	5.79 B	3.41B	0.228 B	17.11 B	5.33 B	3.19 B	0.215 B
R_1	22.27 A	6.68 A	3.72 A	0.278 A	19.83 A	6.38 A	3.42 A	0.304 A
Nitrogen rates								
N_0	15.92 C	4.07 C	2.90 C	0.197 C	13.92 C	3.75 C	2.51 C	0.191 C
N_1	20.00 B	6.59 B	3.58 B	0.254 B	18.41 B	6.01 B	3.49 B	0.249 B
N_2	24.58A	8.03 A	4.22 A	0.309 A	23.08 A	7.74 A	3.89 A	0.337 A
Molybdenum								
M_0	19.16 B	5.95 B	3.43 B	0.129 B	17.72 B	5.51 B	3.21 B	0.116 B
M_1	21.17 A	6.52 A	3.67 A	0.378 A	19.22 A	6.16A	3.40 A	0.403 A

Rizobium inoculation rates: R0 = uninoculated (control) and R1 = inoculated with Rizobium.
Mineral nitrogen rates (kg N ha^{-1}) : N0 = without nitrogen (control),N1= 48 and N2=96 kg N ha^{-1}.
Molybdenum rates : M0 = without molybdenum (control) and M1= 30 µg Mo/l as sodium molybdate

Molybdenum treatment (Tables 1 and 4) significantly increased all the studied vegetative growth characters and green pods yield of common bean plants in both years of investigations. Treated common bean plants with molybdenum achieved higher plant fresh and green pods yield by 6.03and 9.57; and 6.69 and 11.79% compared to the control in the first and the second seasons respectively. Similar results were reported by Chahal and Chahal (1991), who treated pea with molybdenum (30 μg/l) and achieved significantly higher yields of dry matter compared to untreated plants. On the other hand Mo foliar application significantly increased leaves N and Mo contents in both seasons .The higher Mo contents in bean plants with Mo application are similar to that reported for groundnut and soybean (Gupta, 1997)

First order Interactions of *Rhizobium*, Nitrogen and Molybdenum

1-Interaction effects between *Rhizobium* and nitrogen

The data presented in Tables (2 and 5) reflect the effects of the first degree interaction between *Rhizobium* and nitrogen fertilization levels, on vegetative growth characters, green pods yield and leaves N and Mo contents of common bean plants in the two growing seasons**.** The results of the two seasons indicated that the means of all studied characters increased significantly within the treatment combinations involving seed inoculation comparing with uninoculated treatment. Soil application of N at the rate of 96 kg N ha^{-1} to the inoculated seeds produced the best interaction effect among the different combination for all the studied characters in both seasons. These data are in accordance with those of Ishaq (2002) who reported that inoculation pea seeds with the biofertilizers and N application attained the best results on plant height, fresh and dry weight $plant^{-1}$ and dry matter content of leaves and stems. Also the present results agreed to a great extent, with those reported by Merghany (1999) who reported that fresh and dry weight of snap bean increased with increasing N fertilization up to the rate of 216 kg Nha^{-1}. Chetti et al. (1995) studied the effect of nitrogen and *Rhizobium* inoculation on the productivity of groundnut genotype and reported that both nitrogen application and inoculation had significant positive effects on groundnut yield. Kelner et al. (1997) and Lamb et al. (1995) reported that forage legumes have a high capacity to fix N_2 even if high levels of mineral N are available in the soil. With respect to N and Mo contents of leaves of common bean (Table 5) data indicated that raising applied N levels to 96 kg N ha^{-1} significantly increased leaves N and Mo contents over that of the control treatments.

2-Interaction effects between *Rhizobium* and molybdenum

The combined interaction of Molybdenum and Rhizobium inoculation and its influence on vegetative growth characters and green mass yield of common bean plants in the two growing seasons are shown in Tables (2 and 5). The differences occurred between the various treatments are statistically significant in both seasons. The combined effect of Rhizobium inoculation in the presence of molybdenum revealed the highest value in both seasons. Rizobium inoculation with Mo leaf spray caused a positive effect on the most of vegetative growth characters, green pods yield and leaves nitrogen and molybdenum contents in both seasons. The inoculated treatments and Mo fertilization increased Plant fresh weight and pods green yield by 16.04 and 26.16 %; and 23.0 and 45.86% in the first and second seasons respectively. Similar results were obtained by Yanni (1992) who reported that the seed yield of *Rhizobium* inoculated legume crops is increased strikingly by Mo fertilization. The role of Mo as a plant nutrient is related to its function as a metal component of some enzymes that catalyze nitrogen fixation, nitrate assimilation and reduction (Svetsov et al., 1992). A recent study by Hristozkova et al. (2007) established that foliar application of nutrients on pea reduced the inhibitory effect on the root nodulation and nitrogen assimilator enzyme activities due to molybdenum shortage when plants were inoculated with *Rhizobium*.

3- Interaction effects between nitrogen and molybdenum

The comparisons among the means of various treatment combinations of molybdenum treatments and the nitrogen fertilization levels on vegetative growth characters and green pods yield and leaves nitrongen and molybdenum contents of common bean plants are illustrated in Tables (2 and 5). The results of the two seasons indicated that the highest mean values of all studied characters were obtained from the bean plants that were fertilized with nitrogen at the rate of 96 kg N ha^{-1} and sprayed with molybdenum. Plant fresh and dry weights and green bean yield increased by 41.88, 45.66 and 120.48 %; and 46.86, 40.73 and 134.59% of the control in the first and the second season respectively. Berger et al. (1996) found that the Mo foliar applied dosage of 78 g ha^{-1} provided an increase in yield by163% when compared with control. Also Maurya et al. (1993) reported that N uptake increased with Mo application in black gram and Mo application positively affected plant N-yield in noninoculated or inoculated plants. Mendel and Hansch(2002) reported that the stimulatory effect of Mo application could be due to the increase of the metabolic pools required for the synthesis of saccharides, along with the enhanced photosynthetic capacity.

Second order Interactions of *Rhizobium*, Nitrogen and Molybdenum

The second order interactions among all studied factors showed that different studied parameters of vegetative growth, green pods yield and leaves nitrogen and molybdenum contents of common bean plants are significantly affected (Tables 3 and 6). The best treatment combinations that involved seed inoculation, molybdenum foliar application and nitrogen fertilization at the rate of 96 kg N ha^{-1}gave the highest mean values of green pods yield, plant fresh and dry weights and N and Mo contents. The obtained results are in agreement with those presented by Krishnasamy et al. (1985) who reported that molybdenum and nitrogen application significantly increased grain and straw yields of cowpea. Gungula and Garjila (2006) also reported that molybdenum application has been found to significantly increase pods yield of cow pea. On the other hand, Waterer et al. (1992) found that peas plants grown in the presence of NH_4 fixed as much or more N_2 than the plants supplied with minus - NH_4^+ nutrient solution.

Polynomial Quadratic Models.

The polynomial quadratic model was used to describe bean yield response to nitrogen increments under molybdenum fertilization and Rizobium inoculation in two successive summer growing seasons.

The polynomial quadratic model used in the form:

$$Y_i = B_0 + B_1 X_i \pm B_2 X_i^2 \quad (1)$$

Where: Y_i is the expected yield corresponding to nutrient rate X_i B_0 is the intercept, and B_1 and B_2 are the linear and quadratic coefficients, respectively.

The method of the least squares using the experimental results was used to calculate the values of B_0 , B_1 and B_2 in the polynomial model. Thus 4 polynomial quadratic models were established to express the relationship between green pods yield and application rate of N fertilizer under Molybdenum fertilization and *Rhizobium* inoculation for each season (Table 7 and Figs 1 & 2).

The calculated yields in the two seasons closely approximate experimental yields as shown from the highly significant value of determination coefficients (Figs. 3 and 4). Therefore it can be concluded that the effect of nitrogen application, *Rhizobium* inoculation and molybdenum fertilization on increasing green pods yield could be successfully predicted by using polynomial quadratic equations.

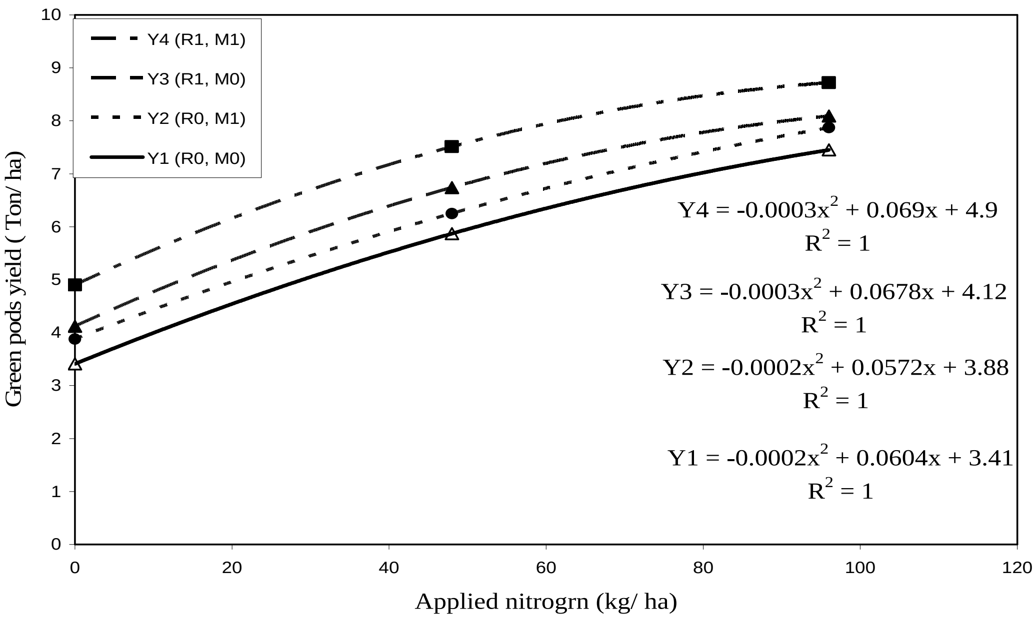

Fig. 1. Green pods yield response curve of common bean cultivar (Giza 3) to nitrogen fertilization Rhizobium inoculation and molybdenum foliar application during the season of 2006

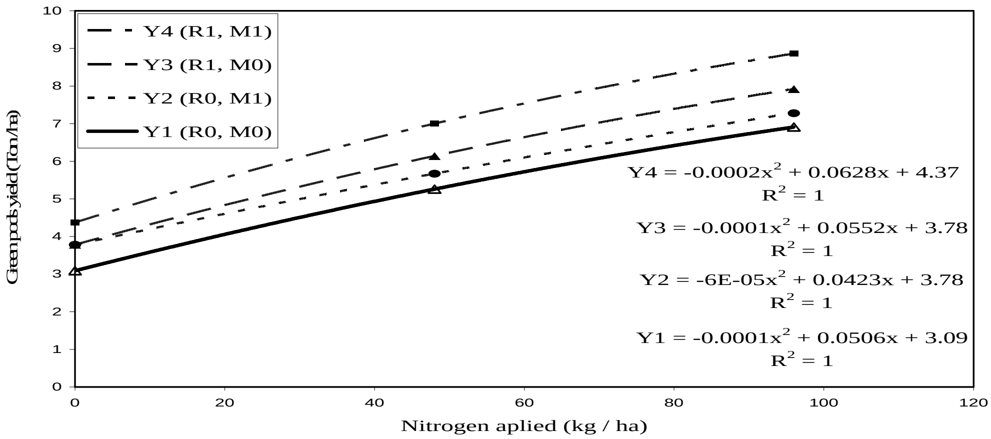

Fig. 2. Green yield response curve of common bean cultivar (Giza 3) to nitrogen fertilization, Rhizobium inoculation and molybdenum forliar application during the season of 2007

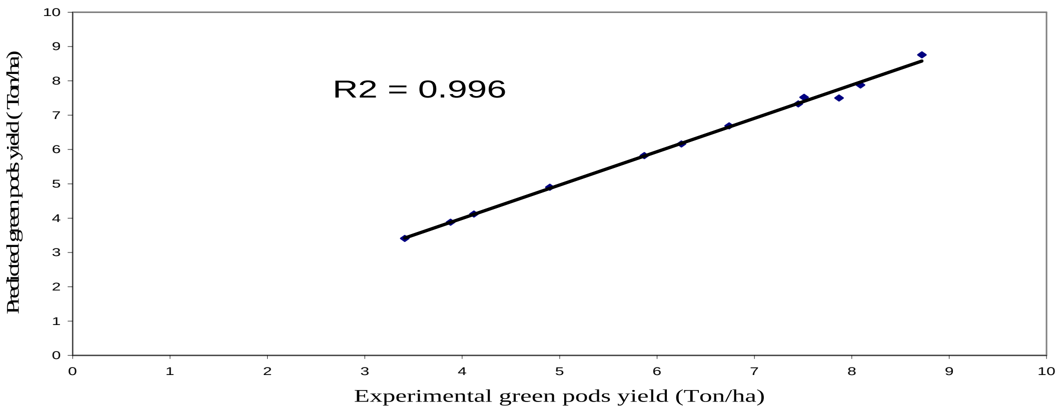

Fig. 3. Correlation between exeperimental and predicated green pods yield of common beans as affected by nitrogen fertilization Rhizobium incolation and molybdnum foliar application during the season of 2006

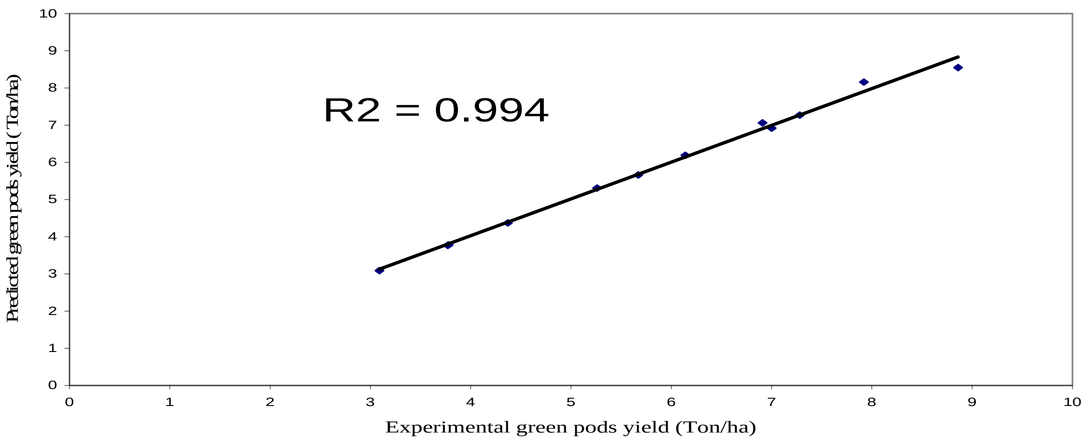

Fig. 4. Correlation between exeperimental and predicated green pods yield of common beans as affected by nitrogen fertilization, Rhizobium incolation and molybdnum foliar application during the season of 2007

Table 5. The first order interaction effects of Rhizobium, nitrogen fertilization and molybdenum foliar application on yield and mineral contents of common bean plants during 2006 and 2007 seasons

Treatments	2006				2007			
	No of green pod	Green pod yield ha $^{-1}$	N%	Mo ppm	No of green pod	Green pod yield ha $^{-1}$	N%	Mo ppm
Rhizobium + Nitrogen								
R0+ N0	14.33 d	3.64 f	2.73 e	0.175 d	12.67f	3.44 e	2.37e	0.152 d
R0+ N1	17.66 c	6.06 d	3.42 cd	0.220 c	17.00 d	5.47 c	3.4 c	0.208 c
R0+ N2	22.17 b	7.66 b	4.07 ab	0.291 ab	21.66 b	7.09 b	3.79 b	0.285 b
R1+ N0	17.5 c	4.51 e	3.08 de	0.219 c	15.17 e	4.08 d	2.67 d	0.230 c
R1+ N1	22.33 b	7.12 c	3.72 bc	0.287 b	19.83 c	6.57 b	3.58 c	0.291 b
R1+ N2	27.00 a	8.41a	4.38 a	0.329 a	24.50 a	8.39a	4.01 a	0389 a
Rhizobium + Molybdenum								
R0+ M0	17.22 d	5.58 c	3.27 b	0.119 c	16.44 C	5.08 c	3.06 c	0.109 c
R0+ M1	18.89 c	6.00 b	3.54 ab	0.338b	17.78 bc	5.37 c	3.31 b	0.322 b
R1+ M0	21.11 b	6.32 b	3.59 ab	0.138 c	19.00 b	6.39 b	3.35 ab	0.124 c
R1+ M1	23.44 a	7.04 a	3.86 a	0.418 a	20.667 a	7.41 a	3.49 a	0.483 a
Nitrogen + Molybdenum								
N_0 + M0	15.00 d	3.76 f	2.78 e	0.095 e	13.33 d	3.44 f	2.48 d	0.078 e
N_0 + M1	16.83 d	4.39 e	3.03 de	0.289 c	14.5 d	4.07 e	2.56 d	0.304 c
N_1 + M0	19.17 c	6.31 d	3.39 cd	0.146 d	17.67 c	5.69 d	3.41 c	0.130 de
N_1 + M1	20.83 c	6.87 c	3.76 bc	0.362 b	19.17 c	6.33 c	3.58 bc	0.369 b
N_2+ M0	23.33 b	7.77 b	4.13 ab	0.145 d	22.16 b	7.41 b	3.73 b	0.140 d
N_2 + M1	25.83 a	8.29 a	4.31 a	0.475 a	24.00 a	8.07 a	4.06 a	0.535 a

Rizobium inoculation rates: R0 = uninoculated (control) and R1 = inoculated with Rizobium.
Mineral nitrogen rates (kg N ha^{-1}) : N0 = without nitrogen (control),N1= 48 and N2= 96 kg N ha^{-1}.
Molybdenum rates : M0 = without molybdenum (control) and M1= 30 µg Mo/l as sodium molybdate

Table 6. The second order interaction effects of Rhizobium, nitrogen fertilization and Molybdenum foliar application on yield and mineral contents of common bean plants during 2006 and 2007 seasons

Seasons	2006				2007			
Treatments	No of green pod	Green pod yield ha $^{-1}$	N%	Mo ppm	No of green pod	Green pod yield ha $^{-1}$	N%	Mo ppm
Rhizobium+Nitrogen+Molybdenum								
R0 + N0 + M0	13.67 g	3.41 h	2.64 f	0.083 g	12.33 h	3.09 g	2.3 g	0.067 f
R0 + N0 + M1	15.00 fg	3.88 gh	2.81 ef	0.266 d	13.00 h	3.78 fg	2.41 fg	0.238 d
R0 + N1 + M0	17.00 ef	5.87 e	3.27cdef	0.127 efg	16.33 fg	5.26 e	3.21 d	0.117ef
R0 + N1 + M1	18.33 e	6.25 de	3.57 bcd	0.313 cd	17.67 ef	5.67 e	3.59 c	0.299 cd
R0 + N2 + M0	21.00 cd	7.45 c	3.9 abc	0.146 ef	20.66 cd	6.91 cd	3.65 bc	0.143 e
R0 + N2 + M1	23.33 bc	7.87bc	4.23 ab	0.436 b	22.67 bc	7.28 bc	3.93 ab	0.428 b
R1 + N0 + M0	16.33 ef	4.12 g	2.90 def	0.107 fg	14.33 gh	3.78 fg	2.63 ef	0.090 ef
R1 + N0 + M1	18.67 de	4.90 f	3.25 cdef	0.331 c	16.00 fg	4.37 f	2.70 e	0.370 bc
R1 + N1 + M0	21.33 c	6.74 d	3.50 cde	0.164 e	19.00 de	6.14 de	3.60 c	0.144 e
R1 + N1 + M1	23.33 bc	7.51 bc	3.95 abc	0.410 b	20.66 cd	7.00 cd	3.56 c	0.438 b
R1 + N2 + M0	25.66 b	8.09 b	4.38 a	0.144 ef	23.67 ab	7.92 b	3.82 bc	0.137 ef
R1 + N2 + M1	28.33 a	8.72 a	4.37 a	0.513 a	25.33 a	8.86 a	4.2 a	0.641 a

Rhizobium inoculation rates: R0 = uninoculated (control) and R1 = inoculated with Rhizobium.
Mineral nitrogen rates (kg N ha^{-1}): N0 = without nitrogen (control), N1= 48and N2= 96kg N ha^{-1}.
Molybdenum rates: M0 = without molybdenum (control) and M1= 30 μg Mo/l as sodium molybdate

Table 7. The polynomial quadratic equations expressing beans green pods yield as affected by N fertilization, Rhizobium inoculation and Molybdenum application

Treatment	Polynomial Quadratic Equations
Season 2006	
R_0 M_0	Y1 = 3.41 + 0.060 x – 0.0002 x^2 (2)
R_0 M_1	Y2 = 3.88 + 0.057x – 0.0002 x^2 (3)
R_1 M_0	Y3 = 4.12 + 0.068x – 0.0003 x^2 (4)
R_1 M_1	Y4 = 4.9 + 0.069 x – 0.0003 x^2 (5)
Season 2007	
R_0 M_0	Y1 = 3.09 + 0.0506 x – 0.0001x^2 (6)
R_0 M_1	Y2= 3.78+ 0.0423 x – 6E-05x^2 (7)
R_1 M_0	Y3 = 3.78 + 0.0552x – 0.0001x^2 (8)
R_1 M_1	Y4 = 4.37 + 0.0628x – 0.0002x^2 (9)

R_0 M_0 = - Rhizobium inoculation and - molybdenum fertilization
R_0 M_1= - Rhizobium inoculation. and + molybdenum fertilization
R_1 M_0= + Rhizobium inoculation and - molybdenum fertilization
R_1 M_1= + Rhizobium inoculation and + molybdenum fertilization

REFERENCES

Al-Rawy, K.M. and A.M. Khalf-Allah. (1980). Design and Analysis of Agricultural Experiments. Text book. El-Mousil Univ. press Ninawa, Iraq. pp.487.

Arisha, H.M. and A. Bardisi.(1999).Effect of nitrogen fertilization and plant spacing on growth, yield and pod quality of common bean under sandy soil conditions. Zagazig J. Agric. Res. 26 (2): 407 - 419.

Berger, P. G., C. Vieira, and G. A. A. Ara´ujo. (1996). Effects of rates and date of molybdenum application on common beans. Pesquisa Agropecu´aria Brasileira 31: 473–490.

Brar, J.S. and P.B. Lal., (1991). Effect of Rhizobium inoculation, phosphorous and molybdenum on yield and its components in Mungbean. Ind. Agriculturist, 35: 67–69.

Chahal V.P.S.and Chahal P.P.K. (1991): Interaction studies between *Rhizobium leguminosarum* and *Meloidogyne incognita* on pea (*Pisum sativum L.*) growth under different concentrations of molybdenum. Plant Soil Sci., *45*: 673–676.

Chapman, H. D and P. f. pratt. (1978). Methods of Analysis for Soils, Plants and Waters. Division of Agriculture Sciences, University of California, Davis, pp 50.

Chetti, M.B., E. Antony, U.V. Mummigatti and M.B. Dodammi., (1995). Role of nitrogen and rhizobium on nitrogen utilization efficiency and productivity potential in groundnut genotypes. *Farming Systems,* 11: 25–33

Consideine, M., (1992). Effect of Urea on photosynthesis and yield in Mungbean. J. Agron. Crop. Sci., 168: 91– 94.

FAO Statistics, (2007). Production Yearbook 2007,

Gabr, S.M., H.A. Elkhatib, and A.M. El-Keriawy**.** (2007). Effect of different biofertilizer types and nitrogen fertilizer levels on growth, yield and chemical contents, of pea plants (*Pisum sativum* L.). J. Adv. Agric. Res. 6 (4):939-955.

Gungula 'D.T. and Y. Garjila. (2006). The effects of molybdenum application on growth and yield of cowpea . American-Eurasian J. Agrie. & Environ. Sci., 1 (2): 96-101.

Gupta, U.C., (1997). *Molybdenum in Agriculture*. Cambridge University Press, UK.

Hristozkova, M., M. Geneva, I. Stancheva an G. geogiev. (2007) . Response of inoculated pea plants to reduce Mo supply .Acta Biologica Hungarica ,58:87-92.

Ishaq, M. S. (2002).Comparisons among the effect of bio-fertilizer, nitrogen and boron on growth, seed production and seed quality of peas (*Pisum sativum* L.).Ph.D.Thesis, Fac. Agric., Alex. Univ. Egypt.

Ismail, R .H. (2002).Physiological studies on biofertilization in pea plants (*Pisum sativum* L.) under calcareous soil conditions .Ph. D. Thesis, Fac. Agric., Ain Shams. Univ. Egypt.

Jongruaysup S., Ohara G.W., Dell B., Bell R.W. (1993): Effects of low molybdenum seed on nodule initiation, development and N_2 fixation in black gran (*Vigna mungo* L). Plant Soil, *156*: 345 – 348.

Kanaujia, S. P., S. K. Sharma and K. B. Rastogi. (1998). Effect of phosphorus, potassium and *Rhizobium* inoculation on growth and yield of pea *(Pisum sativum* L.*)*. Annals of Agric. Res. 19(2): 219-221.

Kelner, D.J., J.K. Vessey, and M.H. Entz. (1997). The nitrogen dynamics of 1-,2- and 3-year stands of alfalfa in a cropping system. Agric. Ecosyst. Environ. 64:1-10.

Krishnasamy, R., T.S. Manikam and G.V. Kothandaraman. 1985. Influence of phosphorous and micronutrient on yield and uptake of NPK in cowpea. Madras Agric. J., 72: 181-184.

Lamb, J.F.S., D.K. Barnes, M.P. Russelle, C.P. Vance, G.H. Heichel, and K.I. Henjum. (1995). Ineffectively and effectively nodulated alfalfas demonstrate biological nitrogen fixation continues with high nitrogen fertilization. Crop Sci.35:153-157.

Lazarovits,G. and J. Nowak. (1997). Rhisobacteria for improvement of plant growth and stablishment. Hort. Sci. 32(2): 188-192.

Ling, E.R. (1963). Determination of total nitrogen by semimicro Kjeldahl method. Dairy Chem., 11: 23-84.

Marschner, H. (1995): Mineral nutrition of higher plants, 2nd edition. Academic press, New York,

Maurya, B.R., K. Kishor and P.C. Ram. (1993). Effects of iron and molybdenum on soybean. J. Maharastra Agri. Univ. 18(1): 128.

Mendel, R., and R. Haensch, (2002). Molybdoenzymes and molybdenum cofactor in plants, J. Exp.Botany, 53, 1689-1698.

Merghany, M.M. (1999)**.**Response of snap bean to different Rhizobium inoculation methods and nitrogen levels under two drip irrigation regimes in new reclaimed sandy soil. Zagazig J. Agric. Res. 26(4): 1091 - 1123.

Moawad, H., W.M. Abd El-Rahim and D. Abd El-Haleem, (2004). Performance of phaseolus bean rhizobia in soils from the major production sites in the Nile Delta. C.R. Biologies, 327: 445-453**.**

Noel, T. C.; C. Sheng, C.K.Yost, R. P. pharis and M. E. Hynes. (1996). Rhizobium leguminosarum as a plant growth Promoting rhizobacterium: direct growth promotion of canola and lettuce. Can. J. Microbiol, 42(3): 270-283.

Page , A.L.,R.H. Miller and D.R Keeneny. (1982). Methods of soil analysis. Part 2. chemical and microbiological properties.2nd edition. Agron .Madison, Wisconsin ,USA.

SAS. (1996). Software program. Cary, North Carolina State. Univ., Karl M Glsener. USA.

Solaiman, A. R. M. and M. Khondaker. (2002). Responses of some pea varieties to *Rhizobium* inoculation, Yield attributes, yield and nutrient content in seed. Bangladesh J. Microbiol. 19(1-2): 41-46.

Solieman, T. H., H. A. ElKhatib and S. M. El-Araby. (2003). Effects of organic manure, mineral nitrogen and bio-fertilizer application on vegetative growth and chemical composition of pea (*Pisum sativum*, L.). Zagazig J. Agric. Res. 30 (3): 751-767

Srivastava, T. K., I. P. S. Ahlawat and J. D. S. Panwar. (1998). Effect of phosphorus, molybdenum and biofertilizers on productivity of pea (*Pisum sativum* L.). Ind. J. Plant Phyiol. 3(3): 237-239.

Svetsov, A.A, A.V Amelin, N.V. Novikova and N.P. Lvov, (1992). The molybdenum cofactor of pea seeds. *Sov. Plant Physiol*., 39: 104–109.

Thakur, A.K. and J.D.S. Panwar, (1995). Effect of Rhizobium VAM interactions on growth and yield in Mungbean. Indian J. P. Physiol., 38: 62–65.

Villora, G., Moreno, D. A.,Romero, L. (2002). Response of eggplant to nitrogen supply molybdenum-nitrate relationships: Biologia Plantarum 45(4): 621-623

Waterer J.G., J.K. Vessey and C.D. Raper (1992): Stimulation of nodulation in field peas (*Pisum sativum*) by low concentrations of ammonium in hydroponic culture. Physiol. Plant., *86*: 215–220.

Yanni, Y.G. (1992) Performance of chickpea, lentil and lupin nodulated with indigenous or inoculated rhizobia, boron, cobalt, and molybdenum fertilization schedules. World J. Microbiol. Biotech., 8: 607–613.

الملخص العربي

تأثير التسميد بالنتروجين والموليبدنم مع التلقيح بالرايزوبيم على النمو والمحصول للفاصوليا

حسن احمد الخطيب

أجريت تجربتان حقليتان خلال عامى ٢٠٠٦-٢٠٠٧ بمحافظة البحيرة كلية الزراعة وذلك لدراسة مدى استجابة محصول الفاصوليا الخضراء "صنف جيزة ٣" للتلقيح الحيوي للبذور بالرايزوبيم(تلقيح – بدون تلقيح) مع التسميد النيتروجيني بمعدلات متزايدة (صفر/ ٤٨، ٩٦ كجم نيتروجين /هكتار) مع إضافة الموليبدنم (بدون إضافة – إضافة بمعدل٣٠ ميكروجرام موليبدنم /لتر كصوديوم موليبدات رشا على الأوراق وتتبع تأثيرات التداخل بين مستويات العوامل الثلاثة على بعض صفات النمو الخضري مثل ارتفاع النبات وعدد الفروع والوزن الطازج والجاف للنبات وكذلك عدد القرون الخضراء والمحصول الكلى الطازج للهكتار ومحتوى الاوراق من النيتروجين الموليبدنم وأوضحت النتائج أن إضافة السماد النيتروجيني المعدني بمعدل٩٦ كجم نيتروجين/هكتار بالإضافة إلى التلقيح البكتيري بالرايزوبيم مع إضافة الموليبدنم قد أعطى أعلى قيم معنوية لمحصول الفاصوليا الخضراء بالمقارنة مع المعاملات الأخرى .

تم تمثيل إنتاجية المحصول الأخضر للفاصوليا في كل موسم بأربع معادلات من الدرجة الثانية باعتبار أن إنتاجية المحصول في التجربة هو داله للتسميد بالنيتروجين والموليبدنم في وجود أو عدم وجود التلقيح البكتيري. وأوضحت الدراسة وجود تطابق معنوي بين المحصول الناتج تجريبيا والمحصول الذي تم التنبؤ به باستخدام المعادلات وذلك لكل المعاملات تحت الدراسة.