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MATHEMATICAL ASPECTS OF SEED PRODUCTION RESPONSE OF PEA (*PISUM SATIVUM L.*) TO NITROGEN AND BIO- FERTILIZATION

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ABSTRACT

The present investigation was caried out to study the effect of seed inoculation with five different biofertilizer types (Azotobacter, Azospirillum, Rhizobium, a mixture of Azotobacter + Azospirillum+ Rhizobium and uninoculated control) and four different fertilization levels of mineral nitrogen (0,30, 60 and 90 Kg N fed^{-1}.) as well as their interactions on seed yield and its components and some chemical contents of dry seeds of pea (*Pisum sativum L.*), cv. Victory Freezer.Inoculation of pea seeds with any utilized biofertilizer type and the application of mineral nitrogen at the rates of 30, 60 and 90 Kg N fed^{-1}, to the growing pea plants, gave significantly higher mean values of dry seeds yield fed^{-1}, number of seeds plant^{-1}, seed weight pod^{-1}, seed index , number of pods plant^{-1}, seed protein and K contents than those of than the uninoculated control, in the two growing seasons.Using the mixed biofertilizer and / or application of nitrogen either at 60 or 90 Kg N fed^{-1}. gave significantly the highest mean values of all studied features of seed yield and its components. Inoculating pea seeds with the mixed biofertilizer coupled with addition of 60 or 90 Kg N fed^{-1}. significantly, increased dry seeds yield fed^{-1}, number of seeds plant^{-1}, seed weight pod^{-1} ,seed index, number of pods plant-1 and K contents in seeds, in both seasons. The obtained results indicated generally that inoculation pea seeds with the mixed biofertilizer and fertilizing the growing plants with nitrogen at the rate of 60 Kg N fed^{-1}. might be considered as an optimal treatment combination for the

production of high yield and good quality of pea. Also, this study provided an evidence about the possibility of using biofertilizers to minimize mineral nitrogen, to decrease pollution and to produce safety products.Polynomial quadratic models were developed and used to describe peas dry yield responses. Four polynomial equations were established to express the relationship between dry seeds yield, and application rate of N fertilizer and seed inoculation with five different biofertilizer types for each season. The equation constants were used to calculate optimum rates of N fertilizer ($N_{opt.}$) and the corresponding optimum yields ($Y_{opt.}$) for all treatments. Nitrogen rates of 51.9 and 60 kg fed^{-1}were found optimum and should be applied along with mixed biofertilizers to produce 705.4 and 627.48 kg fed^{-1}dry seeds for the first and second seasons respectively. The net returns have been maximized as a result of applying optimum N rates.

INTRODUCTION

Pea (*Pisum sativm L.*) is among the four important cultivated legumes next to soybean, groundnut, and beans in the world (Hulse, 1994). It is one of the widely spread, early maturing legume crops grown during the winter seasons in Egypt. The green pods and mature seeds of pea are rich in protein and vitamins. In Egypt, the total area devoted for pea dry seeds production was 9044 feddans and produced total yields of 7000 tons(FAO 2005). Pea is one of the vegetables, whose productivity depends on use of optimum nitrogen fertilizer rates and if not adequately fertilized, considerable yield losses could happen.

Nitrogen (N) is a key component of nutrition for plants and crop production. Since it is required for plants to grow, and it is the basic constituent of proteins, and nucleic acids. It is provided in the form of synthetic chemical fertilizer. However such chemical fertilizers are often in short supply and their indiscriminate use has an adverse effect on long-term soil health and environment, which has received global attention. Moreover, chemical fertilizers are costly and hence are hardly affordable by small and marginal farmers, who constitute the majority of the farming community in developing countries (Tiwary *et al*., 1998). The most realistic solution is, therefore, to exploit the possibility of supplementing chemical fertilizers with organic ones, more particularly biofertilizers of biological origin. These days biofertilizers have emerged as an important component of integrated nutrient management strategy and had a promise to improve an over all crop performance, yield and nutrient supply. Thus, of late increasing attention is being paid to derive the most benefit from biofertilizers.

Biofertilizers are considered the most advanced biotechnology which are capable of mobilizing important nutritional elements in the soil from non-usable to usable form by crop plants through their biological processes (Subba Rao,1993). For the last one-decade, biofertilizers are used extensively as an eco-friendly approach to minimize the use of chemical fertilizers, improve soil fertility status and for enhancement of crop production by their biological activity in the rhizosphere. Extensive research was carried out on the use of bacteria (Azotobacter , Azospirillum and Rhizobium)as biofertilizers to supplement nitrogen fertilizers and observed considerable improvement in the growth of several crop plants (Marwaha, 1995; Thakur and Panwar, 1995).

These investigations aimed to determine the influence of seed inoculation with different biofertilizer types as well as various levels of nitrogen fertilization on seed production and chemical contents of pea plants and to quantify crop-yield relationships with joint nitrogen fertilization and different biofertilizer types; using the polynomial quadratic model.

MATERIALS AND METHODS

Two field experiments were carried out during the two winter seasons of 2003 and 2004 at El-Mahmodia region, Behera Governorate, A.R.E. on silty clay soil having a pH of 8.3, Ec = 2.4 dS/m and the elemental contents of N, P and K were 85, 29 and 316 (ppm), respectively in the first season and 90, 27and 416 (ppm) respectively in the second season. Soil chemical analyses were conducted according to Page *et al.* (1982). Four levels of nitrogen (0, 30, 60 and 90 kg N fed^{-1}) and 5 biofertilizer treatments were combined factorially. Bacterial population of the inoculants used was1.2 x 108 cell/cm^3 obtained from the Biofertilizer Unit, Faculty of Agriculture, Ain Shams University. A total of 20 treatment cobinations were laid out in a Randomized Complete Blocks Design with three replications. The biofertilizer treatments were : uninoculated control; The non-symbiotic N-fixing bacteria *Azotobacter chroococcum* ; The non-symbiotic N-fixing bacteria Azospirillum lipoferium ; the symbiotic N-fixing bacteria *Rhizobium Leguminsarum* and a Mixed biofertilizer containing*Azotobacter chroococcum*+*Azospirillum lipoferium* +*Rhizobium Leguminsarum* in equal parts.The plot area included 5 ridges,each of 4 meters length and 0.6 meter width and the adjacent experimental units were separated by a guard row. Seeds of pea (*Pisum sativum* L.) cultivar Victory Freezer were inoculated and directly sown in hills 15 cm apart on one side of the ridge on October 30, 2003 and October 26, 2004.

The seeds were surface sterilized with 1% sodium hypochlorite for 20 min, then rinsed with water several times.The surface disinfected seeds were coated by soaking seeds in a liquid culture medium of each organism for 15 minutes using 10% arabic gum as Adhesive. For combined inoculations, liquid cultures of the three organisms were mixed in equal proportions and the seeds were then dipped in it **(**Fernandez and Miller, 1986)**.** Uninoculated seeds (control) were soaked in distilled water for 15. minutes also. Nitrogen at different rates in the form of ammonium sulphate (20.5% N), was side banded at two equal portions after 3 and 5 weeks from seed sowing.

All treatments received 200 kg of calcium superphosphate (15.5 % P_2O_5) and 50 kg potassium sulphate (48% K_2O), fed^{-1}. Superphosphate was applied pre-sowing date, whereas, potassium sulphate was added in two equal portions i.e. at 3 and 5 weeks after sowing date. At harvesting time, the matured pods were harvested and the following measurements were recorded: dry seeds yield $feddan^{-1}$, Number of seeds $plant^{-1}$, dry seeds weight pod^{-1}, Seed index (weight of 100 seeds).

For chemical analysis, a random sample of each treatment was taken to determine NPK contents of seeds as follows: N by Kjeldahl method(Chapman and Pratt, 1961), P by spectrophotometrically according to the procedure of John (1970) and K by flame photometer as described by Jackson (1973).The crude protein content was estimated by multiplying the determined N% with a factor of 6.25.

To test the significance of variation resulting from the experimental treatments, the recorded data of various characters of the crop were statistically analyzed using SAS software program (1996). Comparisons among the means of the various treatments were achieved using the New Least Significant Difference procedure at P=0.05 level as, illustrated by Al-Rawy and Khalf-Allah (1980).

RESULTS AND DISCUSSION

The main effect of biofertilizers on dry seeds yield and its components.

The main effects of biofertilizer types; Azotobacter, Azospirillum, Rhizobium and the mixed one on dry seeds yield and its components were found significant in both seasons (Table 1). The results indicated that, inoculating pea seeds, irrespective of the biofertilizer type, promoted dry seeds yield and its components to go forward compared to the uninoculated control. The comparisons among the mean values of biofertilizer types exhibited that inoculation with the mixed biofertilizer, significantly, increased dry seeds yield fed^{-1}, number of seeds $plant^{-1}$and No.of pods $plant^{-1}$ more than the single inoculation with Azotobacter, Azospirillum or Rhizobium in both seasons. Seeds weight pod^{-1} in both seasons and seed index in the second season, on the other hand, were found similar whether pea seeds were inoculated either with single or mixed biofertilizer types. The increase in dry seed yield fed^{-1} with the mixed biofertilizers treatment was estimated to be 6.14, 9.07, 12.89 and 31.86% over that of Rhizobium, Azospirillum, Azotobacter and uninoculated control, as average of the two seasons, respectively . The beneficial effects of rhizosphere bacteria have most often been based on increased plant growth, faster seed germination and better seedling emergence. Plant growth promotion may induce growth through production of phytohormones (Noel *et al*., 1996), improving the availability and acquisition of nutrients (Turner and Backman, 1991) and stimulation of disease resistance mechanisms (Zdor and Anderson, 1992); which all together may increase the uptake of nutrients from the soil and finally accelerate plant growth.

The current results seemed to be in a close agreement with previous results of large number of reports(Fernandez and Miller 1986 and Abd EL-Mouty 2000 on cowpea; Hassouna and Aboul-Nasr 1992 on soybean; Hanna 1999 on broad bean and EL-Mansi *et al.* 2000 on pea, who reported that number of pods plant^{-1} and seed yield fed^{-1} were noticed to be significantly higher as a result of seed inoculation with Rhizobium. Also, Gheeth (2002) found that seed inoculation of snap bean with Rhizobium recorded higher values of number of pods plant^{-1}, weight of 1000 seeds and dry seeds yield fed^{-1}.

The main effect of N fertilizer on dry seeds yield and its components.

The main effects of N fertilizer rates illustrate that the application of 30, 60 and 90 Kg N fed^{-1}.significantly increased dry seeds yield fed^{-1}, number of seeds plant^{-1}, seeds weight pod^{-1}, seed index and No.of pods plant^{-1} over than of the control treatment, in both seasons (Table 1). Among the applied rates, the application of 60 or 90 Kg N fed^{-1} appeared to be sufficient for the plant to express their best performances on dry seeds yield and its components. The corresponding increments in dry seed yield fed^{-1} at 60 and 90 Kg N fed^{-1} over the control, as average of the two seasons, were 47.72 and 44.82 %, respectively, and the difference between these two N levels did not appear to be significant. Such results might be attributed to the potentiality of nitrogen, particularly 60 or 90 Kg N fed^{-1} to assure the adequate and balanced nitrogen requirements, which favored optimum growth and flowering characters and, in turn achieved more seeds yield. Similar trends were obtained by Khalifa (1987) who indicated that increasing the nitrogen fertilizer level to 86 Kg N ha^{-1} was accompanied with a marked increase in dry seeds yield of soybean. Also, Nassar and EL-Masry (1989) reported significant increase on dry seeds yield of common bean plants with increasing the nitrogen application up to 160 Kg N fed^{-1} with a peak at 120 Kg N fed^{-1}. Furthermore, they added that the increase in seed yield was mainly due to the increase in number of pods plant^{-1}. Other investigators emphasized the importance of nitrogen on seed yield and its components, as Bakry *et al*. (1984) and Ismail (2002) on pea; EL-Sawah (1995) and Shiboob (2000) on common bean and Abd El-Mouty (2000) on cowpea.

Table (1). The main effects of biofertilizer types and nitrogen fertilizer rates on dry seeds yield and its components of pea plants during the winter season of 2003 and 2004.

Treatments	dry seeds yield (Kg) fed^{-1}		No. of seeds $plant^{-1}$		Seeds weight pod^{-1} (gm)		seed index (weight of 100 seeds /gm)		No.of pods plant	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Biofertilizer type										
Control	595.17 D	643.67 C	89.71 C	96.74 C	1.64 B	1.70 B	21.99 C	22.58 B	13.06D	15.29 C
Azotobacter	699.05 C	747.59 B	106.51 B	110.77 B	1.80 A	1.76 A	22.96 B	23.96 A	15.01C	18.46 B
Azospirillum	718.16 C	779.84 B	112.12 B	112.83 B	1.77 A	1.81 A	23.11 A B	24.44 A	15.73C	18.69 B
Rhizobium	751.94 B	785.90 B	112.48 B	113.49 B	1.81 A	1.82 A	23.69 A	25.09 A	16.72B	19.09 B
Mixed	804.88 A	827.11 A	122.32 A	123.04 A	1.87 A	1.84 A	23.82 A	25.74 A	17.35A	20.02 A
N rate (Kg N fed^{-1})										
0	569.47 C	543.45 C	79.84 C	81.83 C	1.42 C	1.43 C	21.79 C	20.74 C	12.30C	15.55 C
30	723.44 B	795.54 B	111.44 B	110.94 B	1.84 B	1.84 B	22.81 B	24.27 B	15.74B	18.10 B
60	790.47 A	851.19 A	120.06 A	128.01 A	1.91 A	1.93 A	23.89 A	26.19 A	17.51A	19.44 A
90	772.21A	837.11 A	122.32 A	123.93 A	1.94 A	1.93 A	23.97 A	26.26 A	16.17A	19.19 A

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

Interaction effects of nitrogen and biofertilizers on dry seeds yield and its components

The interaction effects between biofertilizer types and N fertilizer levels on dry seeds yield and its components, in both seasons, are shown in Tables 2 and 3.

Table (2). Interaction effects of biofertilizer types and nitrogen fertilizer rates on dry seeds yield and its components of pea plants during the winter season of 2003.

Biofertilizer / N rate (kg N Fed^{-1})	Control	Azotobacter	Azospirillum	Rhizobium	Mixed
Dry seeds yield fed^{-1} (kg)					
0	410.00 I*	530.31 h	534.84 h	679.12 g	691.97 f g
30	522.31 h	728.02 e-g	758.12 c-f	766.36 c-e	842.35 a b
60	697.99 c-g	775.2 c-e	809.39a-c	803.16 a-e	866.62 a
90	750.41c-f	762.66 c-f	770.30 c-e	759.12 c-f	818.59 a-c
No. seeds $plant^{-1}$					
0	53.02 h	84.32 g	85.29 g	88.76 g	87.83 g
30	83.67 g	108.33 e f	112.06 d e	119.99 b-d	133.17 a
60	108.91 e f	114.08 c-e	128.51 a b	119.30 c d	133.73 a
90	113.26 d e	119.30 b-d	122.62 b c	121.89 b-d	134.54 a
Seeds weight pod^{-1} (gm)					
0	1.37 f	1.42 e f	1.40 e f	1.43 e f	1.48 e
30	1.47 e f	1.91 b c	1.89 b -d	1.94 a-c	1.99 a b
60	1.86 c d	1.91 b c	1.84 c d	1.97 a b	1.99 a b
90	1.86 c d	1.97 a b	1.96 a b	1.91 b c	2.02 a
Seed index (weight of 100 seeds (gm))					
0	20.40 I	21.59 g h	21.83 f-h	22.15 f g	23.00 e f
30	21.19 h I	22.42 e f	22.95 d e	23.69 b-d	23.82 a-c
60	23.00 d e	23.82 a-c	23.81 a-c	24.53 a	24.33 a b
90	23.42 b-d	24.01 a-c	23.87 a-c	24.42a b	24.13 a b
No. pods $plant^{-1}$					
0	9.47k	13.71 I	13.09 hI	13.48 hI	13.36 h
30	9.65 j	15.17 fg	14.65 fg	18.04 b	18.50 a
60	16.10 e-g	16.42 c-f	17.95 b-d	17.23 bc	19.56 a
90	15.36 g	15.60 d-g	15.98 c-f	17.18 b-d	16.53 b

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

Table (3). The interaction effects of biofertilizer types and nitrogen fertilizer rates on dry seeds yield and its components of pea plants during the winter season of 2004.

Biofertilizer / N rate (kg N Fed^{-1})	Control	Azotobacter	Azospirillum	Rhizobium	Mixed
Dry seeds yield fed^{-1} (kg)					
0	396.39 h*	572.07 g	575.84 g	581.30 g	591.66 g
30	584.52 g	791.74 f	821.97 c-f	871.84 a-c	907.64 a b
60	787.56 e f	817.85 c-f	865.14 b c	863.75 b c	921.66 a
90	806.25 d-f	808.69 d-f	856.39 b-d	826.72 c-e	887.50 a b
No. seeds $plant^{-1}$					
0	66.75 h	82.93 g	83.35 g	84.99 g	91.29 g
30	85.98 g	111.01 f	113.13 f	114.80 e f	129.77 a-c
60	117.31 d-f	126.41 a-c	127.24 a-c	131.47 a b	137.63 a
90	116.93 d e	122.73 c-e	123.62 b-d	122.70 c-e	133.65 a
Seeds weight pod^{-1} (gm)					
0	1.39 g	1.42 g	1.41 g	1.46 f g	1.50 f
30	1.65 e	1.81 d	1.90 a-c	1.91 a-c	1.93 a b
60	1.86 c d	1.93 a b	1.96 a	1.93 a b	1.97 a
90	1.90 a-c	1.89 b c	1.93 a b	1.96 a	1.98 a
Seed index (weight of 100 seeds (gm))					
0	19.50 g	20.52 f g	20.78 e-g	22.05 e	20.78 e-g
30	20.28 f g	24.30 d	24.39 d	25.22 d	27.17 a b
60	25.53 c d	25.39 c d	26.33 b c	25.94 b c	27.78 a
90	25.00 c d	25.63 c d	26.28 b c	27.17 a b	27.22 a b
No. pods $plant^{-1}$					
0	11.03 h	15.81 g	16.39 g	16.66g	17.33 g
30	16.39 g	18.66 e f	18.71 c-e	20.34 a-c	21.04 a b
60	17.20 f	19.17 b-f	19.77 a-c	19.92 a-c	21.00 a
90	17.84 d-f	19.44 b-e	19.63 b-d	19.06 b-e	19,87 a-c

***Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05**

The comparisons among the combinations of the two studied factors reflected some significant effects on dry seeds yield fed^{-1}, number of seeds plant-1, seeds weight pod^{-1}, seed index and No.of pods $plant^{-1}$ in both seasons. Generally, the best valuable combinations were the inoculation of pea seeds with the mixed biofertilizer treatment and the application of 60 or 90 Kg N fed^{-1}. Moreover, the treatment combination of mixed biofertilizer and 60 Kg N fed^{-1}, was found sufficient and adequate to produce maximum seed yield. The observed promoting effects of the particular biofertilizer type and the mentioned level of mineral nitrogen, probably, were coupled together and encouraged the vegetative growth which reflected on a higher dry seeds yield. Many authors reported that the inoculation of legumes with compatible strains of the nodule bacteria (*Rhizobium leguminosarum*) considerably,increased seed yield, as reported by Abd EL-Mouty (2000) on cowpea; Shiboob (2000) and Uribe *et al.* 1990 on common bean;and Ishaq (2002) on pea.

The main effect of biofertilizers on chemical contents of dry seeds

Data presented in Table 4 show that inoculation of pea seeds with the different biofertilizer types increased significantly Protein, K and N content of dry seeds as compared with the uninoculated treatment. However, P content in both leaves and seeds did not significantly differ. The mixed biofertilizer was more effective in this concern than the three single biofertilizers.The enhancing effects of biofertilizers on the chemical contents of leaves and dry seeds can be related to the hormonal exudates of the non-symbiotic bacteria which modify growth, morphology and physiology of roots resulting in more acquisition of nutrients by the plant (Jagnow *et al.*, 1991). Brkic *et al*. (2004) reported similar results for beans where seed proteins of inocu-lated plants were higher by 11.5–25% than in non-inoculated plants. A similar trend was also reported by Choudhary *et al*. (1984) on pea.

Table (4). The main effects of biofertilizer types and nitrogen fertilizer rates on the chemical constituents of pea dry seeds during the winter seasons of 2003 and 2004.

Treatments	The chemical constituents of dry seeds of 2003 season			The chemical constituents of dry seeds of 2004 season		
	Protein (%)	P (%)	K (%)	Protein (%)	P (%)	K (%)
Biofertilizer type						
Control	23.14 C	0.61 A	0.94 B	23.07 B	0.67 A	0.91 C
Azotobacter	23.56 A-C	0.60 A	1.03 A	23.47 A B	0.64 A	0.98 B
Azospirillum	23.50 B C	0.61 A	1.03 A	23.54 A B	0.65 A	1.00 B
Rhizobium	23.84 A B	0.57 A	1.02 A	23.72 A	0.66 A	0.99 B
Mixed	24.08 A	0.63 A	1.08 A	23.90 A	0.65 A	1.05 A
N rate (Kg N fed^{-1})						
0	21.26 C	0.56 A	0.83 C	21.41 C	0.64 A	0.85 C
30	23.45 B	0.62 A	0.98 B	23.28 B	0.64 A	0.97 B
60	24.81 A	0.65 A	1.11 A	24.74 A	0.67 A	1.06 A
90	24.97 A	0.59 A	1.17 A	24.74A	0.66 A	1.08 A

**Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

**SPAD= 10 mg chlorophyll g^{-1} fresh weight.

Interaction Effects Of Nitrogen And Biofertilizers On Chemical Contents Of Dry Seeds

Concerning the interaction effects of biofertilizer types and nitrogen fertilizer rates on chemical contents of dry seeds of pea plants(Table 5), the results revealed that the highest mean values for potassium content of seeds were obtained from the plants that were previously inoculated with the mixed biofertilizer and given either 60 or 90 Kg N fed^{-1}. Similar trends were reported by Merghany (1999) on snap bean and Ismail (2002) on pea.

Table (5). The interaction effects of biofertilizer types and nitrogen fertilizer rates on the chemical constituents of dry seeds of peas during the winter season of 2003and 2004.

Biofertilizer / N rate (Kg N Fed^{-1})	Control	Azotobacter	Azospirillum	Rhizobium	Mixed
2003					
Dry Seed protein content (%)					
0	20.95	21.39	20.42	21.32	22.25
30	23.09	23.79	22.97	23.71	23.68
60	24.19	24.45	25.06	25.30	25.11
90	24.32	24.64	25.57	25.03	25.29
Dry Seed P content (%)					
0	0.54	0.60	0.54	0.56	0.55
30	0.65	0.64	0.65	0.55	0.62
60	0.61	0.56	0.68	0.64	0.75
90	0.63	0.61	0.58	0.55	0.58
Dry Seed K content (%)					
0	0.75 g	0.78 g	0.81 g	0.81 g	0.98 e f
30	0.84 g	0.92 f g	1.11 b c	1.00 d-f	1.03 c-e
60	1.06 c-e	1.13 b c	1.09 b-e	1.13 b c	1.15 a
90	1.10 b-d	1.13 b c	1.12 b c	1.15 b	1.17 a
2004					
Dry Seed protein content (%)					
0	21.27	21.45	21.14	21.32	21.96
30	22.98	23.46	23.06	23.47	23.46
60	24.02	24.52	24.98	25.02	25.13
90	24.00	24.45	24.99	25.17	25.07
Dry Seed P content (%)					
0	0.67	0.63	0.65	0.64	0.64
30	0.61	0.64	0.65	0.65	0.66
60	0.70	0.66	0.67	0.67	0.64
90	0.70	0.65	0.65	0.67	0.64
Dry Seed K content (%)					
0	0.77 k	0.81 j k	0.87 h I	0.85 I j	0.96 g
30	0.87 h I	0.91 h	1.05 d e	0.97 f g	0.99 f g
60	0.99 f g	1.14 a	1.02 e f	1.07c d	1.12 a b
90	1.00 f g	1.08 b-d	1.10 a-c	1.08 b-d	1.14 a

**Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

**SPAD= 10 mg chlorophyll g-1 fresh weight.

Polynomial Quadratic Models.

A polynomial quadratic model was used to describe peas yield response to nitrogen increments under different biofertilizers inoculation in the two successive winter growing seasons.

The polynomial quadratic model was in the form:

$$\mathbf{Y_i = B_0 + B_1 X_i \pm B_2 X^2} \quad \textbf{(1)}$$

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 5 polynomial quadratic models were established to express the relationship between dry seeds yield and application rate of N fertilizer under different types of biofertilizers inoculation for each season (Table 6 and Figs 1 & 2).

Table (6): The polynomial quadratic equations expressing peas dry seed yields as affected by N fertilization under different types of biofertilizers inoculation in the two seasons.

Treatment	Polynomial Quadratic Equations
Season 2003	
Control	$Y1 = 400.67 + 5.49x - 0.02x^2$ (2)
Azotobacter	$Y2 = 534.85 + 7.74x - 0.06x^2$ (3)
Azospirilum	$Y3 = 538.92 + 9.08x - 0.07x^2$ (4)
Rhizobium	$Y4 = 677.60 + 4.20x - 0.04x^2$ (5)
Mixed	$Y5 = 694.66 + 6.31x - 0.06x^2$ (6)
Season 2004	
Control	$Y1 = 386.43 + 9.01x - 0.05x^2$ (7)
Azotobacter	$Y2 = 579.98 + 8.17x - 0.06x^2$ (8)
Azospirilum	$Y3 = 583.39 + 9.32x - 0.07x^2$ (9)
Rhizobium	$Y4 = 594.78 + 10.62x - 0.09x^2$ (10)
Mixed	$Y5 = 604.35 + 11.76x - 0.097x^2$ (11)

Fig.(1) Dry seed Yield response curve of peas cultivar Victory freezer as affected by mineral nitrogen levels applied and different biofertilizers inoculation types during the season of 2003

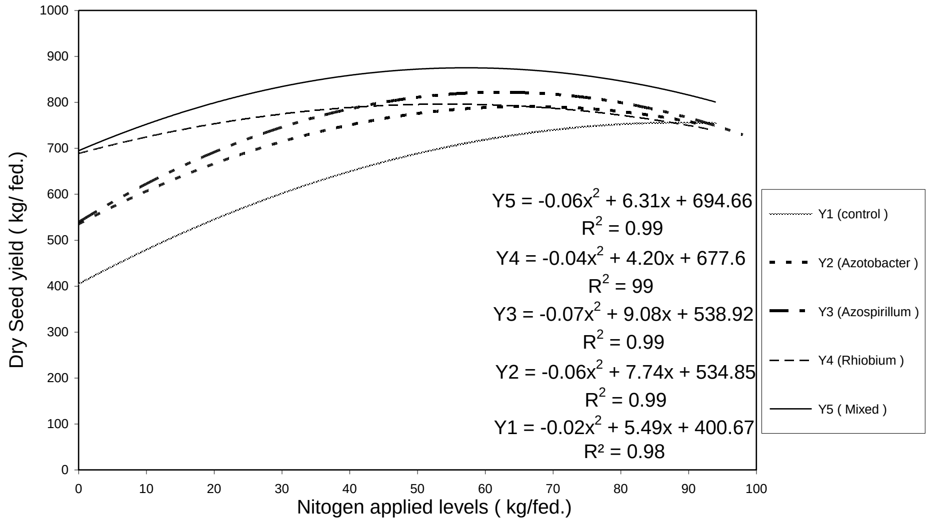
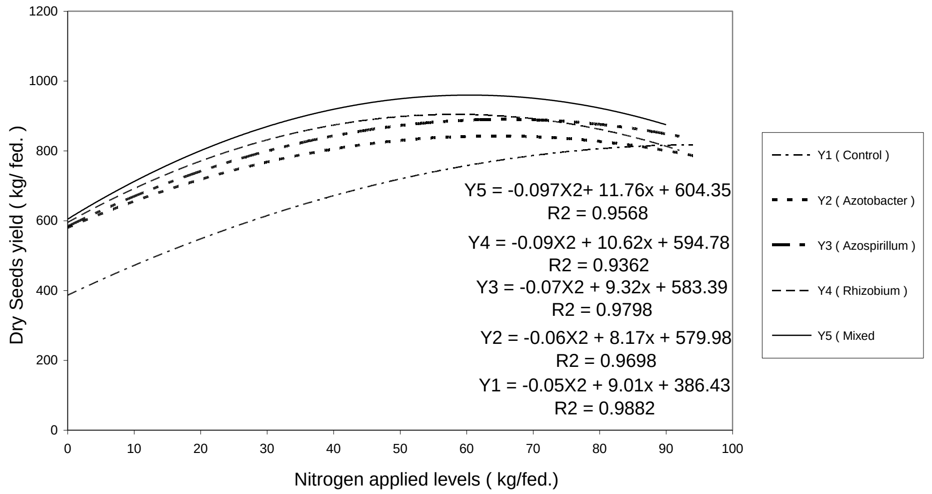


Fig. (1) Dry seed Yield response curve of peas cultuvar victory freezer as affected by mineral nitrogen levels applied and diferent biofertilizer inoculatio types during the season of 2004



The Economical Optimum Rate Of N Application ($N_{opt.}$).

The method of Capurro and Voss (1981) derived from the polynomial quadratic equations was used to calculate the optimum rate of N fertilizer application (N_{opt}) by differentiating Y in Eqs. 2-11 with regard to N (dY / dN) and equating with the ratio of price of fertilizer Unit to price of crop unit. (Table 7).

The local price for a unit of N fertilizer (30 kg N) was estimated as 150 Egyptian pounds (EP) and the local price of 1 kg o of dry seeds of peas was also estimated as 15 EP. Therefore, the values of the N opt in 2003 season were 4.49, 2,12, 2.14,1.71 and 1.73 units of N fad^{-1} at Control, Azotobacter, Azospirillum, Rhizobium and Mixed treatments respectively, whereas the corresponding $N_{opt.}$ values for 2004 season were 2.97, 2.24, 2.20,1.95 and 2.00 units of N fed^{-1} respectively (1 N unit = 30 kg N fed^{-1}).

The Optimum Yield ($Y_{opt.}$).

The corresponding optimum yields were calculated by substituting the values of $N_{opt.}$ In eqs. 2-11 (Table 7). The obtainable optimum yields of dry seeds were 424.92, 550.99 , 558.03, 684.67 and 705.4 kg $fed.^{-1}$ in the first season at Control, Azotobacter, Azospirillum, Rhizobium and Mixed respectively, while in the second season the corresponding optimum yield values were 412.75, 597.98, 603.56, 615.15 and 627.48kg $fed.^{-1}$ respectively. The calculated $Y_{opt.}$ values tended to increase as a result of biofertilizers inoculation (Table 7).

Net Returns Of Peas Dry Seeds Yield Under Nitrogen Application And Bio- Fertilization In 2003 And 2004 Seasons.

Net returns from optimum yield of peas dry seeds that received the optimum level of nitrogen fertilization in the two seasons were calculated and presented in Table 7. The results indicated that, the inoculation of pea seeds with any of the used biofertilizer was associated with higher values of net returns than the uninoculated seeds in both seasons. The net returns were 3575.7 , 5191.9 , 5259.3 , 6590.2 and 6794.5 EP, in the first season for Control, Azotobacter, Azospirillum, Rhizobium and Mixed treatments respectively, whereas, the corresponding values in the second season were 3682.0 , 5643.8, 5705.6, 5859.0 and 5974.8 EP for Control, Azotobacter, Azospirillum, Rhizobium and Mixed treatments respectively. So the net returns rating as a result of adding biofertilizer along with mineral N fertilization could be assigned as follow:

Mixed > Rhizobium >Azospirillum > Azotobacter > Control

Thus, the mixed biofertilizers along with nitrogen application of 60 kg Nfed.$^{-1}$ appeared to be the most effective treatment combination due to the highest net returns compared to the other tested treatment combinations. These results are in a generalagreement with those of Rodelas *et.al.*(1999) on faba bean and Elkhatib *et al.* (2004) on onion.

Finally, it could be concluded that plant growth promoting biofertilizer, might be considered a step towards reducing mineral nitrogen fertilizers and accomplishing the concept of bio-organic farming needed to get clean and safe products for human and animal consumption.

Table (7): Values of optimum rates of N fertilizer, optimum yields and net returns of the peas cultivar Victory as affected by N fertilization and different biofertilizers inoculation types in the two seasons of 2003 and 2004 .

Treatments Biofertilizer types	$N_{opt.}$ (N units fed.$^{-1}$)	$Y_{opt.}$ (kg fed.$^{-1}$)	Net retun (EP)
2003			
Control	4.49	424.92	3575.7
Azotobacter	2.12	550.99	5191.9
Azospirilum	2.14	558.03	5259.3
Rhizobium	1.71	684.67	6590.2
Mixed	1.73	705.4	6794.5
2004			
Control	2.97	412.75	3682.0
Azotobacter	2.24	597.98	5643.8
Azospirilum	2.20	603.56	5705.6
Rhizobium	1.95	615.15	5859.0
Mixed	2.00	627.48	5974.8

Price of 1 kg of peas dry seed = 15 EP. EP= Egyptian Pound
Price of a unit of nitrogen fertilization (30kg N) = 150 EP.

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الملخص العربى

التعبير الرياضي عن استجابة إنتاج بذور البسلة للتسميد النيتروجيني والحيوي

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اجري هذا البحث بهدف دراسة تأثير تلقيح بذور البسلة صنف فكتورى فريزر بأربعة أنواع مختلفة من الأسمدة الحيوية، ثلاثة منهم منفردة من أجناس Azotobacter، Azospirillum، Rhizobium ،و الرابع عبارة عن سماد حيوي مختلط من الأجناس الثلاثة السابقة بالإضافة إلى الكنترول غير الملقح مع وأربعة مستويات من التسميد النيتروجينى المعدني (صفر، ٣٠ ، ٦٠، ٩٠ كجم ن للفدان) والتداخلات بينهم على صفات محصول البذور الجافة و مكوناته و كذلك المحتوى الكيماوي للبذوروكذلك امكانية التعبير الرياضى عن استجابة انتاج البذور للتسميد النيتروجينى والحيوى هذا ويمكن تلخيص النتائج المتحصل عليها فيمايلى:-

أولا :محصول البذور الجافة و مكوناته

1 - أدى تلقيح بذور البسلة بالأسمدة الحيوية الأزوتوباكتر ، الأزوسبرليم ، الريزوبيم و السماد الحيوى الخليط إلى زيادة معنوية فى المحصول الكلى للبذور الجافة للفدان، عدد البذور / نبات ، وزن البذور / قرن ، وزن١٠٠ بذرة وعدد القرون للنبات مقارنة بالكنترول غير الملقح في موسمى الزراعة. و أشارت الدراسة كذلك أن أفضل المعاملات هى معاملة التسميد الحيوى الخليط.

2 - أظهرت الدراسة أن إضافة السماد النيتروجيني بمعدلات ٣٠ ، ٦٠ و٩٠ كجم ن للفدان لنباتات البسلة ، أدت إلى زيادة معنوية فى المحصول الكلى للبذور الجافة للفدان ، عدد البذور / نبات ، وزن البذور و كذلك وزن ١٠٠ بذرة وعدد القرون للنبات وذلك مقارنة بمعاملة الكنترول فى كل من موسمي الزراعة. و أوضحت الدراسة أيضا أن إضافة النيتروجين المعدني عند مستوى ٦٠ أو ٩٠ كجم ن للفدان أعطى أعلى القيم لكل صفات محصول البذور الجافة و مكوناته وكان الفرق بين هذين المستويين غير معنوي.

3 - أدى تلقيح بذور البسلة بخليط السماد الحيوى مع إضافة النيتروجين بمعدل ٦٠ أو ٩٠ كجم ن للفدان إلى زيادة معنوية فى محصول البذور الجافة ، عدد البذور / نبات ، وزن البذور / قرن و وزن ١٠٠ بذرة وعدد القرون للنبات و ذلك فى كلا موسمي الزراعة.

ثانيا :المحتوى الكيماوي للبذور الجافة

1 - تلقيح بذور البسلة بأي نوع من السماد الحيوى أدى إلى زيادة معنوية فى محتوى البذور من البروتين و البوتاسيوم و ذلك مقارنة بمعاملة الكنترول الغير ملقح فى موسمي الدراسة ، بينما عنصر الفوسفور لم يتأثر معنويا" و تفيد الدراسة أيضا أن أفضل نوع من السماد الحيوي هو السماد الحيوى الخليط.

2 - أدت إضافة السماد النيتروجيني بمعدلات٣٠ ، ٦٠ أو ٩٠ كجم ن للفدان إلى زيادة معنوية فى محتوى البذور من البروتين و البوتاسيوم فى موسمي الزراعة ، بينما عنصر الفوسفور لم يتأثر معنويا و توضح النتائج أيضا أن المستويان المرتفعان من النتروجين (٦٠ ، ٩٠ كجم ن للفدان) هما المستويان المناسبان للتسميد.

3 - أوضحت الدراسة أن التأثير المتبادل لكل من السماد الحيوي و النيتروجيني قد أعطى بعض التأثيرات المعنوية و كانت أفضل معاملة تداخليه هي تلقيح بذور البسلة بالسماد الحيوي الخليط مع إضافة ٦٠ أو ٩٠ كجم ن للفدان.

ثالثا التعبير الرياضى

تم تمثيل نتائج إنتاجية المحصول الجاف للبسلة في كل موسم بخمس معادلات من الدرجة الثانية باعتبار أن إنتاجية محصول البسلة في التجربة هو داله للتسميد النيتروجيني والحيوي . وقد استخدمت ثوابت المعادلات لحساب معدلات التسميد النيتروجيني المثلي والمحصول الأمثل لكل المعاملات الحيوية . وأوضحت النتائج أن معدل التسميد النيتروجيني الأمثل الذي يجب إضافته في وجود التلقيح البكتيري هو 51.9 كجم نيتروجين / فدان في الموسم الأول و٦٠ كجم نيتروجين/فدان في الموسم الثاني وذلك لإنتاج محصول جاف قدرة 705.4 كجم/فدان في الموسم الأول 627.48كجم/فدان في الموسم الثاني. كما أوضحت الحسابات تعاظم العائد الاقتصادي كنتيجة لاضافة المعدلات المثلي للسماد النيتروجيني.

رابعا : التوصيات

الدراسات السابقة توصى بصفة عامة آن تلقيح بذور البسلة بخليط من السماد الحيوي مع إضافة ٦٠ كجم ن للفدان هي أفضل المعاملات و التي تعطى أعلى محصول مع جودة عالية كما تفيد الدراسة أيضا بأن استخدام الأسمدة الحيوية يؤدى إلى خفض الكميات المستخدمة من النتروجين المعدني ويقلل التلوث و يساعد على إنتاج ثمار آمنة لصحة الإنس ان.