Yield Response of Peas to Nitrogen and Bio-Organic Fertilization: A Mathematical Model

ELKHATIB, H.A.

Department of Horticulture, College of Agriculture, Damanhour, Alexandria University, Egypt.

ABSTRACT

One of the major problems of N fertilization is the determination of the correct amount to be used in order to increase crop production and to avoid unnecessary environmental effects. A 2-year field study was conducted to assess the dry seeds yield response of pea cultivar (Lincolin) to N fertilization (No = 0, N_1 = 48 and N_2 = 96 kg N ha^{-1}) under organic manuring (O_0 = 0 and O_1 = 60 m^3ha^{-1}) and rhizobium inoculation (R_0 and R_1). Soil application of mineral N at the rate of 48 kg N ha^{-1} (N_1) combined with 60 m^3 ha^{-1} (O_1) organic manuring to the inoculated seeds produced the highest significant values of dry seeds yield and yield components.

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 under organic manuring and rhizobium inoculation for each season. The calculated yields in the two seasons , closely ,approximated experimental yields as evidenced by the highly significant value of coefficient of determination (R^2). The equation constants were used to calculate optimum rates of N fertilizer ($N_{opt.}$) and the corresponding optimum yields ($Y_{opt.}$) for all the treatments. Nitrogen rates of 64 and 53 kg ha^{-1} along with organic manuring (60 m^3 ha^{-1}) and rhizobium inoculation were found optimum to produce 2492 and 2462 kg ha^{-1} dry seeds in the first and second seasons respectively. The net returns were maximized as a result of applying such optimum N rates.

INTRODUCTION

Nitrogen fertilization has an important role in enhancing growth and development of many different vegetable crops. However, the excessive use of inorganic fertilizers represent a major factor of crop production cost and lead to environmental pollution (Fisher and Richter, 1984). It is documented that artificial fertilizers have a pollutant effect on the soil and plants and consequently on the human health.Owing to that, the scientists are looking forward to substitute partially the artificial fertilizers with natural ones like organic fertilizers and biofertilizers for clean and safe organic production.(Verma, 1990; Borin et al, 1987; Seesahai and Ferguson, 1997 and Osman ,1998).

Peas (*Pisum sativum L.*) is one of the popular and important winter vegetable crops in the Mediterranean region (Smart, 1990). Pea seeds, fresh or dry, have a high nutritional value due its high contents of proteins, carbohydrates, vitamins and minerals. In addition pea is the predominant export crop in world trade and represents about 40% of the total trade (Oram and Agcaoili, 1994).However,a very little information is available concerning yield response of peas to nitrogen fertilization in the presence of organic fertilization and / or rhizobium inoculation. Responses are often expressed as mathematical models that describe the data well and aid in defining the optimum fertilization that results in the optimum crop yield, without risking over-fertilization.(Cerrato and Blackmer,1990).

The objectives of the present study were:(1) to evaluate dry yield responses of the pea cultivar lincolin to nitrogen fertilization under organic manuring and rhizobium inoculation , and (2) to quantify crop-yield relationships with joint nitrogen fertilization, organic manuring and rhizobium inoculation; using the polynomial quadratic model.

MATERIALS AND METHODS

Two field experiments were conducted in the two successive winter growing seasons of 1999/2000 and 2000/2001 at the experimental farm of the Faculty of Agriculture, Alexandria University. The soil of the experimental site was clay loam, and its physical and chemical characteristics of the soil illustrated in Table (1),were determined before sowin;according to the methods reported by Page et al.(1982).

The experimental lay out was split-split plots in a randomized complete blocks design with three replicates. Organic fertilizer factor occupied the main plots (60 m^3 ha^{-1} and a control without treatment); whereas, Nitrogen rates (0, 48, and 96 kg N. ha^{-1}) were assigned at random in the sub-plots and seed inoculation treatments (with or without nitrogen fixing bacteria of the genus *Rhizobium*).were arranged in the sub-sub plots . Each experimental unit was 8.2 m^2 and contained 3 ridges 4m long and 70cm wide. Seeds of the pea c.v. lincolin were inoculated just before sowing with the biofertilizer and the uninoculated seeds were involved as a control. Nitrogen fertilizer rates were applied in the form of ammonium nitrate (33.5% N) and were added , as two equal parts, at 25 and 35 days from sowing. Cattle manure, used for organic fertilization,was broadcasted and incorporated into the soil before planting. Chemical properties of cattle manure are summarized in Table 2. At harvesting time, dry pods were harvested and the following measurements were recorded: number of dry pods $plant^{-1}$, weight of seeds $pods^{-1}$, weight of 100 seeds (g) and dry seeds yield, expressed as kg ha^{-1}. All obtained data were statistically analyzed according to Snedecor and Cochran (1980) and means were compared using L.S.D. test. M-state computer program was employed.

RESULTS AND DISCUSSION

The Main Effects of Organic Manuring and Biofertilizers:

Application of organic manure at a rate of 60 m^3 ha^{-1} significantly enhanced dry seeds yield, number of dry pods per plant, weight seeds per pod and weight of 100 seeds as compared to untreated treatments in both seasons

(Table,3). Such an enhancement was probably due to improvement of physical soil properties and nutrients status in the soil (Bhata and Soukla, 1982). Increasing crop yield due organic manuring was also reported by many investigators (Borin etal.,1987; Seesahai and Ferguson,1997;Osman,1988 and gabr,2000)

Inoculation of pea seeds with rhizbium caused significant increases on pods number, weight of seeds per pod, weight of 100 seeds and dry seeds yield in both seasons (Table,3). The improving effect of inoculation on dry seeds yield of pea plants can be explained in terms of improving N nutrition and/or production of phytohormones (Lazarovits and Nowak, 1997;Noel etal.,1996).

The Main Effect of Mineral Nitrogen:

Addition of chemical nitrogen fertilizer at the rates of 48 or 96 kg N ha-1 increased significantly dry seeds yield and yield components. Adding 48 kg N/ha have resulted in 38.6,19.8,10.5 and 66.7% increases, in the first season and 36.0,19.6,9.9 and 60.9% increases, in the second season for number of dry pods /plant, weight of seed/pod, weight of 100 seeds and dry seeds yield respectively. The corresponding increased values; as a result of adding 96 kg N/ha; were 33.4,17.9,5.0,and 53.9% of the control in the first season and 20.7,16.9,9.2 and 40.1%, in the second season, respectively. Such increaments might be attributed to the role of nitrogen in encouraging plant growth through the stimulative effect of the meristematic activity of tissues that lead to a more active photosynthesis .The obtained results are in accordanc with those of Shahien(1996) and Kalyn et al.(1996).However, the comparison between the two nitrogen levels, 48 and 96 kg N ha^{-1}, reflected a reversal effect for the high N level on seeds dry yield and its components; except for the weight of seeds /pod, in which such a reduction appeared insignificant in both seasons. The reversal effects might be attributed to an unbalance in nutritional soil solution caused by the high level of N fertilizer. Farrag et al.(1993) and AboBakr et al. (1993) reported that adding nitrogen fertilizer at a rate of 25kg/Fed was more effective in increasing dry pod yield of pea, as compared to using 50 or 75 kg N/Fed.. Also,Chamberland (1982) and Davies et al.(1985) found that peas responded better to the lower rates or starter N fertilizer than the higher N fertilizer rates.

Interaction Effects Between Organic Manure and Mineral Nitrogen.

The data, presented in Table (4), reflected the effects of the first-degree interaction between organic manure and nitrogen fertilization levels, on dry seed yield and its components in the two growing seasons.

The comparisons among the means of the six treatments combinations, illustrated that application of organic manure along with 48 kg N ha^{-1} resulted significantly in the highest values for dry seed yield and its components, in both seasons This could be due to the additional supply of N and other nutrients through organic manure (Holanda et al., 1986). Singh et al. (1988) showed in a laboratory incubation study, that net release of mineral N from farmyard manure occured after 3-4 weeks, so the initial N requirements of pea plants were therefore met from the mineral N application.The reported Lower yield values from using the combination of organic manure and the rate of 96 kg N ha^{-1} could be explained as reported by Ayisi et al. (2000), who found that nitrogen fertilizer in excess increased vegetative growth but the harvested yield of cowpea was decreased.

Interaction Effects Between Organic Manure and Biofertilizers.

The detected interaction effects of the combined treatments of organic manure and rhizobium inoculation on yield parameters are shown in Table (4). The differences occurred among the various treatments were found significant in both seasons. The combined effect of rhizobium inoculation in the presence of organic manure reflected the highest values for all studied yield parameters in the two seasons. This could be due to the efficiency of organic fertilizers and its mineral contents in enhancing the microbial activities in the soil (Estefanous etal.1997), which encouraged nodules formation and, consequently increase N fixation. A similar trend for organic manure effect was reported by Vogtman and Frick (1989); Ahmed et a. (1997); and El-Araby et al (2003).

Interaction Effects Between Nitrogen and Biofertilizer.

The comparisons among the means of various treatment combinations of the Biofertilizer (rhizobium) treatments and the nitrogen fertilization levels on dry seed yield and its components are illustrated in Table (4). The results of the two seasons indicated that means of all studied characters increased within the treatment combinations involving seed inoculation as compared with uninoculated treatments. Soil application of N at the rate of 48 kg N ha^{-1} to the inoculated seeds produced the best interaction effect among the different combinations on all studied characters, in both seasons. These data are in accordance with that of Eaglesham et al. (1983) and Dart and Wildon (1970) who reported that addition of low levels of N fertilizer had beneficial effects on cowpea and soybean. Also; many investigators, working on cowpea reported that high levels of N fertilizer were found to reduce biologically fixed N (Allos and Bartholomew, 1959), nodule number (Dart and Mercer, 1965) and nodule growth (Summerfield et al., 1977).

Interaction Effects Among Organic Manure, Nitrogen Fertilization and Biofertilizer Inoculation.

The comparisons among the means, reflecting the effects of the second order interaction among all studied factors showed that the different studied parameters of yield components, as well as total dry seed yield, were significantly affected as a result of such an interaction (Table 5). It is evident that the application of 48 kg N ha^{-1};in the presence of organic manure, besides the seed inoculation with N fixing bacteria gave the highest values of dry seed yield ha^{-1} and all its components. Davies et al. (1985) obtained similar results working also on peas.

Polynomial Quadratic Models.

The polynomial quadratic model, used to describe peas yield response to nitrogen increments under organic manure fertilization and rhizobium inoculation in the two successive winter growing season, was in the form:

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

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 dry seeds yield and application rate of N fertilizer under organic fertilization and rhizobium inoculation for each season (Table 6 and Figs 1 & 2).

The calculated yields in the two seasons, closely, approximated the experimental yields as shown from the highly significant value of determination coefficient ($R^2 = 0.96$) in Fig.(3).

The Economical Optimum Rate of N application (N_{opt}.).

The optimum rate of N fertilizer application (N_{opt}) was calculated by differentiating Y in Eqs 2-9; 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 (48 kg N) was 120 Egyptian pounds (EP) and the local price of 1 kg of dry seeds of peas was 10 Ep. Therefore, the values of the N_{opt} ,in 1999/2000 season,were 1.61, 1.43, 1.38 and 1.34 units of N ha^{-1} at $O_0 R_0$, $O_0 R_1$, $O_1 R_0$ and O_1R_1 treatments; whereas the corresponding N_{opt} Values, for 2000/2001 season, were 1.55, 1.26, 1.22 and 1.11 units of N ha^{-1} respectively (1 N unit = 48 kg N ha^{-1}).

The Optimum Yield (Y_{opt}.).

The corresponding optimum yields were calculated by substituting the values of N_{opt} in eqs. 2-9 (Table 6). The obtainable optimum yields of dry seeds were 1512.92, 1890.17, 2162.82 and 2492.05 kg ha^{-1},in the first season, at $O_0 R_0$, $O_0 R_1$, $O_1 R_0$ and $O_1 R_1$; while, in the second season the corresponding optimum yield values were 1716.9, 2269.32, 2391.22 and 2462.62 kg ha^{-1}.

respectively. The calculated $Y_{opt.}$ values tended to increase as a result of organic manuring and rhizobium inoculation (Table,7).

Net Returns of Peas Dry Seeds Yield Under Nitrogen Application and Bioorganic Fertilization, In 1999/2000 and 2000/2001 Seasons.

Net returns from optimum yield of dry seeds of peas received optimum level of nitrogen fertilization in the two seasons, were calculated and are presented in Table (7). It is evident that the net returns obtained by adding organic manure associated with biofertilizer inoculation were the highest in both seasons.

The net returns rating, as a result of adding organic manure and /or biofertilizer along with mineral N fertilization, could be assigned as follows:

$O_1 R_1 > O_1 R_0 > O_0 R_1 > O_0 R_0$, So it could be concluded that applying organic manure, together with the plant growth promoting biofertilizer, is considered a step towards reducing mineral nitrogen fertilizer and accomplishing the concept of bio-organic farming needed to get clean and safe products for human and animal consumption.

Efficiency of N Fertilizer To Reach Optimum Yield.

Capurro and Voss (1981) established the following equation to calculate the nitrogen efficiency at $N_{opt.}$ for the range of Y values from an actual yield (Y_a) to the optimum yield $Y_{opt.}$:

$$EN_a = B_1 + 2\,B_2\,Ni, \text{ and } EN_{opt.} = ½\,(EN_a + Pr).$$

Where: EN_a is the nitrogen efficiency of actual yield Y_a and nitrogen increment N_a while, Pr is the price ratio (N unit price: yield unit price). The values obtained for $EN_{opt.}$ Using B_1 and B_2 values (from eqs. 2-9) were 433.26, 551.86, 684.34 and 792.94 kg peas dry seeds unit^{-1} ha^{-1}, with the ratio of 1: 1.28 : 1.58 : 1.83 in the first seasons at $O_0 R_0$, $O_0 R_1$, $O_1 R_0$ and $O_1 R_1$ while the corresponding values in the second season, were 496.65, 697.86, 796.04 and 791.44; with the ratio of 1 : 1.41 : 1.60 : 1.59 respectively. It is clear that the efficiency of nitrogen fertilizer was increased with addition of biofertilizer or/and organic manure, in both seasons, due to the improvement of some physical and nutritional properties of the soil under the present experimental conditions

REFERENCES

AboBakr, M. A., M. N. Hassan, M. Y. El-Maziney, and A. M. Ahmed. 1993. Effect of fertilization rates of nitrogen, potassium and phosphorus on growth and yield of peas (*Pisum sativum L.*). Dry yield parameters. Minia. J. Agric. Res. & Dev. 15:101-110.

Ahmed, M. K., A. O. Saad, A. T. Thalooth, and M. O. Kabesh. 1997. Utilization of biofertilizer in field crop production: 10-yield response of ground nut to inorganic, organic and biofertilizers. Ann. Agric. Sci. Ain Shams Univ. Cairo. 42(2): 365-375.

Allos, H. F. and W. V. Bartholomew. 1959. Replacement of symbiotic fixation by available nitrogen. Soil Sci. 87:61-66.

Ayisi, K. K., R. J. Nkgapele, and F.D. Dakora. 2000. Nodule Formation and function in six varieties of cowpea (*Vigna unguiculata L. walp.*) grown in nitrogen-rich field soil in south Africa. Soils and fertilizers. 28(1): 17-31.

Bhata, K. S. and K.K. Soukla. 1982. Effect of continous application of fertilizers and manure on some physical properties of eroded alluvial soil. J. Ind. Soc. Soil Sci. 30:32-36.

Borin, M., C. Givpponi, and F. Osele.1987. The effect of organic and mineral fertilizer and soil type on potato tuber formation. In Agraric. 43: 91-92 (C. F. Field Crops Abs. 40: 8072).

Capurro, E. and R. Voss. 1981. An index of nutrient effeciency and its application to corn yield response to fertilizer N. I. Derivation, estimation and application. Agron. J. 73: 128-135.

Cerrato, M.E. and A.M. Blackmer.1990. Comparison of models for describing corn yield response to nitrogen fertilizer .Agron. J. 82: 138-143.

Chamberland, E. 1982. Prediction des besions enengrais N., P. et K des legumes cultivés en sol mineral: Pois et haricots. Can. J. Soil Sci. 62:663-672.

Dart, P.J. and D.C. Wildon.1970. Nodulation and nitrogen fixation by *Vigna sinensis* and *Vicia atropurpurea.* : The influence of concentration, form and site of application of combined nitrogen.Austral.J. Agr. Res. 21:45-56.

Dart, P. J. and F. V. Mercer. 1965. The effect of growth, temperature, level of ammonium nitrate, and light intenisty on the growth and nodulation of cowpea (*Vigna sinensis* Endl. Ex Hassk). Austral. J. Agr. Res. 16:321-345.

Davies, D.R. , G.J. Berry, M. C. Heath, and T. K.Dawkins. 1985. Pea (*Pisum sativum L.*) pp. 147-198 in R. J. Summerfield and E. H. Roberts, eds. Grain Legume crops. W. Collins Sons and Co. Ltd., London, U. K.

Eaglesham, A.R., S. Hassouna, and R. Seegers. 1983. Fertilizer N effects on N2 fixation by cowpea and soybean .Agron. J. 75: 61-66

El-Araby, S. M., H. A. Elkhatib and T. H. Solieman. 2003. Effect of organic manure, mineral nitrogen and biofertilizer application on yield, quality and chemical composition of pea (*Pisum sativum L.*) Zagazig J. of Agric. Res. 30(3): 769-782.

Estefanous, A. N., F.T. Milkhael and G.G. Antoon.1997. Effect of mycorrhizal inoculation and organic fertilization on microbial activity and nutrient release in soil. Bull. Fac. Agric. Univ. Cairo. 48:187-200.

Farrag, M. M., M. N. Hassan, S. H. Gad El-Hak and R. H. Gheth 1993. Effect of rhizobium, nitrogen and phosphorus application on growth and yield of peas. 2. Dry yield. Minia first Conference for Horticultural crops from 19-21 October.

Fisher, A and C. Richter. 1984. influence of organic and mineral fertilizers on yield and quality of potatoes. Proc. The Fifth IFOAM. International scientific conference. Univ. of Kassel, Germany.

Gabr, S. M. 2000. Effect of Some organic fertilizers on growth, yield and quality of some new snap bean cultivars (*Phaseolus vulgaris L.*) Alex. J. Agric. Res. 45(2):.201-212.

Holanda, J. S., J. T. Filno and F. B. Neto. 1986. Fertility changes in two soils under peas fertilized with farmyard manure. Revisto Brasileira deciencia do solo (1984). 8(3): 301-304 (C. F. Soil and fert. 49:3263).

Kalyn, S., U. Singh, R. Singh, J. Bohra and K. Singh. 1996. Fertilizer and irrigation studies on yield economy and NPK uptake of frensh bean (*phaseolus Vulgaris L.*) Fertilizer News. 41(5): 39-42.

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

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.

Oram, P. A., and M. Agcaoili. 1994. Current status and future trends in supply and demand of cool season food legumes. P. 3-49. In: R. J. summerfield (ed.), world crops: cool season food legumes. Kluwer Academic publishers, dordrecht, the Netherlands.

Osman, F. A. 1998. Effect of organic manure, phosphorus and magnesium application on yield components and nutrients uptake of peas. Zagazig J. Agric. Res. 25(5):875-888.

Page, A. L., R. H. Miller and D. R. Keeny. (ed.) 1982. Methods of soil analysis, part2. Chemical and Microbiological properties. Amer. Soc. of Agronomy. Madison, Wisconsin. USA.

Seesahai, A. and T. U. Ferguson. 1997. The yield response of two sweet potato cultivars grown in bags using different soil amendments. Proceedindings of the 1th international Society for tropical Root Crop symposium, 75(1) :29-34 .

Shahien, A. H. 1996. Effect of irrigation frequency and fertilization on pea growth, yield, yield components and total uptake of some 15 macronutrient Annals of agricultural science, Moshtohor.34(2): 669-689.

Singh, Y, S. Bijay, M. S. Maskina, and O. P. Meelw. 1988. Effect of organic manures, crop residues and green manures (*Sesbania oculeata*) on nitrogen and phosphorus transformations in sandy loam at field capacity and under water logged conditions. Biology and fertility of soils. 6:183-187.

Smart, J. 1990. Grain legumes. Evolution and genetic resources. Cambridge University press, Cambridge, U. K. 200p.

Snedecor, G. W. and W. G. Cohran. 1980. Statistical methods. 7th ed. Iowa State Univeresity, Press Ames. Iowa. U. S. A.

Summerfield, R. J., P. J. Dart, P.A. Huxley, A. R. Eaglesham, F. R. Minchin, and J. M. Day. 1977. Nitrogen nutrtion of cowpea (*Vigna unguiculata*): 1- Effect of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expl. Agr. 13: 129-142.

Verma, L.N. 1990. Role of biotechnology in supplying plant nutrients. Fertilizer news. 35: 87-97.

Vogtman, H. and K. Frick.1989. Nutrient value and utilization of biogenic compost in plant production. Agric. Ecosyst. Environ. 27: 471- 475.

Table 1. Physical and chemical properties of the experimental site.

Clay	Silt	Sand	Organic matter	pH	EC dSm^{-1}	N	P	K
	%						mg kg^{-1}	
38.60	16.81	44.59	1.27	7.8	3.34	16	12	256

Table 2. Chemical properties of cattle manure used during the winter seasons of 1999/2000 and 2000/2001.

Seasons	pH	O.M	N	P	K
			%		
1999/2000	8.08	15.75	0.98	0.49	0.98
2000/2001	8.02	18.25	0.60	0.39	1.21

Table 3. Main effects of nitrogen, organic manure and rhizobium inoculation on dry seed yield and its components of pea plants in 1999/2000 and 2000/2001 seasons

Treatments	No. of dry pods / plant	Weight of seeds / pod (g)	Weight of 100 seeds (g)	Dry seed yield kg ha^{-1}
		1999		
Organic Manure				
Without	16:49 B*	1.12 B	15.70 B	1355.46 B
With	20.12 A	1.26 A	16.77 A	1843.68 A
Bio Fertilizer				
Without	17.43 B	1.14 B	15.75 B	1463.29 B
With	19.18 A	1.24 A	16.71 A	1735.86 A
N levels (kg ha^{-1})				
0	14.86 C	1.06 B	15.44 C	1140.62 C
48	20.60 A	1.27 A	17.06 A	1901.61 A
96	19.47 B	1.25 A	16.21 B	1756.49 B
		2000		
Organic Manure				
Without	17.15 B	1.15 B	16.63 B	1582.55B
With	19.97 A	1.25 A	17.73 A	1984.53 A
Bio Fertilizer				
Without	17.47 B	1.17 B	16.86 B	1634.64 B
With	19.65 A	1.24 A	17.49 A	1932.45 A
N levels (kg ha^{-1})				
0	15.67 C	1.07 B	16.15 C	1334.16 C
48	21.31 A	1.28 A	17.75 A	2147.03 A
96	18.91 B	1.25 A	17.63 B	1869.44 B

*Values having a similar alphabetical letter, within a comparable group of means, do not significantly differ from one another, using the revised L.S.D. test at 0.05 level

Table 4. Effects of first degree interaction of organic manure, nitrogen fertilization and rhizobium inoculation on dry seed yield and its components of pea plants in 1999/2000 and 2000/2001 seasons.

treatments	1999 / 2000 seasons				2000/2001 seasons			
	No. of dry Pods / plant	Weight of seeds / pod (g)	Weight of 100 seeds (g)	Dry seed yield kg ha^{-1}	No. of dry Pods / plant	Weight of seeds / pod (g)	Weight of 100 seeds (g)	Dry seed yield kg ha^{-1}
Organic manure x Nitrogen ^{xyz}								
$O_0 N_0$	13.47 e*	0.98 d	14.88 d	956.38 f	14.14 e	1.14 d	15.70 f	1167.64 f
$O_0 N_1$	18.05 c	1.21 b	16.29 b	1577.13 d	19.66 b	1.32 b	16.85 d	1879.91 c
$O_0 N_2$	17.96 c	1.18 bc	15.93 c	1532.88 c	17.67 c	1.34 b	17.33 c	1700.12 d
$O_1 N_0$	16.25 d	1.13 c	16.00 c	1324.86 e	16.80 d	1.24 c	16.61 e	1500.68 e
$O_1 N_1$	23.15 a	1.34 a	17.82 a	2226.08 a	22.96 a	1.46 a	18.65 a	2414.15 a
$O_1 N_2$	20.98 b	1.31 a	16.49 b	1980.1 b	20.15 b	1.40 ab	17.93 b	2038.77 b
Organic manure x Rhizobium								
$O_0 R_0$	15.47 d	1.06 d	15.18 c	1197.24 d	15.38 d	1.22 c	16.19 d	1365.45 d
$O_0 R_1$	17.52 c	1.19 c	16.22 b	1513.68 c	18.93 c	1.31 b	17.06 c	1799.65 c
$O_1 R_0$	19.40 b	1.22 b	16.33 b	1729.33 b	19.56 b	1.34 ab	17.53 b	1903.83 b
$O_1 R_1$	20.85 a	1.30 a	17.21 a	1958.03 a	20.38 a	1.39 a	17.92 a	2065.24 a
Nitrogen x Rhizobium								
$N_0 R_0$	14.00 e	1.00 d	15.04 d	1016.77 f	13.96 e	1.17 c	15.89 f	1182.79 e
N_0R_1	15.72 d	1.11 c	15.84 e	1264.46 e	16.97 d	1.21 c	16.42 e	1485.54 d
N_1R_0	19.41 bc	1.23 b	16.4 b	1733.67c	20.25 b	1.33 b	17.23 d	1948.42 b
N_1R_1	21.79 a	1.32 a	17.71 a	2069.55 a	22.37 a	1.46 a	18.26 a	1563.76 a
N_2R_0	18.90 c	1.20 b	15.83 c	1639.43 d	18.20 c	1.35 b	17.47 c	1772.71 c
N_2R_1	20.04 b	1.30 A	16.59 b	1873.56 b	19.63 b	1.39 ab	17.79 b	1966.18 b

*Values having a similar alphabetical letter, within a comparable group of means ,do not significantly differ from one another, using the revised L.S.D. test at 0.05 level.

x Organic manure rates (m^3 ha^{-1}): O_0 = without and O_1 = 60$m^3 ha^{-1}$.

y Mineral nitrogen rates (kgN ha^{-1}): N_0=without , N_1 =48 and N_2= 96 kg N ha^{-1}.

z Biofertilizer inoculation : R0 =uninocuited and R1 = inoculated with rhizobium.

Table 5. Effects of the second degree interaction of organic manure, nitrogen fertilization and rhizobium inoculation on dry seed yield and its components of pea plants in 1999/2000 and 2000/2001 seasons.

Treatments	1999 / 2000 seasons				2000/2001 seasons			
	No. of dry pods / plant	Weight of Seeds / pod (g)	Weight of 100 seeds (g)	Dry seed yield kg ha^{-1}	No. of dry pods / plant	Weight of Seeds / pod (g)	Weight of 100 seeds (g)	Dry seed yield kg ha^{-1}
$O_0 N_0 R_0$ [xyz]	12.03 i*	0.94 h	14.30 g	814.4 h	11.66 h	1.13 f	15.34 j	948.40 l
$O_0 N_0 R_1$	14.91 h	1.02 g	15.46 e	1098.36 g	16.61 fg	1.16 f	16.06 l	1386.88 h
$O_0 N_1 R_0$	16.84 fg	1.14 e	15.76 ef	1378.94 e	18.02 de	1.22 def	18.02 i	1583.07 f
$O_0 N_1 R_1$	19.26 cd	1.28 bc	16.83 bc	1775.32 d	21.29 b	1.42 ab	17.67 d	2176.74 c
$O_0 N_2 R_0$	17.54 ef	1.11 ef	15.49 f	1398.39 e	16.46 fg	1.32 bcde	17.21 f	1564.86 f
$O_0 N_2 R_1$	18.38de	1.26 c	16.37 cd	1667.36 d	18.88 d	1.35 bcd	17.45 e	1835.37 e
$O_1 N_0 R_0$	15.97 gh	1.06 fg	15.77 ef	1219.15 f	16.27 g	1.21 ef	16.44 h	1417.17 g
$O_1 N_0 R_1$	16.52 fg	1.20 d	16.22 de	1430.57 e	17.33 ef	1.27 cdef	16.78 g	1584.2 f
$O_1 N_1 R_0$	21.97 b	1.32 ab	17.04 b	2088.39 b	22.47 a	1.43 ab	18.44 b	2313.77 b
$O_1 N_1 R_1$	24.32 a	1.35 a	18.59 a	2363.75 a	23.44 a	1.49 a	18.85 a	2514.54 a
$O_1 N_2 R_0$	20.25 c	1.29 bc	16.16 de	1880.46 c	19.93 c	1.38 abc	17.73 d	1980.55 d
$O_1 N_2 R_1$	21.70 b	1.33 ab	16.81 bc	2079.76 b	20.37 bc	1.43 ab	18.12 c	2096.98 c

* Values having a similar alphabetical letter, within a comparable group of means ,do not significantly differ from one another, using the revised L.S.D. test at 0.05 level.

[x] Organic manure rates (m^3 ha^{-1}):O_0 = without and O_1 = 60$m^3 ha^{-1}$

[Y] Mineral nitrogen rates (kgN ha^{-1}): N_0=without ,N_1 =48 and N_2= 96 kg N ha^{-1}.

[Z] Biofertilizer inoculation : R0 =uninoculated and R1 = inoculated with rhizobium.

Table 6. The polynomial quadratic equations expressing peas dry seed yields as affected by N fertilization under organic manure and rhizobium inoculation in 1999/2000 and 2000/2001 seasons.

Treatment	Polynomial Quadratic Equations	
	Season 1999/2000	
$O_0 R_0$	$Y = 814.4 + 854.51x - 261.27x^2$	(2)
$O_0 R_1$	$Y = 1098.4 + 1091.71x - 376.24x^2$	(3)
$O_1 R_0$	$Y = 1219.1 + 1356.67x - 487.53x^2$	(4)
$O_1 R_1$	$Y = 1430.6 + 1573.88x - 583.4x^2$	(5)
	Season 2000/2001	
$O_0 R_0$	$Y = 948.4 + 981.3x - 313.11x^2$	(6)
$O_0 R_1$	$Y = 1386.9 + 1383.71x - 542.36x^2$	(7)
$O_1 R_0$	$Y = 1417.2 + 1580.08x - 640.74x^2$	(8)
$O_1 R_1$	$Y = 1584.2 + 1570.88x - 702.26x^2$	(9)

$O_0 R_0$ = No organic amendment and No inoculation.
$O_0 R_1$ = No organic amendment and rhizobium inoculation.
$O_1 R_0$ = organic amendment (60 m^3 ha^{-1}) and No inoculation.
$O_1 R_1$ = organic amendment (60 m^3 ha^{-1}) and rhizobium inoculation.

Table 7. Values of optimum rates of N fertilizer, optimum yields and net returns for peas cultivar (lincolin) under organic manure application and rhizobium inoculation in 1999/2000 and 2000/2001 seasons.

Treatments	$N_{opt.}$ (Nunits ha^{-1})	$Y_{opt.}$ (kg ha^{-1})	Net retun (EP)
	1999/2000		
$O_0 R_0$	1.61	1512.92	14936
$O_0 R_1$	1.43	1890.17	18700
$O_1 R_0$	1.38	2162.85	20263
$O_1 R_1$	1.34	2492.05	23530
	2000 / 2001		
$O_0 R_0$	1.55	1716.9	16983
$O_0 R_1$	1.26	2269.32	22512
$O_1 R_0$	1.22	2391.22	22566
$O_1 R_1$	1.11	2462.62	23263

Price of 1 kg of peas dry seed = 10 EP. EP= Egyptian pound
Price of a unit of nitrogen fertilization (48 kg N) = 120 E.P
Price of apackage of biofertilizer inoculation for 1 ha = 30 EP.

Fig.1. Dry seed yield response curve of peas cultivar (lincolin) to mineral nitrogen applied under two levels of organic manure and biofertilizer inoculation during the season of 1999/2000

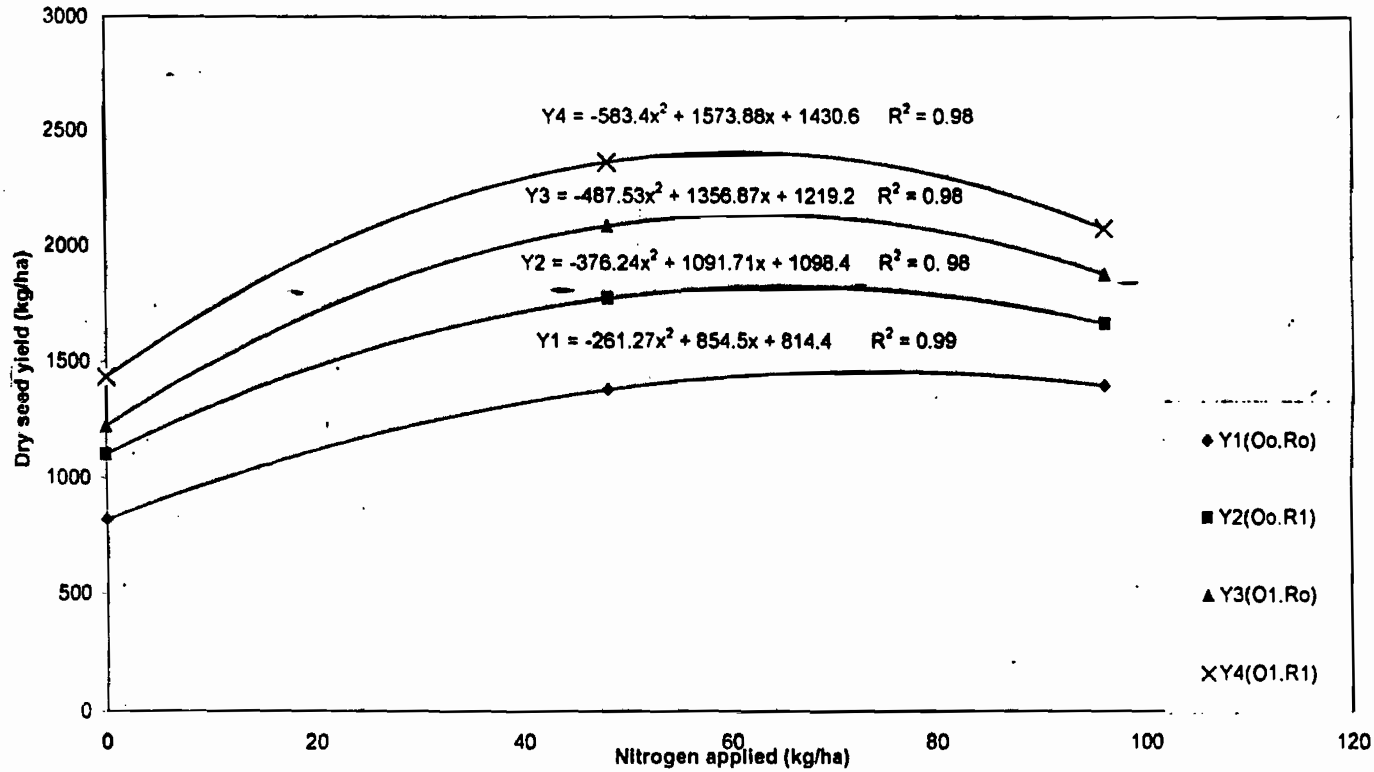


Fig.2. Dry seed yield response curve of peas cultivar (lincolin) to mineral nitrogen applied under two levels of organic manure and biofertilizer inoculation during the season of 2000/2001

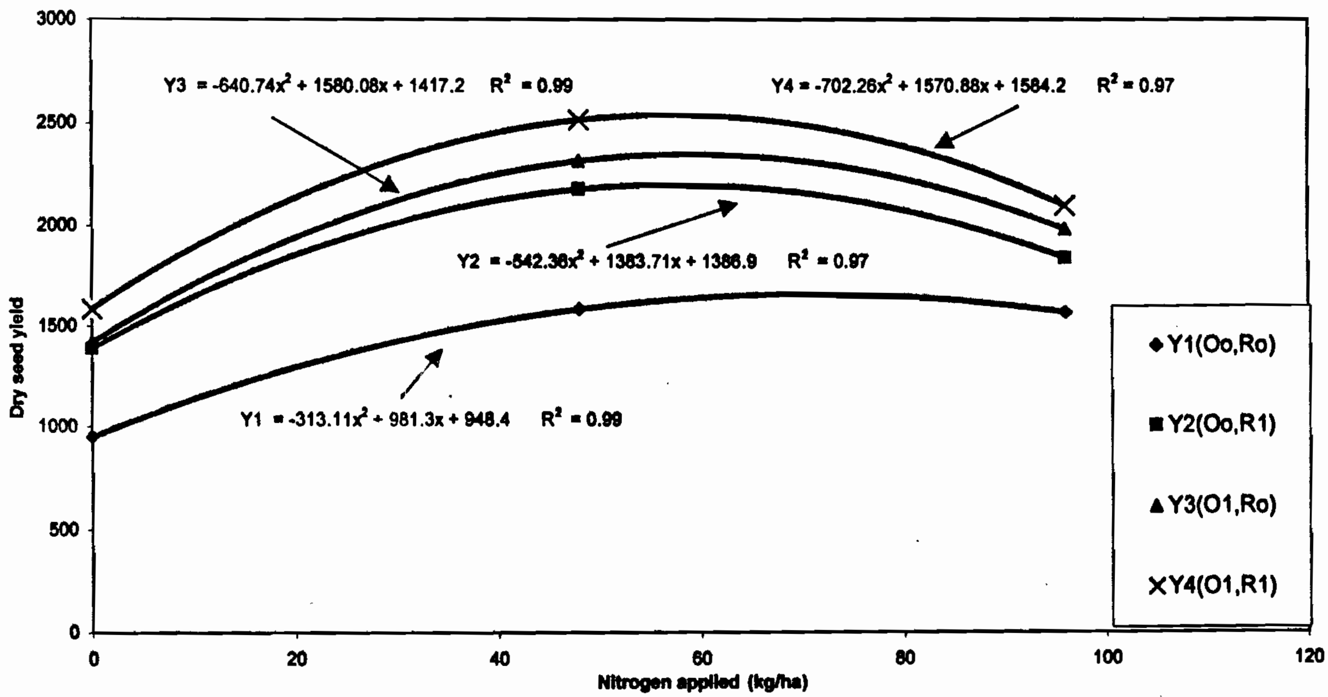
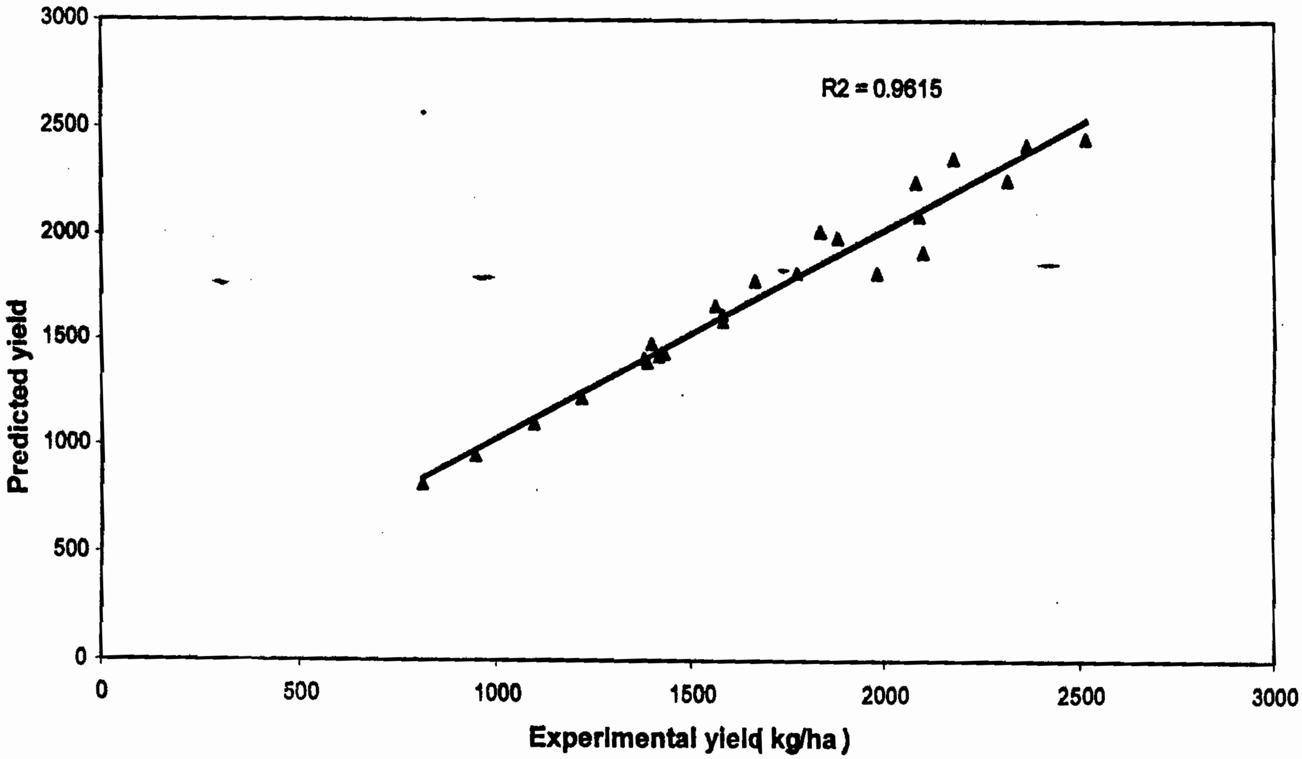


Fig.3. Correlation between experimental and expected dry seed yield of peas (kg / ha) in 1999 and 2000 seasons



الملخص العربي

نموذج رياضي لاستجابة البسلة للتسميد النيتروجيني والعضوي والحيوي

د. حسن أحمد الخطيب

تقدير كمية السماد المعدني الواجب إضافتها لتعظيم الإنتاج ولتفادى التأثيرات البيئية غير المستحبة يعتبر من أهم مشاكل التسميد النيتروجنى المعدني . ولذلك أجريت تجربة حقلية في موسمي شتاء ١٩٩٩/٢٠٠٠ و ٢٠٠٠/٢٠٠١ لتقييم مدى استجابة محصول البسلة الجاف "صنف لينكولن" للتسميد النيتروجيني بمعدلات متزايدة (صفر و٤٨ و ٩٦ كجم نيتروجين /هكتار) في وجود التسميد العضوي (صفر ، ٦٠م^{3} من مخلفات الحيوان/هكتار) والتلقيح الحيوي(عدم التلقيح والتلقيح ببكتريا تثبيت النيتروجين الجوى) . وأوضحت النتائج أن إضافة السماد النيتروجيني المعدنى بمعدل ٤٨ كجم نيتروجين / هكتار بالإضافة إلى ٦٠م^{3}/هكتار سماد عضوى مع التلقيح البكتيرى أعطى أعلى قيم معنوية لمحصول البسلة الجاف بالمقارنة مع المعاملات الأخرى .

تم تمثيل نتائج إنتاجية المحصول الجاف للبسلة في كل موسم بأربع معادلات رياضية من الدرجة الثانية، باعتبار أن إنتاجية محصول البسلة في التجربة هو داله للتسميد النيتروجيني مع اضافة أو عدم اضافة التسميد العضوي في وجود أو عدم وجود التلقيح البكتيري. ولقد أوضحت النتائج وجود تطابق معنوي بين المحصول الناتج تجريبيا والمحصول الذي تم التنبؤ به باستخدام المعادلات الرياضية المقترحة وذلك لكل من المعاملات تحت الدراسة . كما استخدمت ثوابت المعادلات الرياضية لحساب معدلات التسميد النيتروجيني المثلى والمحصول الأمثل لكل المعاملات المدروسة. وأوضحت النتائج أن معدل التسميد النيتروجيني الأمثل الذى يجب إضافته في وجود التسميد العضوى (٦٠م^{3}/هكتار) مع التلقيح البكتيرى هو ٦٤كجم نيتروجين /هكتار في الموسم الأول و٥٣كجم نيتروجين/هكتار في الموسم الثاني، وذلك لإنتاج محصول جاف قدره ٢٤٩٢كجم/هكتار في الموسم الأول ، ٢٤٦٢كجم/هكتار في الموسم الثاني . كما أوضحت النتائج تعاظم العائد الاقتصادي كنتيجة لاضافة المعدلات المثلى للسماد النيتروجيني .