RESPONSE OF PEANUT CROP CULTIVATED ON A NEWLY RECLAIMED SANDY SOIL TO BIO-INOCULATION, GYPSUM ADDITION AND FOLIAR SPRAY WITH IRON

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ABSTRACT:

A field experiment was carried out on a newly reclaimed sandy soil at South-Tahrir Sector, Al-Behira Governorate, Egypt during the two successive summer seasons of 2008 and 2009, under sprinkler irrigation system. This study was conducted to identify the effect of bio-inoculation by *Rhizobium leguminosarum* in combination with applied gypsum at the rates of 0, 0.5 and 1.0 ton fed^{-1} and iron foliar spray at the rates of 0, 0.3 and 0.6 g L^{-1} on improving some soil properties as well as peanut pod or seed yield and its contents of oil, protein and nutrients.

The obtained data showed that application of gypsum led to improve some soil properties, *i.e.*, soil bulk density, total porosity, pH and ECe, where an increased was occurred in soil total porosity. On the contrary, soil bulk density and pH were decreased, and such favorable effects were achieved at the highest rate of gypsum. The data revealed also that the available contents of NPK as macro and Fe, Zn, Mn and Cu as micronutrients in soil after peanut harvesting increased as a result of bio-inoculation with rhizobium and gypsum addition, however, the combined treatment of (gypsum at a rate of 1 ton fed^{-1} with bio-inoculation) gave the best results.

In addition, the applied triple treatment of (bio-inoculation + gypsum + iron foliar spray) significantly increased the number and dry weight of nodules plant^{-1} as well as dry weight of shoot and root of peanut plants at 75 days from sowing. A pronounced increase was achieved in each peanut pod or seed yield and its contents of oil, protein and nutrients (*i.e.*, N, P, K, Fe, Zn, Mn and Cu). The greatest values for the abovementioned traits were recorded with bio-inoculation. Application of gypsum resulted in a significantly increase for each of the previous peanut parameters, except of potassium content in seed that tended to decrease with increasing the applied rates of gypsum.

Iron foliar spray resulted in a significantly increase for each of the previous peanut parameters in both studied seasons as compared to the control. The greatest values were attained by iron foliar spray at the applied rate of 0.6 g L^{-1}, except for P, Zn and Cu contents and uptake that were significantly decreased with increasing the applied rates of Fe as foliar spray. Therefore, under the condition of the studied newly reclaimed sandy soil, the applied gypsum with bio-inoculation plays an effective role for improving soil characters, increasing the available nutrient contents and raising the efficiency of iron foliar spray. This of course positively reflected on peanut yield and improved its seed quality.

Key words: Newly reclaimed sandy soil, rhizobium inoculation, gypsum addition, foliar spray with iron, peanut plants.

INTRODUCTION:

Peanut (*Arachis hypogaea* L.) is considered to be one of the most important edible oil crops in Egypt, which due to its seeds high nutritive value for human and produced cake as well as the green leafy hay for livestock, in addition to the seed oil importance for industrial purposes. Peanut contains about 50% oil, 25-30% protein, 20% carbohydrates and 5% fiber **(Fageria *et al.,* 1997).** Peanut is the main summer crop in newly reclaimed sandy soils in Egypt, which are usually poor in plant nutrients and organic matter.

Nitrogen fixation presented by root nodule bacteria is the main source of nitrogen for peanut. Therefore, inoculation of peanut seeds with effective rhizobium has been recommended by many investigators **(James *et al.,* 2005; El-Sawy *et al.,* 2006 and Abdalla *et al.,* 2009).** Plant growth promoting rhizobium have the ability to enhance the plants growth either directly by phytohormone production, N_2-fixation, sidrophores production ….etc. or indirectly, through biological control of pathogens or induction of host defense mechanisms (Glick, 1995). Calcium appears to be essential for the growth of meristems, translocation regulator, activator for some enzymes and functioning of root tips. It is also present as calcium pectate, which is a constituent of the middle lamella of the cell walls. Calcium defacing causes a stunting of the root system and failure of terminal buds of plant **(Teuscher *et al*., 1960 and Russell, 1961).**

Utilization of gypsum ($CaSO_4.2H_2O$) as a soil amendment refers to improvement of hydrophysical, chemical and biological properties of soil, particularly for agricultural purpose **(Morsy *et al*., 1982).** They added that gypsum promoted earlier maturation up to one week and produced the highest yields. Gypsum is the cheapest and best source of S and Ca nutrients, which associated with various enzymatic processes of all living cells and biosynthesis **(Devakumar, 1995).** Addition of gypsum (as a source of Ca) believed to be one of the important factors controlling yield and its quality of peanut. In this connection, many investigators found that addition of gypsum increased filling percentage of peanut pods, pod yield/fed and improved yield quality **(Taksina, 1994; Ali *et al*., 1995 and Hussein *et al*., 2000).** Also, **Ismail (2005)** reported that gypsum application induced a significant increase for each of pods yield and its components as well as shelling and filling percentages of peanut.

Although micronutrients are needed in relatively very small quantities for adequate plant growth and production, their deficiencies induce a great disturbance in different physiological and metabolic processes inside the plant **(Nassar *et al*., 2000).** In this concern, iron is essential for plant growth where it occurs in chloroplasts and heme and nonheme proteins and is involved in the mechanisms of photosynthetic, electron transfer as well as in nitrate and sulphate reduction. Fe^{2+} and Fe^{3+} ions have also catalytic and structural roles **(Morschner, 1998). Yet, Knany *et al*. (2000)** on soybean and **Nassar (2007)** on peanut stated that oil percentage, seed and straw yields as well as N, P and K contents were significantly increased by foliar addition of iron.

Therefore, the present study was carried out for evaluating the response of peanut plants grown on a newly reclaimed sandy soil to rhizobium inoculation in combination with gypsum and iron foliar spray applications.

MATERIALS AND METHODS:

A field experiment was carried out on a newly reclaimed sandy soil at South-Tahrir Sector, Al-Behira Governorate, Egypt during the two successive summer seasons of 2008 and 2009 under sprinkler irrigation system. This study was conducted to identify the effect of *Rhizobium leguminosarum* as bio-inoculation in combination with gypsum at the rates of 0, 0.5 and 1.0 ton fed^{-1} and iron foliar spray at the rates of 0, 0.3 and 0.6 g L^{-1} added at 30 and 50 days after sowing on improving some soil properties as well as peanut pod or seed yield and its contents of oil, protein and nutrients.

The experimental soil samples (0-30 cm depth) were taken before the performance of the experiments. Some physical and chemical analyses of the experimental soil were determined according to **Black *et al.* (1965) and Page *et al*. (1982),** and then the obtained data are presented in Table (1). Soil available macronutrients were determined by methods cited by **Chapman and Pratt (1961);** and soil available Fe, Zn, Mn, and Cu were extracted by the DTPA **(Lindsay and Norvell, 1978).**

Bacterial inoculants:

Rhizobium leguminosarum were supplied by the Dpartment of Microbiology, SWERI, ARC, Giza. Strains were characterized by effective ability to infect specific host plants and high efficiency in N_2-fixation. Strains were grown on a medium of **Vincent (1970).** The preparation of these inoculants was carried as vermiculite supplemented with 10% peat was packed in polyethylene bags (400 L). Bags were then sealed and sterilized by Gamma irradiation (5.0 x 10^6 rads). Bacterial culture was injected onto the sterilized vermiculite to satisfy 60% of water holding capacity of the carrier mixture.

Peanut seeds of the commercial variety Giza 6 were kindly provided by Field Crops Research Institute, Agric. Res. Center, Giza, Egypt. Seeds of peanut were divided into two parts, the first was inoculated with rhizobial inoculants containing the strain and the second was cultivated without inoculation. Seeds of peanut were mixed with suitable amount of Arabic gum 15% then thoroughly mixed with rhizobial inoculant. The rate of application was 10 g/100 g seeds (200 g inoculant/fed). This process was carried out in the field just before seedling. Seeds of peanut were sown in hill 10 cm apart in ridges on the 18^{th} and 21^{th} of April in the 1^{st} and 2^{nd} seasons, respectively.

Basic application of phosphorus fertilizer, as calcium superphosphate (15.5% P_2O_5) was added during the seed bed preparation at the rate of 30 kg P_2O_5/feddan. Potassium sulphate (48% K_2O) at the rate of 50 kg/fed was applied, however, nitrogen fertilizer was applied at a rate of 30 kg N/fed as ammonium sulphate (20.6% N). Both N- and K- fertilizers were applied in two equal doses, i.e., at planting and one month later. The normal cultural practices for peanut were applied as recommended in the sector. Sprinkler irrigation was applied as plants needed. Peanut was manually harvested on September 13th and 17th in the first and second seasons, respectively.

Table 1. Some physical, chemical and fertility characteristics of the studied soil.

Soil characteristics	Season 2008	Season 2009	Soil characteristics.	season 2008	season 2009
Particle size distribution %:			CEC (c molc kg^{-1} soil)	4.32	4.15
Sand	96.83	93.69	EC (soil paste, dS/m)	0.73	0.75
Silt	1.77	1.53	*Soluble cations (mmolc L^{-1}):*		
Clay	4.40	4.78	Ca^{++}	2.32	2.50
Textural class	Sandy		Mg^{++}	1.69	1.70
Bulk density (g cm^{-3})	1.55	1.53	Na^{+}	3.05	3.03
Total porosity %	41.51	42.26	K^{+}	0.25	0.27
Available water %6.85	6.85	6.97	*Soluble anions (mmolc L^{-1}):*		
Hydraulic conductivity (cm h^{-1})	14.24	14.03	CO_3^{--}	0.00	0.00
$CaCO_3$ %	1.21	1.40	HCO_3^{-}	2.60	2.63
Organic matter %	0.29	0.35	Cl^{-}	2.51	2.48
pH (1:2.5 soil water suspension)	7.82	7.80	SO_4^{--}	2.20	2.49

Season	Available nutrients (mg kg^{-1} soil) N	P	K	Fe	Mn	Zn	Cu
2008	21	3.1	45	2.54	0.82	0.70	0.35
2009	23	3.7	49	3.15	0.90	0.73	0.40

The experimental design was split-split plot with four replicates, and the plot area was 10.5 m^2, and consisting of five rows (3.5 m length and 60 cm between rows). Inoculation with rhizobium was arranged in the main plots. Three rates of gypsum (0, 0.5 and 1.0 ton/fed) were distributed in the sub plots, however, sub-sub plots were occupied by Fe spraying treatments (0, 0.3 and 0.6 g Fe/L) which was done twice at vegetative stage (30 days after sowing) and at pod development period (50 days after sowing) at the rate of 400 L/fed in each spray. Five peanut plants were uprooted randomly from each plot after 75 days for determination plant growth, number of root nodules, dry weight of nodules and shoot and root dry weights.

At harvest, the yield and its components were recorded. Ten plants of the middle two rows were taken randomly from each sub-sub plot to record number of pods/plant, pods and seeds weight (g/plant), 100-seed weight (g) and shelling%. Whole plot was harvested and pods were air dried to calculate pods and seed yield/fed.

Seed contents of N, P, K, Fe, Zn, Mn and Cu were determined using the methods described by **Chapman and Pratt (1961).** Protein content % was calculated by multiplying N% by 6.25. Seed oil content% was determined by using Soxhlet apparatus and petroleum ether as an organic solvent as described by **A.O.A.C. (1990).**

All data were statistically analyzed according to **Snedecor and Cochran (1982).** Means of different treatments were compared using the L.S.D test at 5% probability. Soil samples were collected from the surface layer of each plot (0-30 cm) to determine some physical and chemical analysis according to **Hesse (1977), Loveday (1974) and Black and Hartge (1986).**

RESULTS AND DISCUSSION:

I. Effect of bio-inoculation and gypsum application on some soil properties:

a. Soil bulk density and total porosity:

Data in Table (2) showed that there were no differences between un-inoculated and inoculated treatments on bulk density and total porosity during the two studied seasons of 2008 and 2009. Data also showed that increasing the rates of gypsum addition, generally decreased the bulk density and increased the total porosity. The decrease in bulk density may be attributed to the effect of both applied gypsum and microbial activity on the redistribution of soil particles which tended to decrease soil bulk density, and consequently the total porosity increasing. The best improved effect was subjected with highest rates of gypsum. These finding are in harmony with those outlined by **Abbas *et al.* (2004) and Massoud (2006)** who found that, the soil bulk density tended to decrease due to increasing gypsum addition.

b. Soil pH:

The obtained data in Table (2) showed that the pH values for un-inoculated and inoculated treatments were not affected by rhizobium inoculation. Also, data showed that the effect of gypsum addition on pH values markedly decreased when compared with the treatments without addition. The lowest value of pH (7.48) was obtained at 1.0 ton gypsum/fed with inoculation. The decline in soil pH by gypsum application was probably due to the role of applied gypsum and released SO_4^{2-} **(Mohamed *et al.*, 1997 and Massoud 2006).**

c. Soil electrical conductivity (ECe):

The application of gypsum with inoculation increased the EC in the studied soil as compared with the control in un-inoculated treatments. The addition of gypsum at the rate of 1.0 ton/fed with inoculation was more affected on ECe than the application 500 kg/fed. In this respect, **Modaihsh *et al.* (1989)** stated that the addition of 0.5 ton S/fed significantly decreased the pH and increased the EC in soil. Similar results were obtained by **Nassar (2007)**.

Table (2): Effect of rhizobium inoculation and gypsum application on some properties of the tested soil at harvesting stage.

Bio-inoculation	Gypsum rate (ton/fed)	ECe (dS/m)		pH (1:2.5)		Bulk density (g cm^{-3})		Total porosity %	
		2008	2009	2008	2009	2008	2009	2008	2009
Un-inoculation	0.0	0.75	0.75	7.8	7.80	1.55	1.53	41.51	42.26
	0.5	0.77	0.78	7.7	7.70	1.53	1.50	42.26	43.39
	1.0	0.79	0.80	7.6	7.60	1.5	1.47	43.39	44.52
	Mean	0.77	0.77	---	---	1.53	1.50	42.38	43.39
Inoculation	0.0	0.77	0.76	7.78	7.78	1.55	1.53	41.51	42.26
	0.5	0.81	0.80	7.68	7.68	1.52	1.49	42.64	43.77
	1.0	0.83	0.82	7.6	7.60	1.49	1.46	43.77	44.90
	Mean	0.80	0.79	---	---	1.52	1.50	42.64	43.64

d. Available nutrient contents in soil:

Data in Table (3) showed that available macro and micronutrients content in soil such as N, P, K as well as Fe, Zn, Mn and Cu increased by rhizobium inoculation after harvesting of peanut plants than un-inoculated treatments, probably due to the root nodules which tended to increase all available nutrients contents in soil. These results are in harmony with those obtained by **Mekhemer and Alkahal (2002) and Massoud (2006).**

Table (3): Effect of rhizobium inoculation and gypsum application on some soil available nutrient contents at harvesting stage.

Bio-inoculation	Gypsum rate (ton/fed)	N	P	K	Fe	Mn	Zn	Cu
Season of 2008								
Un-inoculation	0.0	23	3.33	48	2.65	0.85	0.73	0.35
	0.5	34	4.13	60	2.76	0.95	0.88	0.39
	1.0	38	4.86	71	2.83	0.96	0.93	0.42
	Mean	32	4.10	60	2.74	0.91	0.85	0.39
Inoculation	0.0	35	4.06	53	2.79	0.85	1.03	0.38
	0.5	44	4.72	69	2.85	0.95	1.32	0.41
	1.0	49	5.03	76	2.89	1.00	1.41	0.45
	Mean	42	4.60	66	2.84	0.93	1.25	0.41
Season of 2009								
Un-inoculation	0.0	21	3.66	45	3.16	0.92	0.70	0.43
	0.5	28	4.79	68	3.43	0.97	0.82	0.46
	1.0	31	5.06	78	3.61	1.00	0.86	0.48
	Mean	27	4.50	63	3.40	0.96	0.79	0.46
Inoculation	0.0	40	4.01	61	4.05	0.90	0.90	0.51
	0.5	43	5.13	72	4.33	0.97	0.96	0.57
	1.0	50	5.65	80	4.62	1.05	1.00	0.63
	Mean	44	4.93	71	4.34	0.97	0.95	0.57

Regarding gypsum addition, data showed that available nutrients in soil increased with increasing doses of gypsum addition. The greatest values of available macro and micronutrients were obtained with 1.0 ton gypsum/fed. These increments may be due to that gypsum application caused improvement soil properties, and consequently increasing available nutrients. Similar results were obtained by **El-Shahawy (2003), Abbas *et al*. (2004) and Massoud (2006).**

With respect to the combination effect between inoculation and gypsum addition, it can be seen that the high level of gypsum (1.0 ton/fed) with inoculation gave the greatest values of available nutrients content in soil compared with the low rate (0.5 ton/fed.) and control. On the other hand, iron foliar spraying has no appreciable effect on the soil properties.

II. Vegetative growth:

The number and dry weight of nodules developed on peanut roots and dry weight of shoots and roots taken after 75 days from sowing are presented in

Table (4). The results revealed that rhizobium inoculation significantly increased the studied plant parameters as compared with the un-inoculated treatments. This increase may be due to the role of rhizobium in increasing plant growth and N_2-fixation **(Saleh *et al*., 2007)**. Also may be due to the production of phytohormones such as auxins, cytokinins, gibberllins and abscic acid by rhizobium. These findings are in agreement with those obtained by **Husen (2003) and El-Sawy *et al.* (2006)**. The increase in dry weight of shoots and roots may be due to a higher nitrogen accumulation per plant, enhancement of plant vigour and nitrogen fixation **(El-Howeity 2008 and El-Howeity *et al*., 2009).**

In this concern, **Massoud *et al*. (2005)** indicated that rhizobium inoculation of pea seed and other legumes increased nodulation, also, **Abdalla *et al*. (2009)** found that inoculation of peanut with rhizobium led to a significant increase in the nodulation status as compared to the control.

Also, the data showed that addition of gypsum significantly increased the number and dry weight of nodules/plant as well as dry weight of shoots and roots (g) of peanut plants, as shown in Table (5). It can be seen that the highest rate of gypsum (1.0 ton/fed) gave the greatest values of these parameters as compared to the low rates and the control. The positive effect of gypsum application could be attributed to improve physical, chemical and biological soil properties, and consequently led to increase the activation in rhizosphere zone. **Massoud (2006) and Abdalla *et al*. (2009)** obtained similar results.

Table (4): Number and dry weight of nodules, dry weight of shoots or roots after 75 days of planting as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	No. of nodules/plant				Dry weight of nodules (mg/plant)			
		Iron foliar spray (g/L), C							
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoculation	0.0	23.3	25.3	26.6	25.1	150	168	191	169
	0.5	31.6	32.0	33.3	32.9	205	211	228	215
	1.0	30.3	32.5	35.3	32.7	202	228	247	225
	Mean	28.4	29.9	31.7	30.2	186	202	222	203
Inoculation	0.0	56.3	58.6	60.4	58.4	388	392	458	412
	0.5	61.8	65.4	68.4	65.2	390	429	439	419
	1.0	71.5	74.4	76.6	74.1	424	474	484	460
	Mean	63.2	66.1	68.5	56.9	400	431	460	430
L.S.D. at 0.05	A	0.23				20.80			
	B	0.27				12.41			
	C	0.19				3.45			
	AxB	0.38				17.58			
	AxC	0.84				4.87			
	BxC	1.03				5.96			
	AxBxC	1.46				8.43			

Table (5): Dry weight of shoots or roots after 75 days of planting as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	Dry weight of shoots (g/plant)				Dry weight of roots (g/plant)			
		Iron foliar spray (g/L), C							
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoculation	0.0	13.67	16.19	16.81	15.56	1.36	1.54	1.64	1.51
	0.5	19.75	21.65	23.05	21.48	1.75	1.79	1.82	1.78
	1.0	22.26	22.81	24.20	23.09	1.94	1.98	2.03	1.98
	Mean	18.56	20.22	21.35	20.04	1.68	1.77	1.83	1.76
Inoculation	0.0	22.95	24.38	25.53	24.28	2.07	2.16	2.21	2.15
	0.5	24.42	25.84	27.01	25.75	2.23	2.30	2.36	2.30
	1.0	25.72	26.32	28.11	26.71	2.34	2.42	2.47	2.41
	Mean	24.36	25.51	26.88	25.58	2.21	2.29	2.35	2.29
L.S.D. at 0.05	A	0.29				0.024			
	B	0.18				0.020			
	C	0.12				0.017			
	AxB	0.25				0.080			
	AxC	0.17				0.020			
	BxC	0.21				0.290			
	AxBxC	0.30				0.041			

With respect to the effect of iron foliar spray, the data in Tables (4 and 5) showed that number and weight of nodules/plant as well as dry weight of shoots and roots of peanut plants were increased with increasing iron rates. That means there was a gradual response in the studied parameters of peanut plants due the iron levels increase. The greatest increases of these parameters were obtained by the highest rate of iron as foliar spray.

Concerning the combination effect between bio-inoculation and applied gypsum rates, it can be observed that the highest rate of gypsum (1.0 ton/fed) with bio-inoculation gave the greatest values for all studied parameters of peanut plants after 75 days than the low level (0.5 ton/fed) and the control. Also, the interactions effect between the bio-inoculation and iron rates on the previous plant parameters indicated that bio-inoculated treatments were more effective than un-inoculated ones. The highest rate of iron (0.6 g L^{-1}) with bio-inoculation gave the greatest values for all the studied parameters of peanut plant as compared with the low rate (0.3 g Fe L^{-1}) and the control. With regard to the effect of interaction between gypsum and iron levels without bio-inoculation, data indicated that the greatest effect of gypsum was recorded with the highest rate of iron (1.0 ton gypsum fed $^{-1}$ + 0.6 g Fe L^{-1}).

Moreover, the best values of different studied plant parameters were obtained at the combined treatment of (1000 kg gypsum/fed + 0.6 g Fe L^{-1} with bio-inoculation). *i*.e., 76.6, 484, 28.11 and 2.47 for number of nodules/plant, nodules dry weight (mg/plant), dry weight of shoots (g/plant) and dry weight of roots (g/plant), respectively.

III. Yield and its components:

Data in Tables (6 and 7) showed that *Rhizobium leguminosarum* inoculation significantly increased pods and seed yields and their components, *i.e.,* No. of pods/plant, seed weight/plant, 100 seed weight (g) and shelling % as compared with un-inoculated treatments. The positive effect of rhizobium inoculation in yield and its components was achieved due to the activity of root nodules to improve nitrogen fixation by increasing the number of rhizobium, which produced more amounts of bio-fixed nitrogen that led to high peanut yield and its attributes. These results are in agreement with those reported by **Osman and Ahmed (2004) and Abdalla *et al*. (2009)** who found that rhizobium inoculation enhanced seeds yield and its components of peanut plants.

Also, the obtained data showed that application of gypsum significantly increased all studied parameters of peanut yield and its components. The greatest effect of gypsum was recorded with the applied highest rate of gypsum (1.0 ton/fed) as compared with low rate of 0.5 ton/fed and the control. These increments may be attributed to the effective role of calcium as an essential macronutrient on plant growth as an activator for some important enzymes, which in turn affected pod and seed weights. These results are in agreement with those obtained by **Dahdouh (1999), Hussein *et al.* (2000) and Ismail (2005). Abou Baker *et al*. (1994), El-Naggar *et al*. (1996), Gendy *et al.* (1996), El-Saadany *et al.* (2003) and Ismail (2005)** studied the effective role of gypsum application on peanut yield and its quality, and their results are in harmony with the findings of the current study.

Table (6): No. of pods/plant, weight of pods/plant and seed weight/plant as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	No. of pods/plant				Pods weight (g/plant)				Seeds weight (g/plant)			
		Iron foliar spray (g/L), C											
		0.0	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**
Un-inoculation	0.0	26.6	27.2	27.2	27.1	0	33.7	35.3	33.5	24.0	27.0	28.5	26.5
	0.5	28.1	28.5	28.7	28.2	31.4	42.4	44.4	45.2	30.2	33.2	34.3	32.6
	1.0	28.5	29.0	28.7	28.7	38.6	47.4	45.5	45.1	32.5	35.0	34.4	34.0
	Mean	27.7	28.2	28.3	28.0	42.5	41.2	41.7	41.3	28.9	31.7	32.4	31.0
Inoculation	0.0	27.3	27.8	28.2	27.8	40.8	40.5	43.4	40.2	30.3	32.0	34.7	32.3
	0.5	28.9	29.5	29.6	29.3	36.8	51.3	52.6	50.5	37.4	40.0	32.0	39.7
	1.0	30.3	30.6	30.7	30.6	47.5	54.4	56.3	53.8	39.4	42.7	4306	41.9
	Mean	28.8	29.4	29.5	29.2	50.4	49.4	50.1	48.2	35.7	38.6	39.8	38.0
L.S.D. at 0.05	A	0.840				0.08				0.68			
	B	0.048				0.16				0.25			
	C	0.048				0.25				0.24			
	AxB	0.062				0.72				0.35			
	AxC	0.068				0.36				0.33			
	BxC	0.830				0.44				0.41			
	AxBxC	0.120				0.62				0.58			

Table (7): Shelling %, pods yield/fed, weight of pods/fed and 1000 seed weight/plant as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Inoculation, A	Gypsum rate (ton/fed), B	Shelling %				Pod yield (kg/fed)				Seeds yield (kg/fed)				100 seeds weight (g/plant)			
		Iron foliar spray (g/L), C															
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoc.	0.0	65.2	67.0	69.1	67.1	1130	1221	1255	1202	726	792	848	789	65.5	71.0	74.6	70.3
	0.5	71.9	74.0	75.0	73.6	1233	1274	1334	1281	841	904	966	904	76.8	83.1	84.5	81.5
	1.0	74.0	75.1	76.3	75.2	1303	1399	1500	1401	921	999	1081	1001	81.6	86.5	87.9	85.3
	Mean	70.4	72.0	73.5	72.0	1222	1298	1363	1294	829	898	965	898	74.0	80.2	82.3	79.0
Inoc.	0.0	71.1	73.2	75.0	73.1	1284	1354	1415	1382	910	973	1059	981	74.4	78.7	82.7	78.6
	0.5	75.8	78.7	80.7	78.4	1407	1516	1605	1510	1041	1157	1234	1144	87.3	93.0	94.2	91.5
	1.0	80.5	82.4	84.5	82.5	1501	1631	1661	1597	1160	1293	1361	1271	90.7	96.0	96.2	94.3
	Mean	75.8	78.1	80.1	78.0	1397	1510	1550	1496	1037	1141	1218	1132	84.1	89.2	91.0	88.1
L.S.D. at 0.05	A	0.75				18.97				5.63				0.57			
	B	0.31				14.87				28.39				0.53			
	C	0.17				10.82				9.25				0.56			
	AxB	0.44				21.02				40.22				0.75			
	AxC	0.24				15.27				15.18				0.78			
	BxC	0.29				18.70				18.59				0.96			
	AxBxC	0.41				26.45				26.29				1.36			

Data also showed that the effect of iron foliar spray was significantly affected the previous studied peanut parameters. The greatest effect of iron was recorded at the highest rate of 0.6 g L^{-1}. These increments may be attributed to the important role of iron for chloroplasts and heme and nonheme proteins. Also, Fe is involved in mechanism of photosynthetic electron transfer as well as in nitrate and sulfate reduction, where the ions of Fe^{2+} and Fe^{3+} have catalytic and structural roles. Therefore, Fe promotes the growth of green parts, and consequently produces high yield of pods and seeds **(Morschner, 1998 and Nassar *et al*., 2002)**. These results are in a good agreement with those reported by **Singh (2001), Mehasen and El-Ghazoli (2003) and Nassar (2005).**

Concerning the combined effect between bio-inoculation and applied gypsum rates, it could be observed that applied highest rate of gypsum (1.0 ton/fed) in combination with bio-inoculation gave the greatest values of all studied parameters of peanut yield and its attributes as compared with the low rate of 0.5 ton gypsum/fed and the control. Also, the interaction effect between bio-inoculation and applied iron rates on peanut yield and its components indicated that bio-inoculation was more effective than un-inoculated one. Moreover, it could be noticed that the highest iron rate of 0.6 g L^{-1} in combination with bio-inoculation gave the greatest values for all studied parameters of peanut yield and its components as compared with low iron rate (0.3 g L^{-1}) and the control.

Biochemical constituents of peanut seeds:

Data in Tables (8-13) indicated that bio-inoculation treatment of peanut seeds significantly increased N, P, K, Fe, Mn, Zn and Cu contents and uptake as well as oil and protein contents either as percent or kg/fed of peanut seeds as compared with un-inoculated one. The positive effect of rhizobium inoculation may be due to the increase of nodules number of peanut roots, which increase N_2-fixation and its uptake, and consequently increased nitrogen and protein content in peanut seeds. In addition, the positive effect of rhizobium inoculation on the other nutrients of P, K, Fe, Mn, Zn and Cu as well as oil contents in peanut seeds may be due to the pronounced increase in nitrogen bio-fixation, which enhances the vegetative growth of plant, and consequently increased the uptake of these nutrients in peanut seeds. Similar results were obtained by **Osman and Ahmed (2004) and Massoud *et al*. (2005)**.

Data also showed that either N or P content and uptake (kg/fed) as macronutrients as well as Fe, Mn, Zn and Cu contents and uptake (g/fed) as micronutrients and both oil and protein contents (kg/fed) in peanut seeds were significantly increased with increasing the applied gypsum rates. The increments of the nutrient contents as a result of applied gypsum rates may be ascribed to the formation and activation of root nodules, and hence increasing the bio-fixed nitrogen.

Table (8): N, P and K contents in peanut seeds as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	N %				P %				K %			
		Iron foliar spray (g/L), C											
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoculation	0.0	2.18	2.54	2.72	2.48	0.15	0.24	0.22	0.20	0.95	0.98	0.93	0.95
	0.5	2.60	3.00	3.18	2.92	0.32	0.30	0.28	0.30	0.89	0.82	0.80	0.83
	1.0	2.82	3.16	3.38	3.12	0.36	0.35	0.30	0.33	0.70	0.73	0.68	0.70
	Mean	2.53	2.90	3.09	2.84	0.28	0.30	0.27	0.28	0.85	0.84	0.80	0.82
Inoculation	0.0	3.50	3.89	4.17	3.85	0.33	0.30	0.27	0.30	1.18	1.25	1.26	1.23
	0.5	4.00	4.50	4.58	4.36	0.37	0.34	0.32	0.34	1.03	1.04	1.06	1.04
	1.0	4.27	4.63	4.80	4.56	0.42	0.36	0.34	0.37	0.90	0.93	0.90	0.91
	Mean	3.92	4.34	4.52	4.25	0.37	0.33	0.31	0.34	1.03	1.07	1.07	1.06

Table (9): N, P and K uptake by peanut seeds as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	N uptake (kg fed^{-1})				P uptake (kg fed^{-1})				K uptake (kg fed^{-1})			
		Iron foliar spray (g/L), C											
		0.0	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**
Un-inoculation	0.0	16.40	19.87	23.32	19.86	1.08	1.90	1.86	1.61	6.91	7.82	7.91	7.54
	0.5	21.95	27.39	31.20	26.84	2.69	2.71	2.70	2.70	6.72	7.41	7.72	7.28
	1.0	26.24	32.16	37.07	31.82	3.31	3.49	3.24	3.34	6.44	7.29	7.13	7.05
	Mean	21.53	26.47	30.53	26.17	2.36	2.70	2.60	2.55	6.69	7.50	7.68	7.29
Inoculation	0.0	32.39	37.55	44.47	38.14	3.00	2.91	2.85	2.92	10.73	12.16	13.34	12.07
	0.5	41.53	51.60	56.39	49.84	3.85	3.93	3.94	3.91	10.72	12.03	13.08	11.94
	1.0	49.30	59.34	65.60	58.08	4.87	4.78	4.62	4.75	10.44	12.02	12.24	11.57
	Mean	41.07	49.49	55.49	48.68	3.90	3.87	3.80	3.86	10.63	12.07	12.88	11.86
L.S.D. at 0.05	A	0.84				0.06				0.20			
	B	1.27				0.11				0.23			
	C	0.64				0.04				0.10			
	AxB	1.80				0.16				0.32			
	AxC	0.90				0.05				0.15			
	BxC	1.10				0.06				0.18			
	AxBxC	1.56				0.09				0.25			

The present results coincide with those obtained by **Ismail (2005), Othman *et al*. (2005) and Massoud (2006)** who found that gypsum addition to legumes increased N, P, Ca, protein and other nutrients in plants and seeds. On the contrary, a significant reduction in seed K content was obtained due to application of gypsum. This may be due to the existence of antagonism between K and Ca nutrients in soil, such phenomenon is a physiological in nature and occurs during the process of nutrients absorption by roots and further translocation from root to shoots **(Shukla and Mukhi, 1979). Moreover, Ismail (2005)** found that application of high amount of gypsum lowered the uptake of potassium by plant roots.

Table 10,11

Concerning the effect of iron foliar spray on nutrients uptake as well as oil and protein contents of peanut seeds, the obtained data showed that seed contents of N, K, Fe and Mn and uptake as well as protein and oil contents were significantly increased in both tested seasons when spraying the peanut plants with Fe. The reverse trend was true for seed contents of P, Zn and Cu and their uptake, where significantly decreases were occurred with increasing the applied rate of Fe, this phenomenon may be due to the antagonism between Fe and these nutrients within plant parts during the process of absorption of nutrients by roots and further translocation from roots to shoots. These findings are in harmony with those reported by **Anderson and Parkpin (1988) and Nassar (2005)** for either both Fe and Zn or Fe and Cu antagonisms, respectively.

Table (12): Protein and oil contents % of peanut seeds as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	Protein %				Oil %			
		Iron foliar spray (g/L), C							
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoculation	0.0	13.62	15.87	17.00	15.50	45.13	45.65	45.77	45.51
	0.5	16.25	18.75	19.87	18.25	45.82	45.97	46.02	45.93
	1.0	17.62	19.75	21.12	19.50	46.16	46.57	46.83	46.52
	Mean	15.81	18.12	19.31	17.75	45.70	46.06	46.20	45.98
Inoculation	0.0	21.87	24.31	26.06	24.06	46.97	47.08	47.19	47.08
	0.5	25.00	28.12	28.62	27.25	47.13	47.38	47.58	47.36
	1.0	26.68	28.93	30.00	28.50	47.71	47.93	48.05	47.89
	Mean	24.50	27.12	28.25	26.56	47.27	47.46	47.60	47.44

Table (13): Protein and oil in kg fed^{-1} of peanut seeds as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Bio-inoculation, A	Gypsum rate (ton/fed), B	Protein (kg fed^{-1})				Oil (kg fed^{-1})			
		Iron foliar spray (g/L), C							
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoculation	0.0	102.50	124.19	145.75	124.14	327.6	361.5	388.1	359.1
	0.5	137.18	171.18	195.00	167.78	385.3	413.6	444.6	415.2
	1.0	164.00	201.00	231.68	198.89	425.1	465.2	506.2	465.5
	Mean	134.60	165.50	198.80	163.60	379.4	414.1	446.3	413.3
Inoculation	0.0	202.40	234.68	277.93	238.34	427.4	458.1	499.7	461.7
	0.5	259.56	322.50	352.43	311.49	490.6	548.2	587.1	542.0
	1.0	308.12	370.87	410.00	363.00	553.4	619.7	653.9	609.0
	Mean	256.70	309.40	346.80	304.27	490.5	542.0	580.3	537.6
L.S.D. at 0.05	A	11.60				18.91			
	B	14.23				19.67			
	C	9.25				12.00			
	AxB	20.15				27.86			
	AxC	13.05				16.94			
	BxC	15.99				20.70			
	AxBxC	22.61				29.35			

Concerning the combined effect between bio-inoculation and applied gypsum rates, the obtained data showed the highest rate of 1.0 ton/fed in combination with bio-inoculation gave the greatest values of N, P, Fe, Mn, Zn and Cu contents and uptake as well as protein and oil contents (kg/fed). However, the greatest values of potassium content and uptake were recorded when plants received the lowest rate of gypsum with bio-inoculation.

Also, studying the combined effect between the bio-inoculation and Fe foliar spray rates, data observed that the highest rate of iron (0.6 g/L) with bio-inoculation gave the greatest values of N, K, Fe and Mn contents and uptake as well as oil and protein contents in peanut seeds. However, bio-inoculation of peanut plants at zero rate of Fe (spraying with tap water) gave the greatest values of P, Zn and Cu contents and uptake.

As for the effect of interaction between applied gypsum and iron foliar spray, the data indicated that the greatest effect was recorded with the highest rate of both gypsum and iron (1.0 ton gypsum/fed + 0.6 g Fe/L) for increasing N, Fe and Mn contents and uptake as well as oil and protein contents. Meanwhile, the highest rate of gypsum (1.0 ton/fed with 0.3 g Fe/L) gave the greatest values of P, Zn and Cu uptake. Also, the highest rate of Fe without gypsum addition gave the greatest values for potassium content and uptake.

Moreover, the best treatment of interaction between bio-inoculation, gypsum addition and iron foliar spray was obtained at the combined treatment of (1.0 ton gypsum/fed + 0.6 g Fe/L with bio-inoculation) for all nutrient contents and uptake as well as oil and protein contents, except of K content and uptake.

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إستجابة محصول الفول السودانى المنزرع فى أرض رملية حديثة الاستصلاح للتلقيح الحيوى مع إضافة الجبس والرش بالحديد

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أجريت تجربة حقلية على أرض رملية حديثة الإستصلاح فى قطاع جنوب التحرير، محافظة البحيرة، مصر خلال الموسم الصيفى لعامين متتاليين ٢٠٠٨-٢٠٠٩ تحت نظام الرى بالرش. تهدف الدراسة إلى إستبيان تأثير التلقيح الحيوى مع إضافة مستويات مختلفة من الجبس الزراعى (صفر، ٠.٥، ١.٠ طن/فدان) والرش بعنصر الحديد فى صورة مخلبية بمعدلات (صفر، ٠.٣، ٠.٦ جم/لتر) على بعض خواص التربة وكذلك محصولى القرون والبذور بالإضافة إلى المحتوى من المغذيات (نيتروجين، فوسفور، بوتاسيوم، حديد، منجنيز، زنك، نحاس)، بالإضافة إلى الزيت والبروتين لبذور نباتات الفول السودانى.

ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلى:

١. إضافة الجبس الزراعى أدت إلى تحسين بعض خواص التربة، حيث إنخفضت قيم كل من الكثافة الظاهرية، Soil pH، فى حين زادت قيم كل من المسامية الكلية، التوصيل الكهربى ECe، وكانت أفضل النتائج المتحصل عليها عند إضافة المستوى الأعلى من الجبس (١.٠ طن/فدان) مقارنة بباقى المعاملات.

٢. أوضحت النتائج زيادة محتوى التربة من العناصر الكبرى (N, P and K)، وكذلك العناصر الصغرى (Fe, Mn, Zn and Cu) بزيادة معدل الإضافة من الجبس مع التلقيح بالريزوبيوم. وكانت أفضل القيم عند إضافة (١.٠ طن جبس/فدان مع التلقيح بالريزوبيوم).

٣. أدى إضافة كل من الجبس وكذلك الرش بالحديد مع التلقيح بالريزوبيوم وكذلك التفاعل بينهم إلى زيادة معنوية فى عدد، وزن العقد الجذرية وكذلك فى الوزن الجاف للمجموع الخضرى عند عمر ٧٥ يوم من الزراعة.

٤. أدى التلقيح بالريزوبيوم إلى زيادة معنوية لمحصولى القرون والبذور والصفات المحصولية المدروسة (عدد ووزن القرون/نبات، وزن البذور/نبات، وزن ١٠٠ بذرة، نسبة التصافى٪) لنباتات الفول السودانى وكذلك المحتوى الغذائى للبذور من العناصر الكبرى والصغرى، وكذا محتواها من الزيت والبروتين.

٥. أدت أضافة الجبس الزراعى إلى زيادة معنوية لمحصولى القرون والبذور وكذلك الصفات المحصولية تحت الدراسة، وأيضا المحتوى الغذائى للبذور من العناصر الكبرى (النيتروجين، الفوسفور)، وكذلك العناصر الصغرى (حديد، زنك، منجنيز، نحاس) وكذلك محتوى البذور من الزيت والبروتين، بينما سجلت علاقة تضاد عند زيادة معدل إضافة الجبس ومحتوى البذور من البوتاسيوم.

٦. أدى الرش الورقى لنباتات الفول السودانى بعنصر الحديد إلى زيادة معنوية فى محصولى القرون والبذور وكذلك الصفات المحصولية المدروسة ومحتوى البذور من النيتروجين والبوتاسيوم والحديد والمنجنيز وكذلك الزيت والبروتين فى كلا موسمى النمو، وكانت أفضل القيم لجميع الصفات المدروسة عند رش النباتات بالحديد بمستوى ٠.٦ جم/لتر. بينما سجلت علاقة تضاد عند زيادة تركيز الحديد فى محلول الرش ومحتوى البذور من الفوسفور والزنك والنحاس.

٧. الجدير بالذكر أن التأثير المشترك للتلقيح بالريزوبيوم وإضافة الجبس والرش بالحديد متحدة معاً أدى إلى زيادة معنوية فى جميع القياسات السابقة لكل من التربة ونباتات الفول السودانى النامية عليها.

ومن ثم يمكن القول تحت ظروف التجربة فى تربة رملية حديثة الإستصلاح، فإن لإضافة الجبس الزراعى مع تلقيح البذور بالريزوبيوم تأثيراً كبيراً على تحسين خواص التربة وزيادة تيسر العناصر الغذائية بها مع رفع كفاءة الرش بالحديد، مما ينعكس بصورة إيجابية على المحصول الناتج وجودة صفاته.

Table (10): Fe, Mn, Zn and Cu contents in peanut seeds as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Inoculation, A	Gypsum rate (ton/fed), B	Fe (mg kg^{-1})				Mn (mg kg^{-1})				Zn (mg kg^{-1})				Cu (mg kg^{-1})			
		Iron foliar spray (g/L), C															
		0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean	0.0	0.3	0.6	Mean
Un-inoc.	0.0	203	262	293	253	28.3	29.0	31.2	29.5	32.3	38.7	34.7	35.2	4.80	4.50	4.10	4.50
	0.5	247	317	342	302	30.9	30.6	34.2	31.9	45.6	45.3	40.6	43.8	4.90	4.90	4.50	4.80
	1.0	293	335	377	335	32.3	33.5	33.2	33.0	59.5	52.4	45.6	52.5	6.00	5.80	5.20	5.70
	Mean	247	304	337	297	30.5	31.0	32.9	31.4	45.8	45.5	40.3	43.8	5.23	5.06	4.60	5.00
Inoc.	0.0	230	286	342	286	40.9	42.3	44.6	42.6	37.1	37.2	33.5	35.9	6.60	6.30	5.70	6.20
	0.5	263	336	386	328	42.1	43.0	46.4	43.8	53.3	48.5	42.8	48.2	7.20	6.70	6.20	6.70
	1.0	287	379	426	364	45.6	47.3	49.4	47.4	64.3	56.8	52.1	57.7	8.10	7.60	7.20	7.60
	Mean	260	334	384	326	42.9	44.2	46.8	44.6	51.6	47.5	42.8	47.2	7.30	6.87	6.37	6.80

Table (11): Fe, Mn, Zn and Cu uptake by peanut seeds as affected by rhizobium inoculation, gypsum and iron foliar spray applications (combined analysis of 2008 and 2009 seasons).

Inoculation, A	Gypsum rate (ton/fed), B	Fe (g fed^{-1})				Mn (g fed^{-1})				Zn (g fed^{-1})				Cu (g fed^{-1})			
		Iron foliar spray (g/L), C															
		0.0	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**	**0.0**	**0.3**	**0.6**	**Mean**
Un-inoc.	0.0	147	208	248	201	20.5	22.9	26.4	23.2	23.4	30.6	29.4	27.8	3.48	3.56	3.47	3.50
	0.5	208	287	330	275	25.9	27.6	33.0	28.8	38.3	40.9	39.2	39.5	4.12	4.42	4.34	4.29
	1.0	270	335	408	337	29.7	33.4	38.0	33.7	54.7	52.3	49.2	52.1	5.52	5.79	5.62	5.64
	Mean	208	276	329	271	25.4	28.0	32.5	28.6	38.8	41.3	39.3	39.8	4.37	4.59	4.47	4.47
Inoc.	0.0	209	278	362	283	37.2	41.1	47.2	41.8	33.7	36.1	35.4	35.1	6.00	6.12	6.03	6.05
	0.5	274	412	476	387	43.8	49.7	57.2	50.2	55.4	53.8	52.8	54.0	7.49	7.75	7.60	7.61
	1.0	333	490	576	466	52.8	61.1	67.2	60.4	74.5	73.4	70.9	72.9	9.39	9.82	9.79	9.67
	Mean	272	393	471	379	44.6	50.6	57.2	50.8	54.5	54.4	53.0	54.0	7.93	7.90	7.81	7.77
L.S.D. at 0.05	A	3.84				1.82				0.98				0.22			
	B	10.84				1.41				1.75				0.22			
	C	4.43				0.55				0.78				0.08			
	AxB	15.36				1.99				2.48				0.31			
	AxC	6.26				0.78				1.11				0.12			
	BxC	7.66				0.95				1.36				0.15			
	AxBxC	10.84				1.34				1.92				0.21			