

Effect of Magnetic Iron and Biofertilization Treatments on Wheat (*Triticum aestivum* L.) Productivity under Salinity Conditions

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TWO FIELD experiments were conducted at Ras-Sudr Research Station, South Sinai Governorate during two successive seasons, 2011/2012 and 2012/2013 to study the effect of four levels of magnetic iron (0, 50, 100 and 150 kg /fed) and four biofertilization; control, *Pseudomonas fluorescence* and *Rhizobium meliloti* individual and mixed application on the yield parameters of wheat (*Triticum aestivum* L., cv. Sakha 94). Results revealed that increasing of the magnetic iron from 50 up to 150 kg /fed significantly increased all yield and yield components parameters; plant height (cm), spike length (cm), number of spikelets / spike, weight of 1000 grains (g), biological yield (kg /fed), grain yield (kg /fed) and straw yield (kg/fed) compared with the control in each growing seasons. In single inoculation *Rizobium* gave better result than other treatments for all yield criteria in the two growing seasons. The effect of the interaction indicates that inoculating of the *Rizobium*, fertilized with 100 kg magnetic iron /fed resulted in the highest yield and yield components in the two growing seasons. Interaction resulted in between magnetic iron and biofertilization resulted in higher grain protein than the control. In addition, the percentage of K, K/Na ratio, N, and grain protein of the Sakha 94 significantly increased in the two growing seasons. The analysis of the data collected during the study proved that there were statistically significant increases of wheat yield and yield components and some chemical contents due to different rates of magnetic treatments compared by the control which revealed decreases in the previously mentioned characters. Generally, the best treatments were 100 kg magnetic iron /fed and *Rizobium meliloti*. Both treatments were more effective in avoiding the adverse effects of soil salinity on wheat productivity compared to other treatments used.

Keywords: Magnetic iron, biofertilization, *Rizobium meliloti*, *Pseudomonas fluorescence*, Wheat, Grain yield.

Wheat is considered as the major cereal crop in the world in respect of the cultivated area and total production. It provides an almost 20 % of food calories for people in the world as well as in Egypt (Al- Ansari, 2003). Increasing wheat production is the ultimate goal to reduce the wide gap between production and consumption. Wheat is generally classified to be moderately tolerant to salinity (Mass & Hooffman, 1977). One million hectares of the irrigated areas in Egypt

suffer from salinization problems and sodicity (FAO, 2005). The majority of salt-affected soils in Egypt are located in the Northern central part of the Nile Delta and on its Eastern and Western sides. About 900 000 ha suffer from salinization problems in cultivated irrigated areas, 6 % of Northern Delta region are salt-affected, 20 % of the Southern Delta and Middle Egyptian region and 25% of the Upper Egypt region (FAO, 2008). Salinity is one of the serious environmental problems that cause reduction in plant growth and yield productivity in irrigated areas of arid and semi-arid regions of the world, the mechanism by which salt stress damage plants are still a discussing matter due to very complex nature of the salt stress in plants (Zhu, 2001). Plants growing in saline soil come across generally with major drawbacks; that is the increase in the osmotic stress due to high salt concentration of soil (Mesut *et al.*, 2010). Plant productivity is considerably reduced due to osmotic inhibition of water uptake by roots or specific ion effects (Mayak *et al.*, 2004). Salinity increases the uptake of Na^+ or decreases the uptake of P and K^+ which lead to nutritional imbalances (Yildirim *et al.*, 2006).

Under South Sinai Governorate, agriculture suffered from both salt-affected soils beside saline underground brackish water which contains varying amounts of dissolved salts used for irrigation. Under Egyptian condition, application of magnetic technologies is a new concept. Overcoming the negative effect of salinity, using magnetic iron (Fe_3O_4), is one of the most important factors affecting plant growth. It has a black or brownish-red color and it is one of two natural row rocks in the world that is naturally magnetic (Mansour, 2007). Application of a magnetic iron has shown to increase plant height, yield and its components (Sharma *et al.*, 2003). Agro minerals include geological materials that contain one or more recognized plant nutrients and so-called 'rock fertilizers' (Leonardos *et al.*, 2000). Iron ores often contain impurities, undesirable chemical components such as phosphorous, sulfur, sodium, potassium (alkalis), alumina, silica and sometimes titanium (Ismail *et al.*, 2010). Application of magnetic iron increased vegetative growth, yield on pepper plant grown under saline irrigation conditions (Taha *et al.*, 2011). It also includes rocks and minerals that improve the physical status of soils. The use of rocks and minerals as low-cost, locally available geological nutrient resources for agricultural development is not new. Moreover, rocks and minerals are used in crop production systems for several purposes, among them improving soil fertility, correcting the pH of soil, conserving nutrients and water (Podlešný *et al.*, 2005).

The use magnetic iron in agricultural production is mainly to reclaim alkaline sodic soils and it has been tested as an inexpensive material to correct Fe deficiencies in calcareous soils (Barrau & Berg, 1977). It enriched manure to improve a good source for iron on alkaline soils (Bangar *et al.*, 1985). Anonymous (2006) reported that many benefits to crop growth can result from addition of the natural mineral product *i.e.*, magnetic iron including improved soil structure, increased soil organic matter, improved water properties and became more energy and vigor and this known as "Magneto biology", improved

water – holding capacity and cation exchange capacity, increasing water retention by soil and this helps plant growth, moderation of soil temperature, improved crop nutrition from macro and microelements (Taha *et al.*, 2011). Moreover, the magnetic process separates all chlorine, toxic and harmful gases from soils so increases salt movement and solubility of nutrients (Podlešný *et al.*, 2005). If it is known that a real shortage of Fe exists in the soil and is causing deficiency symptoms, the addition of iron fertilizer or other readily available iron sources can correct the shortage.

Biofertilization are good source of nutrients and increase organic matter in soil. It may not only activate N₂-fixation but also growth and production, yield level as well as producing of the growth regulators such as auxin, cytokine, gibberellins,...etc., that increases the grain yield (El-Kased *et al.*, 1996). *Rhizobium* is an important symbiotic for legumes but it plays an important role with non-legumes by producing growth hormones. The first important step for producing growth hormone is root colonization of beneficial bacteria with plants (Kloepper & Beauchamp, 1992). Rhizobia are able to colonize and survive in the rhizosphere of the non-legumes plant to act as plant growth promoting rhizobacteria (PGPR) in the rhizosphere of nonhost legumes and non-legumes (Wiehe & Höflich, 1995). Plant growth promoting rhizobacteria (PGPR) is a group of free-living bacteria that colonize the rhizosphere and exert a beneficial impact on plant health and soil fertility. PGPR can directly facilitate the plant growth in several ways such as syntheses of phytohormones, siderophores production, solubilization of mineral phosphate and synthesis of the enzyme ACC-deaminase (Zahir *et al.*, 2010). Microbial siderophores play an important role in the biocontrol of some soil-borne plant diseases and in plant iron nutrition; rhizobia produce different type of siderophores (Guerinot, 1991).

To overcome iron starvation, *B. japonicum* can utilize its own siderophores and those produced by other organisms (Plessner *et al.*, 1993). Efforts on the interaction of rhizobia with non-legumes have increased during the previous couple of decades, and it has been established that roots of non-legumes could also be associated with rhizobia, devoid of effective nodule formation. Also, several mechanisms *e.g.*, phytohormones production (Zahir *et al.*, 2010), siderophore production (Meyer, 2000) and increased availability of insoluble phosphorus (Fatima *et al.*, 2006) have been proposed by which Rhizobia can stimulate the growth of non-legumes directly and indirectly via suppressing or eliminating deleterious microbes by producing antibiotics (Antoun & Prevost, 2000). Biofertilization technology is practiced for increasing agricultural production, to limit the use of chemical fertilizers and pollution of environment through seed inoculation by different types of bacteria (Abd El-Ghany, 1994). *Rhizobium* colonization in non-legumes such as wheat, *Brassica* and *Arabidopsis thaliana* does not require the *Rhizobium* nodulation genes which are involved in the infection and nodulation of legume roots (Hafeez *et al.*, 2005). Efforts at extending N₂-fixing ability to important non-leguminous crops such as cereals have long been a major goal of researchers in the field of biological nitrogen fixation. Making cereals self-sufficient in N nutrition would be of great

benefit to resource-poor farmers in Africa (Viviene & Dakora, 2004). One approach for achieving this goal has involved the isolation and characterization of N₂-fixing bacteria from a variety of wild and cultivated cereal crops (Stoltzfuz *et al.*, 1997). Plant inoculation with *Rizobium* for example, promoted higher uptake of researchers in NO₃⁻, K⁺ and H₂PO₄⁻ in corn, sorghum and wheat, leading to higher crop yields perhaps rhizobia produce various metabolites such as auxins, cytokinins, riboflavin and vitamins (Dakora, 2003). The main object of this study is an attempt for reducing the effect of magnetic iron and biofertilization treatments on wheat productivity under saline stress conditions at Ras-Sudr region.

Material and Methods

Two field experiments were carried out at Ras-Sudr Agricultural Experimental Station of Desert Research Center, South Sinai Governorate in Egypt during 2011/2012 and 2012/2013 to study the effect of four levels of magnetic iron (0, 50, 100 and 150 kg /fed. Hectare = 2.38 fed) and four biofertilization treatments; control, *Pseudomonas fluorescence* and *Rhizobium meliloti* individual and mixed application on wheat (*Triticum aestivum* L. cv. Sakha 94). The experiments were laid in a split plot design with four replications, where, biofertilization were allocated in main plots and magnetic iron occupied the sub-plots. Sakha 94, used which was obtained from the Agriculture Research Center, Giza, Egypt. The magentic iron treatments were added to the soil once during the plant life in a powder form before sowing. The used magnetic iron contained 3.72 % SiO₂, 14.90% TiO₂, 1.23%, Al₂O₃, 76.56% Fe₂O₃, 0.35% MnO, 1.21% MgO, 0.45% CaO, 0.42% Na₂O, 0.05% K₂O, 0.07% P₂O₅, 0.09% Cl and 0.05% SO₃. It was obtained from “El- Ahram Company for Mining and Natural Fertilizers” (ECMNF), Giza. Egypt. *Rhizobium* and *Pseudomonas fluorescence* were isolated from nodules of vegetable pea at Ras-Sudr station. Pink, healthy and undamaged nodules were selected, then in field experiments wheat grain was planting and inoculated by biofertilization after ten days on soil under Ras-Sudr conditions (Abd El-Ghany, 1994). Table 1 presented the physical and chemical analysis of the soil site.

TABLE 1. Some physical and chemical analysis of the experimental site.

Season	Particle size (%)			Texture (%)	Field capacity (%)	Wielting point (%)	Available water (%)	EC ds/m	O.M (%)	CaCO ₃ (%)	pH
	Sand	Silt	Clay								
2011/12	74.47	10.90	14.63	S. loam	18.45	10.25	8.20	7.80	0.28	52.40	7.74
2012/13	76.60	9.55	13.85	S. loam	17.75	9.80	7.95	6.50	0.15	46.60	7.89
Soluble Cations (meq/100g)					Soluble Anions (meq/ 100g)						
Season	K ⁺	Na ⁺	Mg ⁺⁺	Ca ⁺⁺	SO ₄ ⁻	Cl ⁻	HCO ₃	CO ₃			
2011/12	2.30	40.50	9.20	26.00	29.00	45.50	3.50	0.00			
2012/13	1.30	32.70	8.30	22.70	25.50	37.50	2.00	0.00			
Extractable available elements (ppm)											
Season	N	P	K	Fe	Mn	Zn	Cu	Ni	Pb	Cd	
2011/12	18	7.5	50	6.98	4.86	2.21	1.01	0.33	0.22	0.09	
2012/13	11	5.4	35	5.8	3.77	1.77	0.94	0.25	0.15	0.08	

EC= Electric conductivity, O.M= Organic matter.

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The area of each plot was $2 \times 3 \text{ m} = 6 \text{ m}^2$, which had 4 rows (3 m length, 50 cm apart.). Grains were sown in November, 20th, 2011 in the first season and November, 24th, 2012 in the second season at seeding rates of 80 kg/fed, for the two seasons.

The recommended cultural practices of growing wheat plants were applied. Different soil samples were collected from different sites of Ras Sudr used for isolation, about eleven *Pseudomonas* isolates were obtained as shown in Table 2. Cultures of *Pseudomonas* isolates were purified by successive streaking on King's medium B was based on the formulation of Murray *et al.* (2003). Microscopically examination was carried out to check the purity of cultures. The purified *Pseudomonas* isolates were tested for their phosphate dissolving efficiency quantitatively and qualitatively according to De Freitas *et al.* (1997), also, siderophore production (Reeves *et al.*, 1983) and salicylic acid production (Meyer *et al.*, 1992). The most active fluorescent *Pseudomonas* isolates with phosphate dissolving activity, siderophore production and Salicylic acid production were identified using Bergey's (Table 3).

TABLE 2. Phosphate solubilization, Siderophore and Salicylic acid production by *Pseudomonas* isolates.

<i>Pseudomonas</i> isolates	Phosphate solubilization (cm)	Siderophores ($\mu\text{g/ml}$, 410 nm)	Salicylic acid ($\mu\text{g/ml}$, 527 nm)
1	0.7	36	23
2	1.4	31.4	28.1
3	1.0	40.2	35
4	0.8	39.2	29
5	1.6	31.9	36
6	1.5	44.8	27.3
7	1.1	38	24.1
8	2.4	57.9	40.8
9	1.3	43	26
10	2.0	48	31.5
11	0.9	51	37

Locally isolated *Rhizobium* spp. was maintained at 4°C on yeast extract mannitol agar (YEMA). Biochemical activities of studied microbial isolate to determine; the ability of the tested microbial isolates to produce biochemical activities was evaluated under *in vitro* conditions, through determination of their efficiency for growth regulators production (Rizzolo *et al.*, 1993) and antibiotic production (Jarlier *et al.*, 1996) (Table 4). Soil samples of wheat rhizosphere were collected in both seasons and analyzed for microbial determinations. Total microbial counts were determined on Bunt and Rovira medium (Nautiyal, 1999) using the decimal plate method technique. CO₂ evolution was measured according to Anderson (1982). The most probable number (MPN) of *Pseudomonades* was determined after incubating the tubes at 30±2°C for 48 h on King's B medium (Bergey's, 1994). Estimates of number of *Pseudomonades* by MPN technique were calculated using Cochran's table. At harvest (after 160 days) select randomized ten plants from each plots to determine: plant height (cm), spike length (cm), number

of spikelets / spike, weight of 1000 grains (g) and from 1 m² to biological yield (kg /fed), grain yield (kg /fed) and straw yield (kg/fed). In addition, samples were chosen for the chemical analysis determining the percentage of potassium, sodium and K/Na ratio (Page, 1982). Nitrogen and protein (N X6.25) values were calculated as described by A.O.A.C. (1995). Data were statistically analyzed by using analysis of variances according to Snedecor & Cochran (1990) and means were grouped by LSD test at the 5% probability level.

Results and Discussion

Isolation and characterization of fluorescent Pseudomonas isolates

Different soil samples were collected from the rhizosphere of different crops for *Pseudomonas* isolation; eleven bacterial isolates were isolated, purified and examined for their activities to dissolve phosphate qualitative by Mean diameter of lyses (cm) (De Freitas *et al.*, 1997), production of siderophore (Reeves *et al.*, 1983) and production of Salicylic acid (Meyer *et al.*, 1992) (Table 2).

Identification of Pseudomonas isolate

The most active isolate no. (8), was completely identified according to Bergey's Manual of Determinative Bacteriology (1994). The morphological and physiological characters presented in Table 3. Selected *Pseudomonas* isolate was found to belong to *P. fluorescens*.

TABLE 3. Identification of *Pseudomonas* isolates no.4.

Biochemical reactions	Results
Morphological character:	
Shape	Short rod
Motility	Motile
Gram reaction	Gram negative
KOH solubility test	+
Physiological character :	
Pyoverdin production	+
Pyocyanin production	+
Oxidase reaction	+
Starch hydrolysis	-
Hydrogen sulphide production	+
Catalase production	+
Utilization of : Glucose	+
Trehalose	-
D-Mannose	+

Biochemical activities of Pseudomonas fluorescens and Rhizobium spp.

Microbes under study known to produce a number of secondary metabolites which may affect growth, health of plants, and the relationships between rhizosphere soil microorganisms and plant growth regulators (quantitative (HPLC) / µg/ml) and antibiotic production. Table 4 shows the biochemical activities of the *Rhizobium spp.* and *Pseudomonas fluorescens* used in the trial for production of plant hormones and antibiotics. As shown in Table 4

microorganisms exhibited biochemical and hormonal activities *in vitro* that could result in beneficial action in the field (El-Saidy & Abd El-Hai, 2011).

TABLE 4. Biochemical activities of microbial isolates.

Hormonal activity µg/ml	<i>P. fluorescens</i>	<i>Rhizobium</i>
IAA	10.2	2.7
GA3	1.95	3.29
Cytokinine	18.39	12.4
Antibiotic reduction(mm)		
<i>Escherchia coli</i>	23	-
<i>Salmonella typhi</i>	27	-
<i>Fusarium oxysporum</i>	32	-
<i>Rhizoctonia solani</i>	24	-

Microbial determinations in wheat rhizosphere

Total microbial counts

Initial total microbial counts in Ras Sudr soil was 24×10^5 cfu/g dry soil. Data in Table 5 showed that the counts tended to increase in all treatments compared to the control. Total microbial counts proved an increase in vegetative stage of wheat plant growth followed by harvesting in both growing seasons. Also, interaction treatment between *P. fluorescens* inoculation, *Rhizobium* and magnetic iron application produced the highest total microbial counts as compared with other treatments and control. These results agreed with Abd El-Ghany *et al.* (1997).

CO₂ evolution

The generation of carbon dioxide (CO₂) was determined as an indication of the biological activity in plant rhizosphere. Results in Table 5 clearly showed that mixed treatment with *P. fluorescens* inoculation, *Rhizobium* and magnetic iron application gave high rate of CO₂ evolution compared to all other treatments. Data of CO₂ evolution were almost in harmony with those of total microbial counts discussed before. These results agreed with Visser & Dennis (1992).

Pseudomonas densities

The initial *Pseudomonas* densities in Ras Sudr were 3.8×10^3 cfu/gm dry soil. Data recorded in Table 5 proved a marked increase in *Pseudomonas* densities in first and second season. The increase in *Pseudomonas* densities was higher in the second season than the first one, and the increase was higher vegetative stage but decreased at harvest. The densities under interaction treatment of *P. fluorescens*, *Rhizobium* and magnetic iron application recorded the highest density. The highest increase in *Pseudomonas* densities were obtained by using the interaction treatment with magnetic iron application treatments (0, 50, 100 and 150 kg/fed, respectively). The promoting effect due to the application of *P. fluorescens* not only to the production of organic acid and siderophore which increased the availability of iron uptake but also to the production of plant growth promoting

substances and antimicrobial substances as well which increase soil fertility, microbial communities and plant growth (Yadav *et al.*, 2007). Anandaraj & Leema (2010) confirmed that, combined inoculation increased the population of total bacteria, *Rhizobium* sp. and *Pseudomonas fluorescens* over not inoculated control indicating the ability of the introduced microorganisms to establish them in the rhizosphere.

TABLE 5. Effect of interaction between magnetic iron and biofertilization on biological activity in wheat rhizosphere.

Characters Biofertilizer treatment	First season						
	Magnetic iron (kg/fed)	TC×10 ⁵ cfu/gm dry soil		CO ₂ mgCO ₂ /100 g dry soil/24h		Ps×10 ³ cells/gm dry soil	
		Veg.	Harv.	Veg.	Harv.	Veg.	Harv.
Without inoc.	Control	37	34	16.3	15.7	4.1	3.9
	50	42	38	21	19.8	6.4	5.3
	100	43	40	24	20.6	7	6.1
	150	45	41	27	23	7.8	6.8
<i>P.fluorescens</i>	Control	31	28	17	16.1	4.5	4.2
	50	52	49	24.1	22	7.2	6.3
	100	60	57	25	22.6	9.3	8
	150	63	59	25	23	9.5	8.7
<i>Rhizobium</i>	Control	34	31	16	15.2	4.8	4.1
	50	56	51	27	26	8.2	7.5
	100	64	57	29	27.3	9	8.4
	150	66	59	30	28	9.6	9.1
Mix (<i>P.fluorescens</i> + <i>Rhizobium</i>)	Control	36	33	18	16.5	5.2	4.7
	50	63	59	31	28.4	9.3	8.5
	100	71	65	33	30	9.8	8.9
	150	77	68	35	31.7	10.3	9.4
L.S.D at 5%		1.62		0.139		0.53	
Second season							
Without inoc.	Control	43	38	18.1	16.4	4.7	4.2
	50	48	45	23	19.6	7.2	6.3
	100	51	49	27	22.9	8.6	8.1
	150	53	50	30	26	9	8.3
<i>P.fluorescens</i>	Control	38	35	19	17.2	5.1	4.8
	50	57	52	28.6	25.3	7.9	7.1
	100	66	61	31.8	28.9	9	8
	150	69	65	33	30.4	10.3	9.8
<i>Rhizobium</i>	Control	37	34	18.7	17.6	5.6	5.1
	50	56	50	32.5	30.4	9.4	8.5
	100	64	59	34	32.5	10.2	9.6
	150	66	61	37	35.1	11	10.4
Mix (<i>P.fluorescens</i> + <i>Rhizobium</i>)	Control	36	32	19.2	18	5.5	5.1
	50	63	58	33	31.7	9.8	9.5
	100	71	67	37	34.9	10.7	10.5
	150	77	68	39	36.4	11.8	10.5
L.S.D at (5%)		1.44		0.37		0.71	

Tc: total microbial count

Ps: *Pseudomonas fluorescens*

*Wheat yield and yield components**Effect of magnetic iron on wheat yield and yield components*

Data in Table 6, show that increasing magnetic iron levels from 50 up to 150 kg /fed, wheat yield and its components characters increased significantly :plant height (cm), spike length (cm), number of spikelets / spike, weight of 1000 grains (g), biological yield (kg /fed), grain yield (kg /fed) and straw yield (kg/fed) in the two growing seasons. Results of the current study demonstrate that magnetic treatments improved wheat yield and its components compared to the control. It was also clear that all previously mentioned characters were progressively increased with increasing the dose of magnetite, where the highest significant increases in yield parameters obtained under the highest magnetite dose (150 kg/fed) compared to control plants. Magnetic treatments may affect phytohormone production leading to improved cell activity and plant growth (Maheshwari, 2009). The present results are in harmony with those of Sudhakar *et al.* (2002), Abd El-Al (2003) and Esitken & Turan (2004), also to that obtained by De Souza (2005) whom reported that magnetic treatments led to a remarkable increase in plant root and stem length as well as fresh and dry weights during the nursery period of tomato plant.

TABLE 6. Effect of magnetic iron on wheat yield and its components in the two growing seasons.

Characters Magnetic Iron (kg/fed)	Plant height (cm)	Spike length (cm)	No. of spikelets/ spike	1000- grains weight (g)	Biological yield (kg /fed)	Grain yield (kg /fed)	Straw yield (kg/fed)
2011/2012 season							
0	68.43	11.72	16.63	33.83	1146.57	819.60	326.97
50	77.84	12.7	17.66	39.33	2334.93	1145.24	1189.69
100	86.01	13.79	18.52	45.33	3757.63	1396.95	2360.68
150	87.58	14.02	18.75	47.25	4210.14	1554.47	2655.67
LSD _{5%}	1.22	0.23	0.21	1.03	105.26	26.26	96.15
2012/2013 season							
0	67.267	11.49	16.17	32.92	1023.58	737.36	286.22
50	74.67	12.22	17.13	37.83	2023.62	1092.82	930.80
100	82.32	13.41	18.23	44.17	3428.44	1322.24	2106.20
150	86.65	13.80	18.42	45.92	3577.07	1474.20	2102.87
LSD _{5%}	0.93	0.16	0.16	0.59	116.81	18.48	84.11

The present results agree with those of, Taha *et al.* (2011), who reported that, the application of magnetic treatment improved growth of pepper plant under salt condition. Such effect of magnetic field may be due to weakness bonds between certain ions and thought to be a major factor affecting on their activity in soil and plant. Obtained data agree those reported by Ismail *et al.* (2010), who reported that many benefits to crop growth can result from addition of the natural mineral product *i.e.*, magnetic iron including improved soil structure, increased soil organic matter, improved water properties and become more energy and

vigor and this known as "Magneto biology", improved water – holding capacity and cation exchange capacity, increasing water retention by soil and this helps plant growth, moderation of soil temperature, improved crop nutrition of macro and microelements. Moreover, the magnetic process separates all chlorine, toxic and harmful gases from soil which increases salt movement and solubility of nutrients. Behrouz & Mojtaba (2011), pointed out that magnetic iron application had increased the ability of soil to get rid of salts. Also, It was resulted in a better assimilation of nutrients and fertilizer in plants during the vegetative period and increased crop production.

Effect of biofertilization on yield and yield components

It is interesting to note that, there were significant effects of all biofertilization treatments on yield and its components compared with inoculated soil, where the highest significant increase in yield and its components appeared under *Rhizobium* compared with the other treatments and control. Soil wheat plant inoculated with *Rhizobium meliloti* produced higher grain yield and its components than those inoculated with *Pseudomonas fluorescense* and the mixture of the two species of bacteria (*Pseudomonas + Rhizobium*). This may be due to *Rhizobium* is an important symbiotic for legumes but it plays an important role with non-legumes by producing growth hormones and different types of siderophores which established roots of non legumes also several mechanisms *e.g.*, phytohormones production (Zahir *et al.*, 2010). These results were true in the two growing seasons, (Table 7). This may be *Rhizobium* supply more plant hormones (auxin, cytokine, gibberellins...etc.) as reported by El-Kased *et al.* (1996). These may be due to recycling nutrient elements as natural resources and increase in the amount of fixed nitrogen by plant and all over the soil and produce active substances which help in plant nutrient uptake. Zahir *et al.* (2010), reported similar findings of increased grain yield of wheat with biofertilization treatments. This is due to plant growth promoting rhizobacteria (PGPR) is a group of free-living bacteria that colonize the rhizosphere and exert a beneficial impact on plant health and soil fertility. PGPR can directly facilitate plant growth in several ways such as syntheses of phytohormones, siderophores production, solubilization of mineral phosphate and synthesis of the enzyme ACC-deaminase .

Effect of the interaction between magnetic iron and biofertilization

The effect of the interaction between different magnetite iron doses and biofertilization indicate significant increases in wheat yield due to the magnetic treatments under different biofertilization, especially the highest significant increase in yield characters obtained under the combined effect of *Rhizobium meliloti* and 100kg/fed, of magnetic treatments compared with other treatments (Tables 8a and 8b). This increase in yield characters as a result of magnetite treatments may be due to that magnetic treatments improved capacity for nutrient and water uptake, providing better physical support to the developing shoot; better root growth and development in young seedlings might lead to better root systems throughout the lifetime of a plant (Lynch, 1995).

TABLE 7. Effect of different biofertilization on wheat yield and its components in two growing seasons.

Characters Treatment	Plant height (cm)	Spike length (cm)	No. of spikelets/spike	1000-grains weight (g)	Biological yield (kg/fed)	Grain yield (kg/fed)	Straw yield (kg/fed)
2011/2012 season							
Control	69.18	11.38	16.34	34.58	992.01	512.78	479.23
<i>Pseudomonas fluorescence</i>	75.46	12.75	17.62	40.92	1818.62	1179.70	638.92
<i>Rhizobium meliloti</i>	88.16	14.08	18.84	46.00	4424.51	1697.41	2727.10
Mix (<i>Pseud.</i> + <i>Rizo.</i>)	86.87	14.02	18.75	44.25	4214.13	1526.37	2687.76
LSD _{5%}	1.33	0.18	0.27	1.65	94.52	20.89	62.01
2012/2013 season							
Control	67.83	11.0	16.13	33.17	913.77	468.98	444.79
<i>Pseudomonas fluorescence</i>	74.08	12.24	17.38	38.75	1668.11	1112.97	555.14
<i>Rhizobium meliloti</i>	85.26	13.93	18.28	45.33	3776.18	1594.71	2181.47
Mix (<i>Pseud.</i> + <i>Rizo.</i>)	80.73	13.74	18.15	43.58	3694.65	1449.97	2244.68
LSD _{5%}	1.12	0.23	0.27	0.70	274.46	18.31	43.12

TABLE 8a. Effect of interaction between magnetic iron and biofertilization on wheat yield and its components .

Characters Treatments		Plant height (cm)	Spike length (cm)	No. of spikelets/spike	1000-grains weight (g)	Biological yield kg/fed	Grain yield kg/fed	Straw yield kg/fed	
Biofertilization	Magnetic iron (kg/fed)	2011/2012 season							
		Control	0	60.77	10.4	15.73	25.33	798.47	155.37
		50	67.73	11.2	16.10	33.00	924.43	357.47	566.96
		100	73.07	11.4	16.43	38.00	1035.90	642.57	393.33
		150	75.17	12.2	17.10	42.00	1209.23	895.73	313.50
<i>Pseudomonas fluorescence</i>	0	66.20	11.3	16.50	35.00	904.30	532.9	371.40	
	50	73.90	12.53	17.53	39.67	1300.73	1017.67	283.06	
	100	79.20	13.47	18.10	43.33	2041.10	1339.9	701.20	
	150	83.27	13.70	18.33	45.67	3058.33	1528.33	1530.00	
<i>Rhizobium meliloti</i>	0	70.43	12.23	17.07	36.67	1423.57	1122.40	301.17	
	50	87.37	13.63	18.60	43.33	3438.93	1751.77	1687.16	
	100	98.13	15.33	19.93	53.00	6666.90	1959.87	4707.03	
	150	96.73	15.10	19.77	51.00	6168.63	1955.60	4213.03	
Mix (<i>Pseud.</i> + <i>Rizo.</i>)	0	76.33	12.93	17.20	38.33	1489.97	1167.73	322.24	
	50	82.37	13.43	18.67	41.33	3675.60	1454.07	2225.53	
	100	93.63	14.63	19.60	47.00	5286.60	1645.47	3641.13	
	150	95.17	15.07	19.80	50.33	6404.37	1838.20	4566.17	
LSD _{5%}		2.663	0.496	0.456	2.027	295.274	57.501	---	

TABLE 8b. Effect of interaction between magnetic iron and biofertilization on wheat yield and its components.

Characters		Plant height (cm)	Spike length (cm)	No. of spikelets/spike	1000-grains weight (g)	Biological yield kg/fed	Grain yield kg/fed	Straw yield kg/fed
Treatments		2011/2012 season						
Biofertilizer	Magnetic iron (kg/fed)							
Control	0	59.84	9.80	15.47	24.33	710.60	140.40	570.20
	50	65.77	10.80	16.03	32.00	809.37	322.47	486.90
	100	71.03	11.47	16.13	36.33	946.67	593.70	352.97
	150	74.70	11.93	16.90	40.00	1170.43	819.37	351.33
<i>Pseudomonas fluorescense</i>	0	65.87	11.03	16.10	33.67	960.70	276.23	684.47
	50	72.73	11.97	17.23	36.67	1174.13	952.13	222.00
	100	77.27	12.77	17.97	41.00	1870.70	1241.81	628.89
	150	80.47	13.20	18.20	43.67	2866.90	1481.70	1385.20
<i>Rhizobium meliloti</i>	0	69.77	12.10	16.40	36.33	1246.50	978.00	368.50
	50	83.10	12.93	17.90	41.33	2808.77	1695.10	1113.67
	100	96.17	14.90	19.57	53.00	5925.50	1880.43	4045.07
	150	92.00	15.03	19.23	50.67	5123.97	1825.30	3298.67
Mix (<i>Pseud.</i> + <i>Rizo.</i>)	0	73.60	13.03	16.70	37.33	1376.53	1054.83	321.70
	50	77.10	13.17	17.33	41.33	3302.20	1401.57	1900.63
	100	84.80	14.50	19.23	46.33	4952.90	1573.03	3379.87
	150	87.43	15.03	19.33	49.33	5146.97	1770.43	3376.54
LSD _{5%}		2.041	0.345	0.356	1.304	255.826	40.473	-----

Biofertilization like *Rhizobium* supplemented 75% (100 kg iron ore /fed) of the recommended dose of magnetic iron in wheat which not only reduce the chemical fertilizers but also equalized the yield of wheat when compared with 100 % (150 kg iron /fed) of the recommended dose of magnetic iron alone to improve wheat utilization of fertility status (Hasabo, 2006). Abd-Elbary *et al.* (2007), reported that the application of iron nutrient solution, magnetic iron, metal compound fertilizer and liquid culture of the bacteria, suppressed several species of plant-parasitic nematodes and improved the growth of the host crops, and changes in the physiological and the chemical properties of the soil (Zahir *et al.*, 2010).

Chemical composition of wheat grain yield

Effect of magnetic iron on chemical composition of wheat grain yield

Data indicated in Fig. 1 a and 1b show that the effect of magnetic iron on percentage of K, Na, K/Na ratio, N and protein content in wheat grain were significant in the two growing seasons, except those of sodium content in the second season. Magnetic treatments showed gradual and significant increases in N and K K/Na , protein content in the two growing seasons, except sodium content of wheat grain compared with control in both seasons. Highest accumulation was obtained under (150 kg/fed) magnetite dose. These may be due to the role of iron which was important in the activation of several enzyme

systems in plants including: fumaric hydrogenase, catalase, oxidase and cytochrome. A shortage of Fe also impairs chlorophyll production. Iron is thought to be associated with the synthesis of chloroplastic protein.

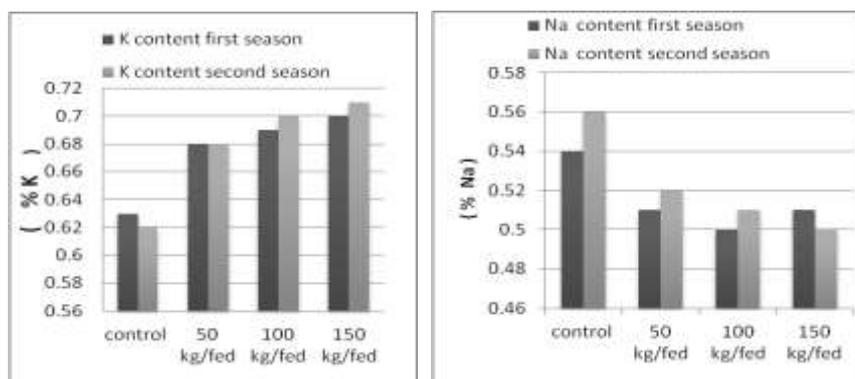


Fig. 1a. Effect of magnetic iron on K and Na contents of wheat grain in two growing seasons.

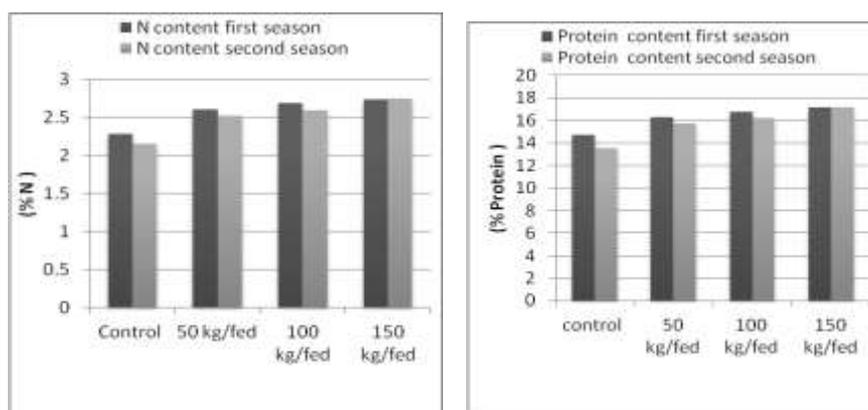


Fig. 1b. Effect of magnetic iron on N and protein content of wheat grain in two growing seasons.

The increase in N and K concentrations with magnetic treatments may be due to its effect on adsorption of N and K from soil colloidal complex and thus increasing its availability to plants. Also, magnetic treatments improve availability, uptake, assimilation and mobilization of these nutrients within the plant system (Maheshwari, 2009). These results were in line with those obtained by Mansour (2007) who reported that there were gradual increments in nitrogen, phosphorus, potassium, calcium and iron concentration in cauliflower leaves with increasing magnetite levels. Moreover, Maurya *et al.* (1993) and Krzywy & Gowacka (1998) reported increase in N content with increasing magnetite doses.

Effect of the biofertilization on chemical composition of wheat grain yield

Results in Fig. 2a and 2b, show that the effect of biofertilization on K, Na, K/Na ratio, N and protein content in grain of wheat were significant in the two growing seasons. *Rhizobium* was superior to other treatments in all characters in the two growing seasons except K content which was not significant in the first growing season. The grain analyses reveal that the uptake of the important nutrients of N and protein were improved by varying degrees. Such improvement in the chemical composition of both grain and straw has an impact on their nutritional value for human and animal consumption. Though the application of *Rhizobium* proved superiority compared with other sources in terms of high yield and plant uptake of essential elements. These results agreed with those obtained by Dakora (2003), who found that plant inoculation with *Rhizobium* for example, promoted greater uptake of NO_3^- , K^+ and H_2PO_4^- in corn, sorghum, and wheat, leading to higher crop yields. Rhizobia may produce various metabolites such as auxins, cytokinins, riboflavin and vitamins.

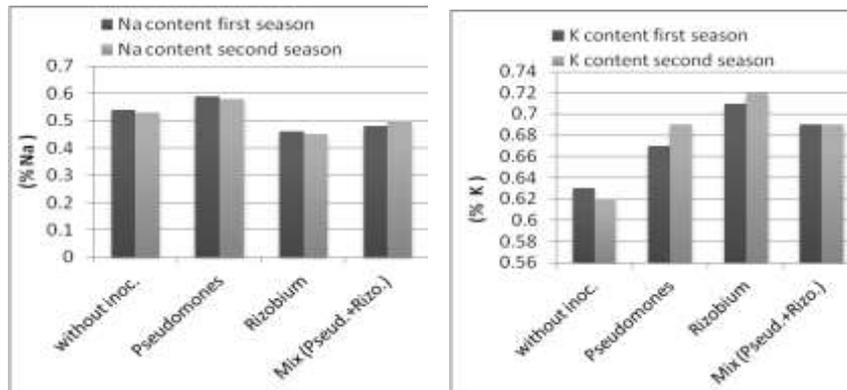


Fig. 2a. Effect of biofertilization on Na and K contents of wheat grain in two growing seasons.

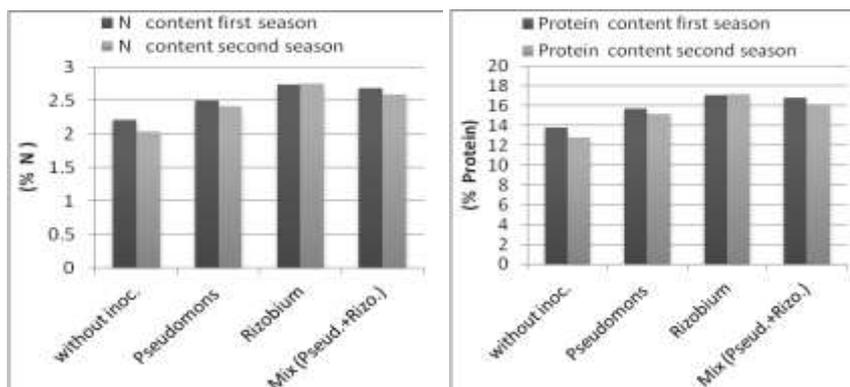


Fig. 2b. Effect of biofertilization on N and protein content of wheat grain in two growing seasons.

Effect of the interaction between magnetic iron and biofertilization on chemical composition of grain yield

Results in Table 9, show that the effect of interaction between magnetic iron and biofertilization on the percentage of K, Na, K/Na ratio, N and protein content in grain of wheat in the two growing seasons, was significant, except K content of grain in the second season. Maximum values of the aforementioned criteria were obtained in the tissue of wheat grain fertilized by 150 kg / fed and inoculated with *Rhizobium*. These may be due to the increase of nitrogen content in grain supply by *Rhizobium*.

TABLE 9. Effect of the interaction between magnetic iron and biofertilization (2011/20112 and 2012/2013 seasons) .

Biofertilization	Magnetic Iron (kg/fed)	K (%)		Na (%)		K /Na ratio		N (%)		Protein content %	
		1 st	2 nd	1 st	2 nd						
Control	0	0.63	0.64	0.54	0.53	1.17	1.21	2.31	1.92	14.44	12.00
	50	0.63	0.64	0.53	0.52	1.19	1.23	2.38	2.00	14.88	12.50
	100	0.64	0.65	0.52	0.51	1.23	1.27	2.39	2.25	14.94	14.06
	150	0.65	0.65	0.51	0.51	1.27	1.27	2.40	2.30	15.00	14.38
<i>Pseudomonas fluorescense</i>	0	0.64	0.64	0.53	0.52	1.21	1.23	2.40	2.25	15.06	14.06
	50	0.65	0.65	0.51	0.50	1.27	1.30	2.41	2.43	14.94	15.19
	100	0.66	0.67	0.50	0.49	1.32	1.37	2.48	2.45	15.50	15.31
	150	0.67	0.67	0.49	0.49	1.37	1.37	2.50	2.42	15.63	15.13
<i>Rhizobium meliloti</i>	0	0.64	0.65	0.51	0.51	1.25	1.27	2.41	2.45	15.06	15.31
	50	0.67	0.66	0.49	0.48	1.16	1.38	2.49	2.51	15.56	15.69
	100	0.68	0.68	0.48	0.47	1.42	1.47	2.56	2.63	16.00	16.44
	150	0.69	0.69	0.47	0.46	1.47	1.50	2.68	2.72	16.75	17.00
Mix (<i>Pseud.</i> + <i>Rizo.</i>)	0	0.64	0.65	0.51	0.50	1.25	1.30	2.43	2.46	15.19	15.38
	50	0.66	0.66	0.49	0.50	1.35	1.32	2.53	2.50	15.81	15.63
	100	0.67	0.68	0.48	0.47	1.39	1.45	2.56	2.58	16.00	16.13
	150	0.68	0.69	0.47	0.47	1.45	1.47	2.68	2.60	16.75	16.25
LSD 5%		0.01	Ns	0.02	0.04	-----	-----	0.01	0.01	0.07	0.07

Conclusions

The application of magnetic iron and *Rhizobium meliloti* have profoundly alleviated salinity effects and improved performance by increasing wheat productivity as evidenced by the application of magnetic iron at 100 kg/fed with *Rhizobium meliloti* to reduce soil salinity for minimizing the hazard of salts on wheat productivity under saline stress conditions.

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تأثير معاملات الحديد المغناطيسي والتسميد الحيوى على انتاجية القمح تحت ظروف الملوحة

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قسم الإنتاج النباتي وقسم خصوبة وميكروبيولوجيا الأراضى - مركز بحوث الصحراء- المطرية - القاهرة - مصر.

أقيمت تجربتين حقليتين بمحطة جنوب سيناء التابعة لمركز بحوث الصحراء - راس سدر بمحافظة جنوب سيناء خلال موسمين زراعيين متتاليين ٢٠١٢/٢٠١١ و ٢٠١٣/٢٠١٢ وذلك لدراسة تأثير ثلاث مستويات مختلفة من الحديد المغناطيسي (٥٠ و ١٠٠ و ١٥٠ كجم/ فدان) بالإضافة إلى بدون إضافة الحديد في التربة مع نوعين من البكتريا المعزولة من تربة منطقة الدراسة (الرايزوبيم والسيدوموناس بالإضافة إلى مخلوط بينهما) كتسميد حيوى مقارنة بغير المعامل على صنف القمح سخا ٩٤ والتي تم ريهم من بئر بالمنطقة والتي تصل نسبة ملوحة ٦٨٦٨ جزء في المليون عن طريق شبكة ري مجهزة بالمحطة. أوضحت الدراسة النتائج التالية:

- ١- زاد محصول القمح ومكوناته معنويا بزيادة معاملة الحديد المغناطيسي من ٥٠ كجم حتى ١٥٠ كجم حديد مغناطيسي/ فدان في كلا الموسمين .
- ٢- تفوق الرايزوبيم كتسميد حيوي على المعاملتين الاخريتين (بكتريا السيدوموناس والمخلوط بينهما) في صفات المحصول ومكوناته في كلا الموسمين .
- ٣- كان التفاعل بين معاملة الحديد المغناطيسي وبكتريا الرايزوبيم معنويا في صفات المحصول ومكوناته حيث كانت أفضل معاملة هي ١٠٠ كجم / فدان حديد المغناطيسي/فدان مع بكتريا الرايزوبيم في كلا الموسمين .
- ٤- زادت نسبة البوتاسيوم و نسبة البوتاسيوم / الصوديوم و النتروجين و البروتين وقلت نسبة الصوديوم في حيوب القمح صنف سخا ٩٤ بإضافة الحديد المغناطيسي للتربة بمعدل ١٥٠ كجم/ فدان مع معاملة الرايزوبيم كتسميد حيوى بمفرديهما او معا في كلا الموسمين.
- ٥- ينصح في الاراضى المتأثرة بالأملاح كما في منطقة راس سدر بمحافظة جنوب سيناء معاملة صنف القمح سخا ٩٤ بالرايزوبيم (كمثبت للحديد في الصورة الميسرة في التربة من خلال تحوله إلى مركبات السيدروفورا) الذي يؤدي إلى تقليل معدل إضافة الحديد المغناطيسي في التربة إلى ١٠٠ كجم/فدان وبالتالي إعطاء محصول جيد و زيادة العائد الأقتصادي للمزارعين.