Responses of Wheat – Rice Cropping System to Cyanobacteria Inoculation and Different Soil Conditioners Sources under Saline Soil

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Abstract: A Field experiment was conducted in the clayey soil of the farm at Sahl El-Hossynia Agric. Res. Station in EL-Sharkia - Governorate, Egypt. The institute farm is located at 31° 8' 12.461" N latitude and 31° 52' 15.496" E longitude. wheat crop (*Triticum aestivum* L) was planted during winter season (2010-2011) and rice crop (*Oryzae sativa*) was planted during summer season (2011) to study the effectiveness of cyanobacteria inoculation combined with different sources of soil conditioners to improve soil chemical properties, soil biological activity and reflected to productivity of both wheat and rice crop system; total content of mineral nutrients of both tested plants were taken in consideration.

Results indicated that, in general, applying cyanobacteria inoculation in combined with some soil conditioners decreased slightly pH and EC values, while organic matter (OM) and Saturation Percent (SP) were increased as compared to control treatment. Also, applying cyanobacteria in combined with fulvic acid (FA) and /or humic substances (HS) significantly superior for decrease EC, SAR and ESP values in soil at both studied seasons. Moreover, cyanobacteria inoculation combined with compgypsum increases organic matter (OM) content in soil after two cultivated seasons.

In addition, positive significant responses existed for available N, P and K as well as soil biological activity (total count bacteria, CO_2 evolution, dehydrogenase activity and nitrogenase activity) in the studied soils under cultivation with both wheat and rice as a result of applied gypsum combination with cyanobacteria inoculation as compared to control treatment.

On the other hand, wheat and rice yields (straw and grain) along with total content of macronutrients (N, P and K) increased significantly in response to cyanobacteria inoculation in combination with gypsum as compared to other treatments and\or control treatment.

In conclusion, the application of cyanobacteria inoculation combined with humate organic acids helpful to improve the soil properties of saline soils. Also, the cyanobacteria inoculation combined with gypsum improved available and uptake macronutrients reflected that on the yield components.

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Key words: Cyanobacteria inoculation, soil conditioners, gypsum, compost, humic acids, fulvic acid, polyvinyl acetate, wheat (*Triticum aestivum* L.), rice (*Oryzae sativa*).

1. Introduction

Wheat and rice are important cereal crops in Egypt. They are also major cash crops for the farmers and handsome amount of foreign exchange is earned through export of rice. Thus, their role in strengthening the economy of the country may not be neglected.

The main problem at Sahl El-Hossynia soil is related to high salinity conditions. Soil degradation caused by salinizations and sodication were of universal concern. Saline (EC > 4 dSm^{-1}), or salt affected soil is a major environmental issue, as it limits plant growth and development, causing productivity losses **(Qadir et al., 2008).** Salt affected soils are characterized by excessively high levels of water- soluble salts, including sodium chloride (NaCl), sodium sulfate (Na_2SO_4), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$), among others. In the salinity case, NaCl is a major salt contaminant in the soil. It has a small molecule size and when oxidized by water, producing sodium ions (Na^+) and chloride ions (Cl^-), which are easily absorbed by the root cells of higher plants and transferred to the whole plant using xylem uploading channels, also cause ionic and osmotic stresses at the cellular level of higher plants, especially in susceptible species **(Rodriguez-Navarro and Rubio, 2006).** There are many procedures that can be used to improve salt affected soils, such as, water leaching, chemical remediation including gypsum ($CaSO_4.H_2O$), calcite ($CaCO_3$), calcium chloride ($CaCl_2$) and phytoremediation including organic matter such as farmyard manure, green manure, organic amendment, compost and their components, **(Feizi et al., 2010).**

In Egypt, improving salt affected soils is considered as an important part in the agricultural security program. Management of the salt affected soils requires a combination of agronomic practices depending on chemical amendments, water quality and local conditions including climate as well as crop economic policy.

Gypsum is commonly used as amendment for the reclamation of saline – sodic and sodic soils and reducing the harmful effects of high sodium irrigation water because of its solubility, low – cost, availability and ease of handling **(Abdel-Fattah, 2012).** The relative effectiveness of gypsum and sulfuric acid has received the most attention because they are widely used as reclamation amendments. In addition, **Khan et al. (2010)** found a positive significant improvement in saline-sodic soil properties, i.e., EC, SAR and pH in response to gypsum applied in ridges, farmyard manure and agricultural practices that resulted in an increase in wheat grain yield by 42 % over control. Besides,**Cha-um et al. (2011)** evaluated the efficiency of the same treatment on remediation of saline soil and found that rice recorded of 79.6 % spikelet fertility in response to gypsum and FYM against 46.4 % for the same soil without the use of gypsum and FYM. Also, **Abdel-Fattah (2012)** revealed pronounced decreases in EC, pH, SAR and ESP in a saline-sodic soil due to the application of gypsum and two types of compost either they applied solely or in combination, compared with control. They added that combined treatments were more efficient.

The significance of organic matter has been proved through its effect on improving the physical conditions of soils for crop growth besides its role as fertilizers. Compost is one from of organic matter producer, which can be used to improve the soil physical, chemical and biological properties of salt affected soils and it can be converted as ideal manure with high contents of macro and micronutrients. The application of organic manures, as compost or humic substances, increased the available N, P & K and organic carbon content in the soil and moreover, the reduction of soil bulk density and pH **(Dhanushkodi and Subrahmaniyan, 2012).**

Biofertilizers are non-bulky, less expensive, ecofriendly agricultural in puts, which could play a significant role in improving plant nutrients supplies as complementary and supplementary factors. Cyanobacteria play an important role in maintenance and building up of soil fertility, consequently increasing rice growth and yield as a natural biofertilizer **(Song et al., 2005).** The acts of cyanobacteria include: (1) Increase in soil pores and production of adhesive substances. (2) Excretion of growth – promoting substances such as hormones (auxin, gibberellins), vitamins and amino acids **(Rodriguez et al., 2006).** (3) Increase in water holding capacity through their jelly structure. (4) Increase in soil biomass after their death and decomposition. (5) Decrease in soil salinity and preventing weeds growth **(Saadatnia and Riahi, 2009).** (6) Increase in soil phosphate by excretion of organic acids. Furthermore, **Palaniappan et al. (2010)** pointed out that the cyanobacteria are being used as biofertilizer for plants, as food for human consumption and for the extraction of various products such as vitamins and drug compounds.

The present study aims to evaluate the efficiency of different soil conditioners sources in combination with cyanobacteria inoculation on wheat - rice yields grown in saline soil in a wheat-rice cropping system.

2. Materials and Methods

Field experiments were conducted in clay soil at Sahl El-Hossynia Agric. Res. Station Farm in EL-Sharkia Governorate; Egypt to study the effect of cyanobacterial inoculation in combination with different soil amendments on saline soil. The farm is located at 31^{o} 8' 12.461" N latitude and 31^{o} 52' 15.496" E longitude. Some physical and chemical characteristics of the studied soil are presented in Table (1).

The experiments were carried out during two successive seasons; on both wheat (SaKha, 93) in winter season (2010 - 2011) and rice (SaKha, 104) in summer season (2011). The experimental design was a randomized complete block design with three replications.

The experiment included nine treatments as follows:

1. (T1) 100 % mineral fertilizer (N, P &K) (recommended doses).
2. (T2) Cyanobacteria (SBCI) only.
3. (T3) SBCI + Humic acids 3% (v/v).
4. (T4) SBCI + Fulvic acid 3% (v/v).
5. (T5) SBCI + Humic substances 3%(v/v).
6. (T5). SBCI + sulphur (16 Kg fed^{-1}.)
7. (T6) SBCI + gypsum ((4 ton fed^{-1}).
8. (T8) SBCI + compgypsum (2 :1) at rate of 6 ton fed^{-1}
9. (T9) SBCI + polyvinyl actete (0.20% w/v).

Some properties of humic acids, fulvic acid and compost are presented in Tables (2 a) and (2 b).

Dried flakes from the soil based cyanobacteria inoculum (SBCI) were inoculated to wheat plants 10 days after sowing at the rate of 6 kg fed^{-1}, while rice received SBCI inoculum 30 days after sowing at the rate of 3 kg SBCI fed^{-1}. Cyanobacteria inoculum (SBCI) is composed a mixture of *Anabaena* *fertilissima, Nostoc linckia, Nostoc commune* and *Nostoc muscorum.* The cyanobacterial inoculum was prepared as described by **Vennkataraman (1972).**

Table (1): Some characteristics of the experimental soil

Soil characteristics	Values
Particle size distribution %	
Coarse Sand	5.40
Fine Sand	4.20
Silt	40.40
Clay	50.00
Texture class	Clay
Chemical properties	
pH (suspension 1:2.5)	8.09
EC dS m^{-1} (saturated paste extract)	10.90
Organic matter %	0.62
Soluble cations and anions (meq L^{-1})	
Ca^{++}	43.30
Mg^{++}	39.70
Na^{+}	79.80
K^{+}	1.70
CO_3^{--}	- - -
HCO_3^{-}	5.78
CL^{-}	87.80
SO_4^{--}	70.92
SAR	12.40
ESP	14.60
Available macro& micronutrients (mg kg^{-1})	196.00
N	7.00
P	133.00
K	
Fe	9.00
Mn	1.88
Zn	1.82
Cu	5.40

Table (2 a): Some characteristics of humic and fulvic acids

Determination	Humic acids	Fulvic acid
EC dS m^{-1}	61.0	59.00
pH	5.00	2.00
Available nutrients (mg L^{-1})		
Fe	0.44	0.33
Mn	0.058	0.048
Zn	0.94	0.64
Cu	0.03	0.09

Table (2 b): Some characteristics of compost applied in the Experiment

Analysis	Values
Moisture %	**12.00**
pH (1 :10)	**8.02**
EC dS m^{-1}	**3.14**
OM %	**24.50**
C :N	**29.6 :1**
Total N %	**0.48**
NH_4 – N mg Kg^{-1}	**55**
NO_3 – N mg Kg^{-1}	**155**
Total P %	**0.38**
Total K %	**0.60**

All treatments applied before cultivation except for cyanobacterial inoculation and received mineral fertilizers at the recommended doses for both wheat and rice crops. Superphosphate (15 % P_2O_5) at a rate of 200 Kg fed^{-1} added basically before sowing during soil preparation. Nitrogen added at rates of 340 Kg fed^{-1} and100 Kg fed^{-1} for both wheat and rice, respectively, in three split equal doses after 15, 30 and 60 days from sowing in the form of ammonium sulfate (20 % N). While, potassium added at the form potassium sulfate (48 % K_2O) at a rate of 50 Kg fed^{-1} in two equal doses at sowing and 30 days from sowing for both wheat and rice.

At harvest, surface soil samples collected and subjected to the analysis of some soil chemical properties as described by **Cottenie et al. (1982)**.

Straw and grains of both wheat and rice crops collected from each plot, oven dried at 70°C for 48 h, and the weighed up to a constant dry weight, ground and prepared for digestion according to **Page et al. (1982)**. The digests were then exposed to the estimation of N, P, K and Na (**Cottenie et al., 1982).**

Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) carried out according to **Abdel – Fattah (2012).** Sodium adsorption ratio (SAR) estimated by using the following equation, where ionic concentration of the saturation extracts is expressed in meq L^{-1}.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Exchangeable sodium percentage (ESP) was estimated by using the following equation

$$ESP = \frac{100\,(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)}$$

Obtained results were subjected to statistical analysis according to **Snedecor and Cochran (1980)** and the treatments were compared by using the least significant difference (L.S.D. at 0.05 level of probability).

As well as, at harvest, a part of the collected soil samples was devoted for the determination of the soil biological activity in terms of nitrogenase activity (N_2-ase) **(Hardy et al., 1973)**, dehydrogenase activity (DHA) **(Casida et al., 1964)**, carbon dioxide evolution **(Pramer and Schmidt, 1964)** and total count bacteria **(Allen, 1959).**

3. Results and Discussion

Soil chemical properties

Data in Table (3) show the changes of some soil chemical properties in response to the application of different soil conditioner materials along with the inoculation with cyanobacteria.

Saturation percent (SP) and organic matter (OM):

Results revealed that the saturation percent (SP) has slightly insignificant increase due to the applied treatments compared to control. However the exception was for the treatments of comp-gypsum and PVA in combination with cyanobacteria inoculation at winter and summer seasons (wheat and rice crops), which recorded insignificant decreases for the saturation percent.

With regard to organic matter (OM), results showed that all applied treatments increased significantly the OM compared to control treatment. This trend was true for both seasons. Application of comp-gypsum in combination with cyanobacteria (T8) recorded high significant increases in OM content of soil being 0.48% and 0.80% in winter (wheat) and summer (rice) seasons against 0.26% and 0.65% for control treatment, respectively. Cyanobacteria play an important role in maintenance and building up the soil fertility. The acts of these cyanobacteria include: (1) Excretion of growth – promoting substances such as hormones, vitamins, amino acids as organic matter **(Rodriguez et al., 2006),** (2) increase in soil biomass after their death and decomposition **(Saadatnia and Riahi, 2009)**. Also, under salt stress condition, application of cyanobacteria to the soil lead to increase the soil organic matter, which is consequently, increased the soil biological activity by increasing the soil CO_2 evolution leading to increase the soil fertility **(Singh et al., 2008).**

Table (3): Effect of cyanobacteria inoculation in combination with some soil conditioners on some chemical properties in soil under saline condition

A:- Wheat

Treatments		pH	O.M (%)	EC (dSm^{-1})	SP	Anions (meq L^{-1})				Cations (meq L^{-1})			
						CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
NPK (Control)		7.61	0.26	9.63	79.7	-	13.3	47.3	38.2	18.8	24.6	55.0	0.42
Cynobacteria only		7.57	0.30	7.23	80.0	-	9.58	30.7	45.0	16.6	22.8	44.4	0.45
Cynobacteria	Humic acids(HA)	7.61	0.47	6.47	80.0	-	10.8	28.0	38.1	19.2	22.4	34.1	1.22
	Fulvic acid(FA)	7.54	0.42	5.38	81.2	-	9.17	11.7	33.3	15.0	11.5	26.3	1.29
	Humic substances (HS)	7.52	0.47	5.37	84.7	-	12.5	27.0	14.2	18.3	10.9	23.3	1.18
	Sulphur (S)	7.55	0.47	6.32	82.2	-	12.5	22.7	39.2	23.3	17.6	32.3	1.13
	Gypsum	7.60	0.32	8.30	80.5	-	10.0	30.7	58.9	28.2	21.6	49.4	0.39
	Compgypsum	7.57	0.48	7.80	79.8	-	10.8	13.3	40.4	25.8	32.3	33.9	0.53
	PVA	7.55	0.46	7.33	78.7	-	10.0	16.0	48.6	20.2	19.2	34.8	0.42
LSD. 5 %		NS	0.11	4.03	NS	-	2.19	11.5	27.0	9.99	13.4	16.9	0.44

B:- Rice

Treatments		pH	OM %	EC (dSm^{-1})	SP	Anions (meq L^{-1})				Cations (meq L^{-1})			
						CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
NPK (Control)		7.73	0.65	8.57	80.0	-	8.00	38.9	42.2	24.4	27.7	41.1	1.20
Cynobacteria only		7.72	0.69	6.66	85.5	-	8.66	29.7	29.0	17.8	21.7	26.8	1.05
Cynobacteria	Humic acids(HA)	7.80	0.71	7.35	82.0	-	8.67	33.8	39.8	22.2	25.2	33.8	1.00
	Fulvic acid(FA)	7.76	0.78	6.37	83.0	-	8.66	25.6	32.2	23.3	15.4	26.8	1.05
	Humic substances (HS)	7.74	0.67	6.21	81.0	-	8.69	26.9	35.8	23.3	19.4	27.8	1.00
	Sulphur (S)	7.77	0.68	7.51	84.0	-	5.78	32.4	45.4	28.9	18.5	35.0	1.16
	Gypsum	7.73	0.69	8.32	82.0	-	8.67	40.5	41.1	28.9	23.3	37.2	1.11
	Compgypsum	7.77	0.80	6.93	78.5	-	8.67	31.1	38.8	24.4	20.6	32.5	1.03
	PVA	7.79	0.66	6.68	75.0		8.68	28.4	38.3	22.2	22.0	30.0	1.10
LSD. 5 %		NS	NS	0.86	NS	-	1.82	3.99	3.33	0.02	2.89	4.31	0.02

Soil electric conductivity (EC) and soil reaction (pH).

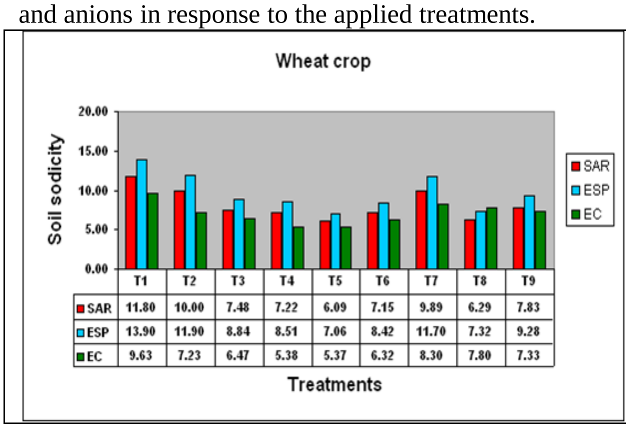
Results revealed that the values of pH and EC in soil have insignificant and significant decreases, respectively, as affected by the studied treatments compared to control. Application of fulvic acid (FA) and humic substances (HS) in combination with cyanobacteria led to significant superior decreases of pH and EC values in winter and summer seasons. However, an exception being obtained for pH at summer season. On the other hand, the application of gypsum in combined with cyanobacteria (T6) was the least affected treatment than other treatments. In this concern, the applied cyanobacteria treatments reduced EC, according to **Molnar and Ordog (2005)** who noted that some plant growth promoting regulators (PGPRs) are found to be released by cyanobacteria; these PGPRs represent the defense systems that encounter the salt stress leading to decrease the soil EC degree. Also, the cyanobacteria have the ability to excrete extracellular a number of compounds, like polysaccharides, peptides, lipids, organic acids leading to decrease the soil pH **(El-Ayouty et al., 2004).** Organic matter, including FA, FYM and HS as well as gypsum may function as salt-ion chelating agents, which detoxify the toxic ions, especially Na^+ and Cl^-, as indicated by low EC in soil treated with both organic matter and gypsum **(Zahid and Niazi, 2006).** Recently, **Khan et al. (2010)** found that the application of gypsum improved the soil chemical properties by reducing the EC and pH parameters that might be due to substitution of exchangeable Na by Ca that produced more soluble salts (NaCl or Na_2SO_4) and was leached by the irrigation water **(Lebron et al., 1994).** Concerning the effect of organic matter as compost, FA, HA and HS on the decreasing the soil pH, their effect illustrated by the indirect effect in decreasing sodium and the direct effect of organic acids, which formed either during decomposition of compost or by the application of HA and FA **(Abdel – Fattah, 2012).**

Soluble cations and anions.

Regarding the effect of different sources of soil conditioners in combination with cyanobacteria on soluble cations and anions contents in soil at both tested seasons, results indicate that the same trend observed in pH and EC was true for both soil cations and anions in response to the applied treatments.

Soil sodicity.

To complete the picture, the calculation of the sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP) are as expressive of the salinity. Soil sodicity in terms of SAR of the soil paste extract and ESP of the soil are presented in Fig. (1), both SAR and ESP decreased considerably by the application of all treatments compared to control. The SAR at applied of different sources of soil conditioners ranged from 11.8 (100% NPK) to 6.09 (cyanobacteria + HA) for the first season (wheat crop) and ranged from 8.06 (100% NPK) to 6.02 (cyanobacteria + HA) for the second season (rice crop) compared with the initial values of 12.4, thus exhibiting a decrease of between 4.84 to 50.9 % and 34.7 to 51.5 % for the first and second seasons, respectively. The ESP gave the same trend as that of the SAR. The ESP values showed decreases ranged between 4.79 to 51.6 % for the first season and 34.4 to 51.4 % for the second season. The application of humic substances (HS) in combination with cyanobacteria inoculation showed greater decrease in SAR and ESP than other treatments. The data agree with results reported by **Khan et al. (2010)** and **Abdel - Fattah (2012)** who showed that the application of organic amendments either singly or in combination decreased in SAR and ESP compared to control, This behavior can be attributed to the decrease in soil salinity resulted from the organic amendments that may function as salt – ion chelating agents, which detoxify the toxic ions, especially Na^+ and Cl^-, as indicated by low EC in soil treated with amendments.



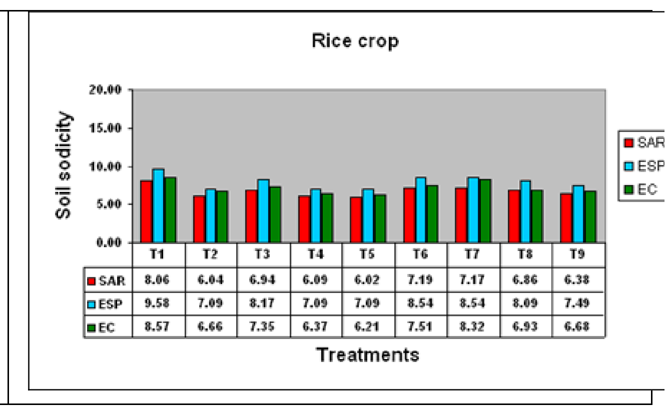


Fig. (1): Effect of inoculation with cyanobacteria and different soil conditioners sources on SAR and ESP in soil under saline condition after wheat- rice harvested.

Finally, the EC values was plotted against ESP and SAR as well as plotted between for the last at two seasons, these parameters are showed in Fig (2). ESP (r^2 =0.587) and SAR (r^2 = 0.598) in the soil cultivated with wheat were positively related to the increase EC values.

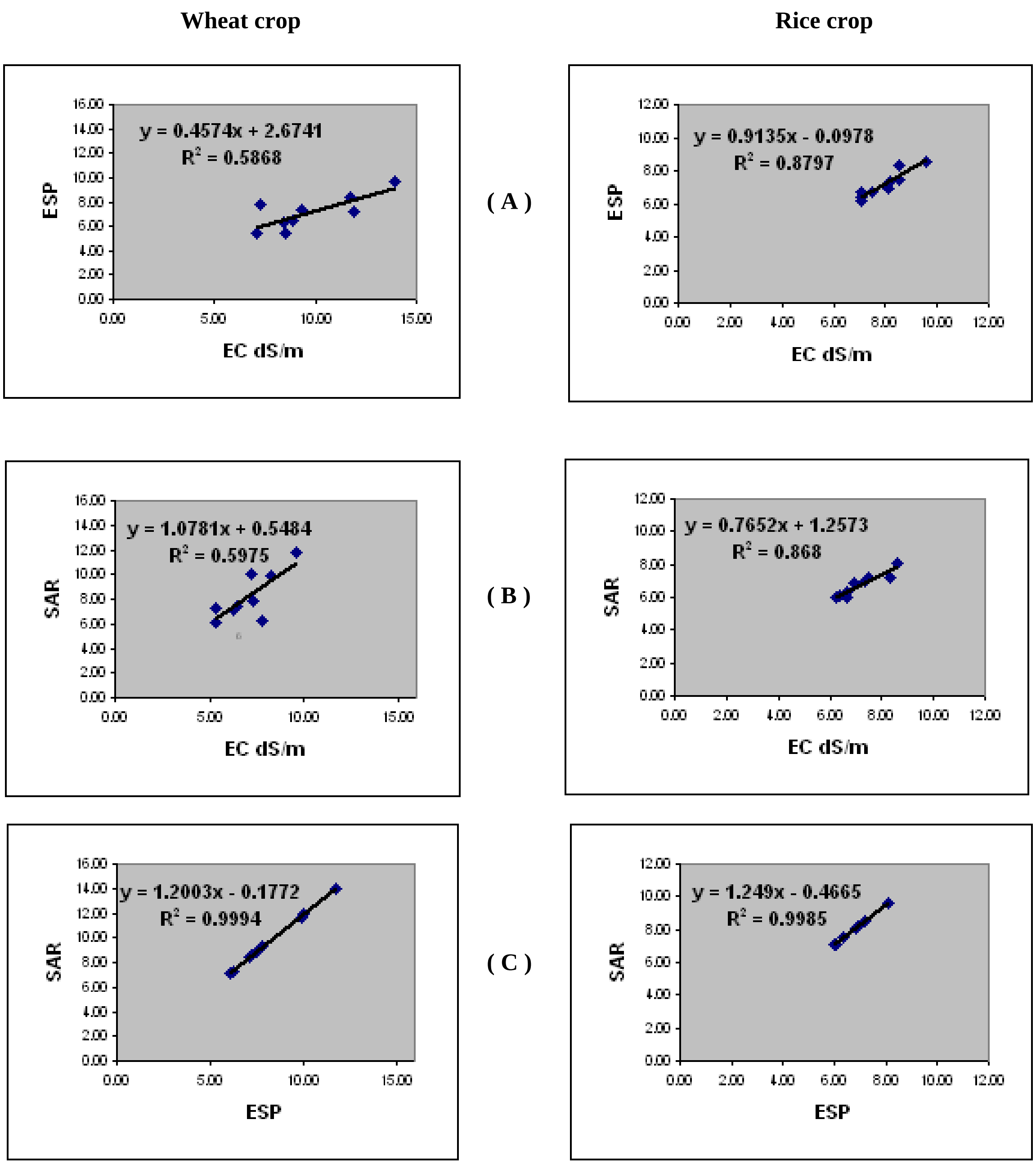


Fig. (2): Relationship between ESP and EC (A), SAR and EC (B) and SAR and ESP (C) in soil under saline condition after wheat- rice harvested.

The same trend was observed for ESP (r^2 = 0.879) and SAR (r^2 = 0.868) in the soil of rice. Also, the relationship between SAR and ESP was positively (r^2 = 0.99). This indicated the positive effect among the all studied parameters (EC, SAR and ESP). As illustrated above, the relation between EC, ESP and ASR is more obvious in the case of rice than in wheat. These may be due to the leaching effect.

Nutrients availability in soil after harvesting of both wheat and rice cropping system.

The data representing availability of soil macronutrients (N, P and K) after wheat and rice harvesting are shown in Table (4). Statistical analysis showed that all applied treatments increased significantly the soil macronutrients availability (N and K) compared to the control treatment. This trend was true for both crops. On the other hand, the applied treatments had not significantly increased the soil P availability. However, the use of gypsum in combination with cyanobacteria inoculation gave the highest soil available N, P & K values after harvesting of both wheat and rice.

Table (4): Effect of cyanobacteria inoculation in combination with some soil conditioners on available macronutrients in soil under saline condition after wheat and rice harvested

Treatments		Available of macronutrients mg kg^{-1} soil					
		N	P	K	N	P	K
		A:- Wheat			B:- Rice		
NPK (Control)		238	12.6	245	137	5.39	242
Cynobacteria only		334	22.2	315	201	9.43	313
Cynobacteria	Humic acids(HA)	299	19.2	281	191	7.70	329
	Fulvic acid(FA)	288	17.8	279	173	6.72	329
	Humic substances(HS)	325	18.5	319	201	8.02	320
	Sulphur (S)	345	22.1	337	205	9.97	335
	Gypsum	364	28.5	345	210	10.7	342
	Compgypsum	327	17.2	332	196	6.97	332
	PVA	266	16.8	262	173	5.87	305
LSD. 5 %		48.6	8.92	43.3	33.1	3.97	36.5

In this respect, **Dhanushkodi and Subrahmaniyan (2012)** pointed out that the application of compost as soil conditioners increased available N in soil compared to control and reported that available N increased due to mineralization of native N by soil organisms. The addition of organic soil conditioners well decomposed and humified organic matter adds mineralized nitrogen and humic substances, this reduces the loss of N from leaching and volatilization. Also organic acids produced during decomposition of organic matter reduced the activity of polyvalent cations through chelation and reduced the P fixation and increase the availability of P. Furthermore, soil conditioners induced the availability of K because soil conditioners itself adds an appreciable quantity of K to the soil and also due to rapid decomposition and mineralization which release higher amount of NH_4^+ ion leading to increase the availability of K in soil.

Obtained results also showed that the highest significant values of soil available N, P and K were due to for the application of gypsum combined with cyanobacteria as compared to other tested treatments. Increases in the values of soil available macronutrients at winter season (wheat), as compared to control, recorded 52.9%, 126% and 40.8% for N, P and K, respectively. The corresponding increases in N, P and K at summer season (rice) recorded 53.3%, 98.5% and 41.3%, respectively. In spite of that, application of polyvinyl acetate (PVA) combined with cyanobacteria was generally non-significantly inferior. These results agree with those reported by **Dhanuskkodi and subrahmaniyan (2012)** who mentioned that the gypsum is the most economical amendment to reclaim the sodic soils. This due to that, the gypsum application sustained the available nutrients status of soil that perhaps due to the reclamation effect on soil. However, lowering pH and EC values of the soil by the use of gypsum is due to downward movement of Na owing to its replenishment by calcium as a result of solubilization of gypsum. Also sodium can be leached from the soil as Na_2SO_4. The availability of all nutrients in soil remarkably improved by the application of gypsum, which creates more favorable environment in soil and maintain elements in a more available form due to reclamation effect. On the other hand, **Singh et al. (2008)** reported that the cyanobacteria added to the soil, under salt stress condition, led to increase the soil biological activity, which is consequently increased the soil fertility that in turn is reflected positively on the availability the macro and micro-nutrients in soil. Recently, **Sahu et al. (2012)** reported that cyanobacteria play an important role to build-up soil fertility that consequently increases the yield. Biofertilizer are essential components of organic farming and play vital role in maintaining long term soil fertility and sustainability by fixing atmospheric dinitrogen (N=N), mobilizing fixed macro and micro nutrients, convert insoluble phosphorus in the soil into forms available to plants, thereby increases their efficiency and availability. The blue-green algae (cyanobacteria) are capable of fixing the atmospheric nitrogen and convert it into an available form of ammonium required for plant growth.

Soil biological activity.

Data in Table (5) indicate the effect of inoculation with cyanobacteria combined with different soil conditioners on the soil biological activity in terms of total count bacteria, CO_2 evolution, dehydrogenase activity and nitrogenase activity after wheat and rice harvesting under wheat – rice cropping system. Results revealed that all the treatments that received cyanobacteria inoculation increased the soil biological activity compared to the control treatment (NPK only). However, the use of gypsum along with cyanobacteria gave the highest values of total count bacteria, CO_2 evolution, dehydrogenase activity and nitrogenase activity in both wheat and rice soils. The corresponding values were 18 x 105 cfu g dry soil^{-1}, 141.46 mg CO_2 100 g dry soil^{-1} day^{-1}, 295.11 mg TPF g dry soil^{-1} day^{-1}and 1936.79 mmole C_2 H_2 g dry soil^{-1} day^{-1} (wheat soil) and 21 x 105 cfu g dry soil^{-1}, 171.56 mg CO_2 100 g dry soil^{-1} day^{-1}, 415.65 mg TPF g dry soil^{-1} day^{-1} and 2250.12 mmole C_2 H_2 g dry soil^{-1} day^{-1} (rice soil) for count bacteria, CO_2 evolution, dehydrogenase activity and nitrogenase activity, respectively. Also, it was noticed that the values of the soil biological activity terms in rice soil were higher than those recorded in wheat soil. Generally, the combination of the humic substances and/or gypsum with cyanobacteria enhanced relatively the soil biological activity in both wheat and rice soils after harvesting under wheat-rice cropping system. In this concern, **Zulpa et al. (2008)** studied the effect of cyanobacteria products of *Tolypothrix tenuis* and *Nostoc muscorum* on the microbiological activity and the nutrient content of the soil. The biomass and extracellular products of both strains increased the soil microbial activity. *N. muscorum* and *T. tenuis* biomasses increased the soil oxidizable C (15 & 14%), total N (10 & 12%) and available P (22 & 32%), respectively. *T. tenuis* extracellular products increased by 28% oxidizable carbon and N. muscorum extracellular products increased by 15% the available phosphorus. These are caused the soil biological activity to be increased also because they are a continuously renewable carbon source. **Caire et al. (2000)** established that cyanobacteria can increase the soil enzymatic activity. **Aref and EL- Kassas (2006)** found that cyanobacteria inoculation to maize field enhanced significantly any of total count bacteria, cyanobacteria count, CO_2 evolution, dehydrogenase and nitrogenase activities compared to the control treatment received no inoculation. They explained that bio-fertilization with cyanobacteria led to increase microorganisms' community and in turn soil biological activity in soil through increasing the organic matter and microbial activity. **Saruhan et al. (2011)** revealed that humic compounds added to soil increased the soil fertility through increasing the soil microbial population including beneficial microorganisms. They explained that humic substances are major components of organic matter, often constituting 60 to 70% of the total organic matter, thus they may enhance the plant nutrients uptake through stimulation of microbiological activity. **Ulkan (2008)** postulated that addition of humic acids to soil in wheat cultivation stimulated the soil microbiological activity that led to increase the soil fertility.

Table (5): Effect of cyanobacteria inoculation in combination with some soil conditioners on soil biological activity after wheat and rice harvesting under saline condition

Treatments		Total count bacteria x 10^5 *cfu g dry soil^{-1}		CO_2 Evolution (mg CO_2 100 g dry soil^{-1} day^{-1})		**DHA activity mg TPF g dry soil^{-1} day^{-1}		***N-ase activity (mmole C_2H_2 g dry soil^{-1} day^{-1})	
		Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice
NPK (Control)		11	14	112.15	131.16	220.12	315.12	950.12	1215.12
Cynobacteria only		13	16	125.12	145.48	256.23	335.85	1200.13	1624.65
Cynobacteria	Humic acids(HA)	16	19	137.13	161.75	284.25	390.13	1239.25	1834.85
	Fulvic acid(FA)	15	17	131.14	156.18	270.18	370.23	1226.45	1756.23
	Humic Substances. (HS)	14	16	128.12	152.13	262.25	358.78	1218.95	1678.94
	Sulphur (S)	13	15	124.96	142.13	251.76	328.58	1189.14	1465.84
	Gypsum	18	21	141.46	171.56	295.11	415.65	1936.79	2250.12
	Compgypsum	17	19	138.65	160.98	280.65	395.15	1715.43	2178.95
	PVA	12	12	121.50	136.18	230.12	320.14	985.68	1153.64

cfu = Colony formed uint^{-1}. ** DHA = Dehydrogenase activity. ***N-ase = Nitrogenase activity.

Yield and its components at harvest stage.

Statistical analyses of data in Table (6) show that the straw, grains and 1000-grain weight of both wheat and rice yields had significantly influenced by different applied treatments, compared to the control treatment.

The highest values of yield components were recorded by the treatment received gypsum in the presence of cyanobacteria. On the other hand, the lowest values for both yield components were recorded by the treatments received industrial conditioner (PVA) combined with cyanobacteria inoculation. Relative percentage in yield components of wheat plants, as compared to control, recorded 38.8%, 134% and 15.6% for straw, grains and weight of 1000-grain, respectively; the corresponding increases in components of rice plants recorded 23.8%, 52.6% and 50.0%, respectively. These results agree with those reported by **Khan et al. (2010)** who showed that the increase in wheat yield on the ridges supplemented with gypsum may be due to ameliorative effect of gypsum that lowers the SAR and EC for soils. Also, **Dhanushkodi and Subrahmaniyan (2012)** pointed out that the application of gypsum improve soil physico-chemical environment in the root zone and lowering the pH and ESP leading to increase the rice yield. The supply of nutrients through gypsum provides conductive physical environments leading to better aeration, root activity and nutrient absorption and the consequent complementary effect that resulted in higher grain yield. With respect to effect of cyanobacteria, results confirmed by the findings of **Youssef et al. (2011)** who found that the application of humic acids enriched with cyanobacteria led to increase significantly yield components of barley and faba bean crops under salt stress condition. Also, **Paudel et al. (2012)** found that the blue - green algae (cyanobacteria) inoculum applied with low doses of NPK, gave significant increase in all parameters of rice yield over control.

Furthermore, cyanobacteria is characterized by their cytokinins, gibberellins and auxins content that enhance the plant growth and moreover, these materials is proved to overcome the adverse effect of salinity in saline soil **(Strik and Staden, 2003).**

Table (6): Effect of cyanobacteria inoculation in combination with some soil conditioners on the yields of wheat and rice under saline condition

A: - Wheat

Treatments		Weight of straw Kg fed^{-1}.	Relative percentage	Weight of grains kg fed^{-1}.	Relative percentage	Weight of 1000 - grain (g)	Relative percentage
NPK (Control)		896	-	1996	-	57.6	-
Cynobacteria only		1069	19.3	3363	68.5	63.5	10.2
Cynobacteria	Humic acids (HA)	1184	32.1	4083	104	63.6	10.4
	Fulvic acid (FA)	1148	28.1	3147	57.7	61.2	6.25
	Humic substances (HS)	1118	24.8	2980	49.3	63.6	10.4
	Sulphur (S)	1090	21.7	3308	65.7	65.6	13.9
	Gypsum	1244	38.8	4673	134	66.6	15.6
	Compgypsum	1016	13.4	2661	33.3	65.8	14.2
	PVA	921	2.79	2428	21.6	60.4	4.86
LSD. 5 %		161	-	1215	-	5.43	-

B:- Rice

Treatments		Weight of straw Kg fed^{-1}.	Relative percentage	Weight of grains Kg fed^{-1}.	Relative percentage	Weight of 1000 grain (g)	Relative percentage
NPK (Control)		564	-	487	-	10.0	-
Cynobacteria only		636	12.8	575	18.1	10.6	6.00
Cynobacteria	Humic acids (HA)	675	19.7	646	32.6	10.6	6.00
	Fulvic acid (FA)	639	13.3	703	44.4	15.0	50.0
	Humic substances(HS)	664	17.7	651	33.7	13.3	33.0
	Sulphur (S)	671	18.9	587	20.5	15.0	50.0
	Gypsum	698	23.8	743	52.6	15.0	50.0
	Compgypsum	653	15.7	632	29.8	13.3	33.0
	PVA	567	18.3	560	14.9	10.9	9.00
LSD. 5 %		116	-	123	-	2.62	-

Total contents of macronutrients in plants.

With respect to total content of macronutrients for wheat and rice plants, generally, results revealed that the application of different treatments gave significant positive influences on total content of macronutrients in straw and grains for wheat and rice plants as compared to control (Table 7). Application of gypsum a combined with cyanobacteria inoculation increased significantly the total content of macronutrients for both straw and grains of wheat and rice crops. Also, the behavior of the total macronutrients content followed the same trend of those recorded by yield components. In spite of that application of PVA combined with cyanobacteria decreased this parameter.

Table (7): Effect of cyanobacteria inoculation in combination with some soil conditioners on nutrients total content in both wheat and rice under saline condition

A: - Wheat

Treatments		**N Kg fed^{-1}.**		**P Kg fed^{-1}.**		**K Kg fed^{-1}.**		**Na Kg fed^{-1}.**	
		Straw	Grains	Straw	Grains	Straw	Grains	Straw	Grains
NPK (Control)		13.6	12.4	4.10	9.28	7.74	4.40	1.94	1.23
Cynobacteria only		21.5	17.8	7.10	16.5	22.1	6.03	4.22	3.60
Cynobacteria	Humic acids (HA)	28.6	19.8	8.26	15.0	18.9	7.38	6.91	5.64
	Fulvic acid (FA)	22.0	19.1	6.43	20.2	20.9	5.68	3.63	2.74
	Humic substances(HS)	19.1	18.9	7.52	17.1	17.4	6.10	5.21	4.15
	Sulphur (S)	23.2	18.6	7.43	17.5	15.1	6.97	6.91	4.98
	Gypsum	31.5	21.2	12.1	27.1	25.7	8.56	7.53	6.59
	Compgypsum	17.3	16.6	5.32	16.5	17.9	5.65	3.14	3.07
	PVA	14.5	14.1	5.25	10.0	12.2	4.70	2.29	1.95
LSD. 5 %		8.57	3.52	3.12	11.4	17.1	1.85	2.51	2.16

B:- Rice

Treatments		**N Kg fed^{-1}.**		**P Kg fed^{-1}.**		**K Kg fed^{-1}.**		**Na Kg fed^{-1}.**	
		Straw	Grains	**Straw**	Grains	**Straw**	**Grains**	**Straw**	**Grains**
NPK (Control)		8.72	12.3	0.96	0.74	6.07	1.13	1.45	0.32
Cynobacteria only		10.3	14.0	0.68	1.29	7.08	1.59	1.92	0.67
Cynobacteria	Humic acids (HA)	10.3	14.8	0.90	1.24	6.38	1.61	1.68	0.73
	Fulvic acid (FA)	10.6	16.1	0.63	1.13	7.13	1.94	1.67	0.69
	Humic substances(HS)	10.2	15.1	1.12	1.25	7.64	1.67	1.92	0.63
	Sulphur (S)	9.71	14.1	1.07	1.14	7.01	1.59	1.63	0.55
	Gypsum	11.6	17.6	1.36	1.59	7.89	2.13	2.37	0.82
	Compgypsum	10.1	14.9	0.86	1.11	6.68	1.65	1.48	0.55
	PVA	8.98	12.3	0.69	0.64	6.34	1.44	1.29	0.47
LSD. 5 %		2.36	3.09	0.44	0.28	2.23	0.35	0.54	0.23

The application of algal extracts significantly increased the contents of the total chlorophyll and antioxidant phenomenon. As well as algal extracts exhibited strong positive correlation with the increase of wheat fresh weight, grain weight and yield and yield components. They explained that algal spray application significantly increased the plant nutrients content and had a positive effect on plant growth, oxidation behavior and activity of antioxidant enzymes in plants affected by salt stress. Furthermore, both cyanobacteria and *Azolla* extracts are characterized by their cytokines, gibberellins and auxins content that enhance the plant growth and furthermore these materials is proved to overcome the adverse effect of salinity in saline soil **(Aref et al., 2009).** Recently, mentioned that the application of gypsum creates more favorable environment in soil and maintain elements in more available form due to declamatory effect, which is consequently increased the soil fertility that in turn is reflected positively on the uptake of nutrients by plants. In addition, biofertilizers play a significant role in improving plant nutrients supplies as complementary and supplementary factors. They help in increasing the biologically fixed atmospheric nitrogen, also increases the availability of native and applied P and other crop nutrients. **(Dhanushkodi and Subrahmanlyan, 2012).**

The total contents of N, P, K and Na ranged from 13.6 to 31.5 Kg fed^{-1}, 4.10 to 12.1 Kg fed^{-1}, 7.74 to 25.7 Kg fed^{-1} and 1.94 to 7.53 Kg fed^{-1} for straw of wheat plants as well as 12.4 to 21.2 Kg fed^{-1}, 9.28 to

27.1 Kg fed^{-1}, 4.4 to 8.56 Kg fed^{-1} and 1.83 to 6. Kg fed^{-1} for grains against 8.72 to 11.6 Kg fed^{-1}, 0.96 to 1.36 Kg fed^{-1}., 6.07 to 7.89 Kg fed^{-1} and 1.45 to 2.37 Kg fed^{-1}. for straw of rice as well as 12.3 to 17.6 Kg fed^{-1}, 0.74 to 1.59 Kg fed^{-1}, 1.13 to 2.13 Kg fed^{-1} and 0.32 to 0.82 Kg fed^{-1} for grains, respectively.

Moreover, results showed that the total content of sodium in straw for both wheat and rice was progressively increased compared to grains. This may indicate that the accumulation of salts in plants resulted from high salts in soil, which reflected on nutrient uptake by plants especially for sodium. Also, sodium uptake in both straw and grains decreased while K uptake increased in treatment of gypsum a combined with cyanobacteria may be possible reason of higher yield in condition of salinity soil. These findings were observed by **Cha-um et al. (2011)** who found that the Na^+ and Cl^- are absorbed rapidly by the root system of rice and accumulate in the whole plant, which will then display symptoms of toxicity in both vegetative and reproductive stages. In the present study, Na+ in Jasmine rice grown in saline soil treated with gypsum and FYM was very low, whereas K+ was enriched when compared to the control. The properties of organic matter **(Tejada et al., 2006)** and gypsum **(Chaudhry, 2001)** in treating saline soil have been reported for the purposes of saline soil remediation **(Makoi and Verplancke, 2010)** for the cultivation of crops such as rice, wheat **(Qadir et al. 2001)** ; organic matter, including FYM and green manure and gypsum may function as salt-ion chelating agents which detoxify the toxic ions, especially Na+ and Cl-, as indicted by low EC in soil treated with both FYM and gypsum (**Hanay et al., 2004 and Zahid and Niazi, 2006).**

Conclusion

In conclusion, the application of cyanobacteria inoculation combined with organic acids (fulvic acid and humic substances) is helpful to improve the soil properties of saline soils (EC, SAR and ESP). Also, the cyanobacteria inoculation combined with compogypsum and gypsum improved organic matter content and the available nutrients in soil. As well as, the improve of macronutrients uptake (N, P and K) in wheat and rice cropping system, which in is reflected on the yield and its components.

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