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ROLE OF PHOSPHORUS FERTILIZATION IN ALLEVIATION ADVERSE EFFECTS OF SALINITY ON WHEAT GROWN ON DIFFERENT SOIL TYPES

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ABSTRACT

Optimum fertilization management is an important technique to alleviate the adverse effects of salinity stress on plants. A pot experiment was conducted to evaluate the ameliorative role of inorganic and organic P-sources on wheat grown under salt stress in three soil types deficient in available P. Wheat plants (*Triticum asetivum* L. cv. Shakha 93) were grown on alluvial, sandy and calcareous soils under salinity levels of 4, 8 and 12 dS/m of saturated paste extract (EC_e) and supplied with constant rate of 30 mg P_2O_5/kg soil as superphosphate (SP), cattle manure (CM) and 1:1 mixture of SP and CM , beside 0 P as control.

The results revealed that plants grown on the sandy soil were more susceptible to the adverse effects of salinity compared with that planted on the alluvial one, especially at 0 P. However, plants grown on the calcareous soil were moderately affected. In addition, varying soil type caused significant differences in the aboveground biomass and uptake of N, K, P and Zn in shoots and grains, where maximum values were attained in the alluvial soil followed by calcareous soil. Grains and straw yields and contents of N, P and K in the shoot tissue, grains and straw decreased significantly with increasing EC_e from low (4 dS/m) to high level (12 dS/m). In contrast, increasing ECe slightly increase Zn concentrations and induced significant increases in Zn uptake in the aerial parts of wheat plants. It was obvious that P ameliorated wheat growth under salt stress, and this role was greater under moderate and high salinity. The increases in

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N, P, K and Zn uptake appeared driven by P application were more conspicuous in the sandy and calcareous soils. Results also indicated that combined application of inorganic and organic P-sources treatment surpassed both when each applied solely, and this was true under all tested soil types and salinity levels.

Keywords: Phosphorus, salinity, wheat, soil type, fertilization.

INTRODUCTION

Soil salinity is the main factor retards sustainable crop production, especially in arid regions. Based on the FAO/UNESCO Soil Map of the world, there is 953×10^9 ha of salt-affected soils cover 10% of the earth land (FAO, 2008; Elgharably, 2008 and Ashraf, 2010). Moreover, Soil salinity is being progressively exacerbated by improper agronomic practices. In Egypt, salinity situation is more worsen where more than 35% of the whole arable lands are affected by different degrees of salinity and/or alkalinity (Mashali, 1997; El-Hendawy, 2004 and Elgharably, 2008). The demographic pressure make the increase of food production is the primary solicitude for Egypt. Accordingly, scaling up saline soil productivity is a vital tool in establishing food security.

Salt stress causes a number of detrimental effects on plants such as osmotic effects, ion toxicity, hormonal imbalance, generation of reactive oxygen species and nutritional imbalance (Athar and Ashraf, 2009). One of the important techniques in alleviating the adverse effects of salt stress on plants is the proper fertilization management practices (Colla et al., 2008). Soil phosphorus fertility is an important growth-limiting factor for most crops, particularly under salt stress (Al-Karaki, 1997; Abid *et al.,* 2002 and Ahmed, 2007). The soil manager can be easily deal with P fertility through P-fertilizers additions. Application of organic fertilizers to soil is a common practice, especially in saline environments, due to their ameliorative effects on soil conditions and plant growth (Halajnia *et al.,* 2009). Many previous studies evaluated crops response to P-fertilization under normal conditions, however, information on the efficiency of inorganic and organic P-sources to wheat under saline conditions are still minor.

Wheat is the first cereal crop in the world for human nutrition and animal feeding. However, Egypt imported more than 6.2×10^6 ton/

year, therefore, magnitude efforts must be done towards increasing wheat production. Wheat is moderately salt tolerant and sodicity tolerant crop with 50% yield loss at EC_e of 13 dS/m and 40% ESP, respectively (Ayers and Westcott, 1985 and Bohn *et al.*, 2001). Hence, wheat is commonly planted in salt-affected soils. Accordingly, the specific objective of this study was evaluating the relative efficiency of inorganic and organic P-sources for wheat under different soil types and salinity levels.

MATERIALS AND METHODS

To achieve the aim of the study, a pot experiment was conducted at the Institute of Efficient Productivity, Zagazig University during 2006/2007 season. The study was consisted of 36 treatments representing all possible combination between three soil types, three soil salinity levels and four phosphorus fertilization sources.

Three different soil samples varied in their texture and origin were chosen as tested soils in this work to represent the main types of Egyptian soils. These were Nile alluvial soil from El-Zagazig, calcareous soil from El-Nubaria and sandy soil from the experimental farm of the Faculty of Agriculture of Zagazig University located at El-Khattara, 45 km east of El-Zagazig city. The tested soils were sampled for the surface layer (0-30 cm), and the samples were air-dried, crushed using a weedy roller, sieved through a 2-mm sieve, and thoroughly mixed. Some initial physical and chemical properties of these three soils are given in Table 1. Black polyethylene pots (25cm diameter and 35cm height) were filled with exactly 8 kg portions of the soil material.

Three soil salinity levels measured as electrical conductivity of the saturated paste extract (EC_e) were intended. The EC_e of the soil samples were artificially raised to 4, 8 and 12 dS/m to represent the slight, moderate and strong soil salinity degrees, respectively. A natural salt composed of 55.73% NaCl, 25.37% Na_2SO_4, 14.74% $NaHCO_3$, 2.94% $Ca(HCO_3)_2$, 1.11% $Mg(HCO_3)_2$ and 0.11% KCl was used to create the targeted soil salinity levels. This salt was collected from a salt layer presents on the surface of an extreme saline soil at San Al-Hagar, Sharkia Governorate.

Table 1. Initial physical and chemical characteristics of the soil samples used in the experiment

Soil properties	Soil Type		
	Alluvial	Calcareous	Sandy
Particle size distribution, (%)			
Sand	18.6	50.6	84.0
Silt	27.1	30.3	06.3
Clay	54.3	19.1	09.7
Texture class	clay	loam	sand
$CaCO_3$, g/kg soil	29	376	19
Organic carbon, g/kg soil	14.7	6.4	3.5
Soil saturation volume, L water/kg soil	0.510	0.339	0.244
Field capacity, g water/kg soil	365	225	107
Real density, Mg/m^3	2.61	2.63	2.68
Bulk density, Mg/m^3	1.12	1.39	1.62
EC_e (saturated paste extract), dS/m	1.88	1.40	0.80
pH (1:2.5, soil : water suspension)	8.00	8.36	8.32
Soluble ions, $mmol_c/L$ (saturated paste extract):			
Ca^{2+}	4.34	4.22	2.86
Mg^{2+}	2.50	2.12	1.07
Na^+	10.25	6.92	4.38
K^+	0.63	0.50	0.37
CO_3^{2-}	-	-	-
HCO_3^-	4.50	3.68	2.64
Cl^-	6.25	5.76	3.55
SO_4^{2-}	6.97	4.32	2.49
Plant-available nutrients, mg/kg soil:			
Nitrogen (NH_4-N + NO_3-N)	62.3	21.8	13.9
Phosphorus (Olsen-P)	6.67	3.25	4.13
Potassium (NH_4OAc-extractable K)	263	196	123
Zinc (DETPA-extractable Zn)	1.08	0.49	0.61

Before it used, the salt was firstly dried at 70°C for 3 hs, moved to a desiccators to be cold and then ground. The equation proposed by Villa-Castorena *et al.* (2003) with some modifications was used to calculate the amount of salt required to generate each desired salinity level as follows:

$$A = \frac{(EC_{et} - EC_{en})(EF)(PSV)}{1000}$$

where: A the amount of salt added to the pot in g, EC_{et} the target soil salinity level in dS/m, EC_{en} the native or initial soil salinity in dS/m, EF an empirical factor used to convert ECe in dS/m to total dissolved salts in mg/L in the soil saturated paste extract (Dudley, 1994). This constant is 640 for soil extracts in the EC_e range from 3 to 30 dS/m (Bresler *et al.*, 1982 and Bohn *et al.*, 2001), PSV the pot soil saturation volume in liters. The PSV was calculated from soil porosity, which was estimated from the measured soil bulk density (Jury *et al.*, 1991). The calculated amounts of the salt were dissolved in tap water and added to each pot.

Wheat plants were supplied with constant rate of 30 mg P_2O_5/kg soil as superphosphate (SP) 15.5% P_2O_5, cattle manure (CM) and 1:1 mixture of SP+CM, beside 0 P as control. The composition of the used CM is 243, 13, 1.25, 20 and 0.14 g/kg of organic carbon, N, P, K and Zn. All P-sources were broadcasted on the soil surface and manually tilled into the upper (10 cm) layer just before wheat sowing.

In 24 November of 2006, ten grains of wheat (*Triticum asetivum* L. cv Shakha 93) were sown in each pot. Two week after germination, wheat seedlings were thinned to 5 plants per pot. The plants were irrigated with tap water as needed with raising soil moisture content to its field capacity during irrigation. Nitrogen was added to all soils at rate of 100 mg N/kg soil in the form of NH_4NO_3 (33.5% N) in three equal splits at sowing date, 21 and 42 days after sowing. Also, the sandy and calcareous soils were fertilized with K at rate of 48 mg K_2O /kg soil in the form of K_2SO_4 (48% K_2O), added with the second split of N fertilizer dose.

At initiation of the flowering stage, plant shoots of the central kin of each pot were carefully cut near the soil surface, and the remainder plants were leaved to complete maturity. At the end of growing season (3 May of 2007), wheat plants were harvested at soil surface, threshed and yields of straw and grains were estimated.

Samples of each plant organ were dried in a ventilated oven at 70°C for 48h, and their dry weights were recorded. Representative sub-samples of oven-dried shoots, grains and straw were ground in a metallic mill to pass a 0.2 mm mesh. A set of plant powders was wet-digested in a mixture of H_2SO_4 and $HClO_4$ acids for determinations of total N, P, K, and Zn.

The physical and chemical analyses of the soils were performed according to the recommended methods of U.S. Salinity Laboratory Staff (1954); Jackson (1967) and Jaiswal (2004). The plant and compost digests were analyzed for total N, P, K and Zn using the standard methods described by Baruah and Barthakur (1997) and Jaiswal (2004).

The collected data were subjected to analysis of variance using Statistical Package for Social Sciences (SPSS Base 11.0, 2001) according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Effect of Soil Types, Salinity Levels and P-Sources on Wheat Yield

The yield of grains, straw or biomass (grains and straw) of wheat plants grown on the alluvial soil were significantly ($p \leq 0.05$) higher than that grown on the sandy one (Table 2). However, yields of plants grown on the calcareous soil manifested intermediate trend. In contrast, harvest index (grains/biomass) of plants in the calcareous soil was significantly highest compared with that in either sandy or alluvial soils, suggesting more efficient synthesis and translocation of the metabolites. These findings were consistent under all the investigated soil salinity levels and P-sources. The noticeable vigor plant growth in the case of the alluvial soil is expected and mainly attributable to its comparative initial fertility (Table 1). Marschner *et al.* (2005) reported that soil properties such as soil texture determined its suitability as a plant growth media through influential in air-moisture balance, preserve nutrients, and in microbial community-composition which in turn, can influence plant growth by affecting nutrients availability.

Wheat grains and straw yields decreased drastically with increasing salinity (EC_e) from slight (4 dS/m) to moderate level (8 dS/m) (Table 2). Raising EC_e to 12 dS/m, the negative effects on the aboveground biomass were clearly discernible. In the same manner, the harvest

Table 2A. Grains and straw yields of wheat plants (g/pot) as affected by soil types, salinity levels and fertilizer-P sources

Soil type	Soil salinity (EC_e), dS/m	Fertilizer-P sources					Fertilizer-P sources				
		Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean
		grains yield					straw yield				
Alluvial	4	17.1	28.0	27.2	27.9	25.1	12.6	16.2	16.6	17.8	25.1
	8	12.9	20.1	19.1	19.2	17.8	9.4	12.6	12.8	12.5	11.8
	12	8.6	12.5	12.7	12.7	11.6	8.0	9.4	10.1	9.9	9.3
	Mean	12.9	20.2	19.7	19.9	18.2	10.0	12.7	13.2	13.4	12.3
Sandy	4	9.5	13.7	15.6	16.9	13.9	4.7	7.3	7.5	7.8	6.8
	8	1.7	5.7	6.2	5.6	4.8	3.0	4.8	4.5	4.9	4.3
	12	-*	-	1.5	1.5	0.8	0.3	0.6	1.3	1.5	0.9
	Mean	3.7	6.5	7.8	8.0	6.5	2.7	4.2	4.4	4.7	4.0
Calcareous	4	15.1	19.8	20.2	21.3	19.1	6.5	11.7	10.6	10.3	9.7
	8	12.0	14.8	15.3	14.8	14.2	5.1	9.1	9.0	9.2	8.1
	12	6.7	10.0	10.2	10.7	9.4	3.4	6.8	6.7	6.7	5.9
	Mean	11.3	14.9	15.2	15.6	13.3	5.0	9.2	8.8	8.7	7.9
Grand means		9.3	13.7	14.2	14.5		5.9	8.7	8.8	8.9	
Means of soil salinity levels:											
4 dS/m				19.4					13.9		
8 dS/m				12.3					8.1		
12 dS/m				7.3					5.4		
LSD at 0.05:											
Soil type				1.0					0.8		
Soil salinity level				0.5					0.6		
P-source				0.6					0.6		
Soil type × salinity level				0.9					NS		
Soil type × P-source				NS					1.1		
Salinity level × P-source				1.0					1.1		
Soil × salinity × P-source				NS					NS		

SP hint at superphosphate, CM denote to cattle manure, and NS is abbreviation of non-significant. * Plants failed to form grains.

Table 2B. Total yield (grains + straw) yield (g/pot) and harvest index (grains/aboveground biomass) of wheat plants as affected by soil types, salinity levels and fertilizer-P sources

Soil type	Soil salinity (EC_e), dS/m	Fertilizer-P sources					Fertilizer-P sources				
		Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean
		Total yield					Harvest index				
Alluvial	4	29.7	44.3	43.7	45.7	50.2	0.58	0.63	0.62	0.61	0.61
	8	22.3	32.7	31.8	31.7	29.7	0.58	0.61	0.60	0.61	0.60
	12	16.6	21.9	22.7	22.5	20.1	0.52	0.57	0.56	0.56	0.55
	Mean	22.9	32.9	32.9	33.3	30.5	0.56	0.61	0.60	0.60	0.59
Sandy	4	14.3	21.0	23.2	24.7	20.8	0.67	0.65	0.67	0.69	0.67
	8	4.7	10.4	10.7	10.5	9.1	0.36	0.54	0.58	0.53	0.53
	12	0.3	0.6	2.8	3.0	1.7	*-	-	0.54	0.50	0.53
	Mean	6.4	10.7	12.2	12.7	10.5	0.34	0.60	0.60	0.57	0.62
Calcareous	4	21.6	31.4	30.8	31.5	28.8	0.70	0.63	0.66	0.67	0.66
	8	17.1	23.9	24.3	24.	22.3	0.70	0.62	0.63	0.61	0.64
	12	10.3	16.8	16.8	17.3	15.3	0.65	0.59	0.60	0.62	0.61
	Mean	16.3	24.1	24.0	24.3	20.5	0.68	0.61	0.63	0.63	0.64
Grand means		15.2	22.4	23.0	23.4		0.63	0.60	0.62	0.62	
Means of soil salinity levels:											
4 dS/m				33.3					0.65		
8 dS/m				20.4					0.59		
12 dS/m				12.7					0.54		
LSD at 0.05:											
Soil type				1.6					0.01		
Soil salinity level				0.7					0.02		
P-source				0.9					0.02		
Soil type × salinity level				1.2					0.04		
Soil type × P-source				1.6					0.04		
Salinity level × P-source				1.6					0.04		
Soil × salinity × P-source				NS					0.07		

SP hint at superphosphate, CM denote to cattle manure, and NS is abbreviation of non-significant. * Plants failed to form grains.

index decreased drastically with increasing EC_e up to 12 dS/m irrespective of the soil type and P-source. Ahmad (2007) and Elgharably (2008), also found a decrease in plant dry matter production of barley and wheat plants with high level of salinity. The decrease in yield under high salinity could be attributed to interference in the absorption of plant nutrients and physiological water stress created by high salt concentration due to increased osmotic pressure of soil solution (Marschner, 1995; Hu and Schmidhalter, 2005 and Qadir *et al.*, 2008).

The results also indicated that phosphorus ameliorated wheat growth under saline soil conditions (Table 2). Applying P increased significantly grains and straw yields compared with control treatment. Yet, harvest index have an opposite trend where the highest values were noticed in the control treatment. This means that the counteracted adverse salinity induced by applying P was reflect mainly in enhancing dry matter production of the straw over grains. The yield increase with applying P under saline soil conditions was perhaps related to increased concentrations and uptake of essential plant nutrients and decreased concentration and uptake of toxic ions (Na^+ and Cl^-) and widening of Ca/Na and K/Na ratios. The results reported by Naheed *et al.* (2008) supported this suppose where they found that P applied through rooting medium inhibit the accumulation of Na^+ and Cl^- in leaf and roots, while enhance the leaf and root K^+, P along with Ca^{2+}. It can be easily noticed the significant differences between P-sources in their effects on the wheat yield. Combined application of a mixture of SP and CM surpassed either SP or CM when each applied solely.

The interactions between soil types, salinity levels and/or P-sources on wheat yield and harvest index were statistically significant in general.

The highest grains yield of 28 g/pot was attained in the alluvial soil at 4 dS/m and application of SP. It is also obvious that wheat plants failed in forming grains in the sandy soil when salinity was 12 dS/m under 0 P or use of SP as single P-source. This demonstrates the superiority of organic P-source (CM) in alleviating salt stress than inorganic one especially at high salinity of the sandy and calcareous soils. This result is in agreement with the previous finding on the ameliorative role of organic fertilizers on plant growth under salinity stress (Qadar, 1998 and Naheed *et al.,* 2007).

Effect of Soil Type, Salinity Levels and P-Sources on Some Nutrients Uptake by Wheat Plants

Nitrogen

The data in Table 3 show that N concentration in the wheat shoot at the initiation of booting stage (60 days after sowing) was influenced by soil types, salinity levels and P-sources. Similarly, N concentrations and its accumulated in grains and straw of wheat plants tended to be greatly influenced. Except straw N concentration, soil type significantly ($P \leq 0.05$) affected N concentrations in the other different wheat organs. The heights N concentrations were observed for plants grown on the alluvial soil compared with that planted on the sandy and calcareous soils. Moreover, there were significant ($P \leq 0.05$) differences between the three soils in their effects on N taken up in the grains, straw and in the aboveground biomass. The low concentration and uptake of N by wheat plants under the sandy soil may be attributed to the high attained soil salinity over targeted one and low fertility status as inherent trait. Fayed (1983) and Zaghloul (1998) noticed that the concentrations and amounts of N taken up in the different parts of wheat, maize and barley plants were represented a general function of the initial fertility status of the investigated soils which were alluvial, sandy and calcareous.

The obtained data also show that N concentrations in shoot tissue, straw and grains and its accumulation in the aboveground biomass of wheat were negatively affected by soil salinity levels in the three soil types under all P-sources (Table 3). The N concentration in wheat shoot tissue decreased from 1.876% to 1.726% and 1.614% as soil salinity levels increased from 4 to 8 and 12 dS/m, respectively. Likewise, increasing salt stress from 4 to 8 and 12 dS/m decreased grains N concentrations from 2.054% to 1.846 and 1.458%, and straw N concentrations from 0.574% to 0.494% and 0.436%, respectively. Furthermore, soil salinization induced significant ($P \leq 0.05$) decreases in N taken up in straw and grains. This is not surprising finding since an increase in Cl^- uptake and accumulation is

Table 3. Nitrogen concentrations (%) in grains, straw and its uptake (mg/pot) in the total yield of wheat plants as affected by soil types, salinity levels and fertilizer-P sources

Soil type	Soil salinity (EC_e), dS/m	Fertilizer-P sources					Fertilizer-P sources					Fertilizer-P sources				
		Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean
		Grains N concentration					Straw N concentrations					Total N uptake				
Alluvial	4	1.839	2.065	2.275	2.321	2.125	0.552	0.623	0.616	0.611	0.601	431	598	722	760	628
	8	1.655	2.132	1.972	2.231	1.997	0.428	0.487	0.568	0.548	0.508	265	455	450	496	417
	12	1.397	1.917	1.905	1.894	1.778	0.424	0.458	0.502	0.478	0.465	152	283	291	287	253
	Mean	1.630	2.038	2.051	2.149	1.967	0.468	0.523	0.562	0.546	0.525	283	445	488	514	433
Sandy	4	1.724	2.155	2.175	2.373	2.107	0.469	0.642	0.563	0.579	0.563	186	341	382	446	339
	8	1.638	1.857	1.729	1.864	1.772	0.350	0.485	0.540	0.515	0.473	39	128	132	130	107
	12	*-	*-	1.739	1.816	0.889	0.302	0.396	0.463	0.468	0.407	1	3	33	34	18
	Mean	1.121	1.337	1.881	2.017	1.589	0.374	0.508	0.522	0.521	0.481	75	157	182	203	154
Calcareous	4	1.803	1.950	1.944	2.024	1.930	0.402	0.602	0.589	0.634	0.557	297	457	455	496	426
	8	1.579	1.841	1.830	1.831	1.770	0.366	0.569	0.534	0.536	0.501	208	324	328	320	295
	12	1.521	1.808	1.719	1.778	1.707	0.345	0.469	0.463	0.467	0.436	114	212	206	222	189
	Mean	1.634	1.866	1.831	1.878	1.802	0.371	0.547	0.529	0.547	0.498	206	331	330	346	304
Grand means		1.462	1.723	1.921	2.015		0.404	0.511	0.538	0.537		188	311	722	760	
Means of soil salinity levels																
4 dS/m				2.054					0.574					464		
8 dS/m				1.846					0.494					273		
12 dS/m				1.458					0.436					153		
LSD at 0.05:																
ST				0.111					NS					3.7		
SS				0.079					0.026					1.9		
PS				0.076					0.035					2.0		
ST×SS				0.137					NS					3.3		
ST × PS				0.131					NS					3.5		
SS × PS				0.131					NS					3.5		
ST × SS × PS				0.227					NS					NS		

SP hint at superphosphate, CM denote to cattle manure, and NS is abbreviation of non-significant. * Plants failed to form grains often accompanied by a decrease in shoot-NO_3^- concentration (Grattan and Grieve, 1999 and Athar and Ashraf, 2009). Numerous of studies have shown that salinity can reduce N accumulation in plants due to one or more of the following: (1) Cl^- antagonism of NO_3^- uptake (Abid *et al.*, 2002), (2) salinity's effect on reduced water uptake (Lea-Cox and Syvertsen, 1993), (3) extreme loss of available NH_4-N via NH_3 volatilization (Tisdale *et al.*, 1985), and (4) low rates of organic N mineralization (Foth and Ellis, 1997).

There was significant ($P \leq 0.05$) interaction between soil type and salinity levels on the grains N concentrations, N uptake in grains, straw and biomass of wheat plants (Table 3). It is of interest to point out that the adverse effects of salinity stress on the concentrations and uptake of N by wheat plants were more pronounced under high salinity level (12 dS/m) in the sandy soil.

It is evident from Table 3 that N concentrations and its uptake in the different parts of wheat plants were appreciably improved by adding P compared with the control treatment (0 P), regardless of soil type and soil salinity levels. Phosphorus fertilization resulted in significant ($P \leq 0.05$) increase in N concentrations and uptake in shoot tissue, straw, and grains. The stimulatory effects of P on plant growth characters and nutrients uptake efficiency may be due to its role in enhancing root growth and enhancing metabolic processes such as photosynthesis, glycolysis and synthesis of fats, thereby enhancing nutrients absorption (Marschner, 1995 and Foth and Ellis, 1997). These results are in harmony with those obtained by Metwally *et al.* (2004).

There was significant ($P \leq 0.05$) effect between the fertilizer-P sources treatments on N concentration and its uptake. This result indicating that the studied P-sources differed in their beneficial role to alleviate adverse effects on plants grown under salinity stress. The highest values of N contents of wheat plants were obtained with the combined application of superphosphate (SP) with cattle manure (CM); SP+CM treatment; irrespective of soil type or salinity levels. Moreover, it appears that CM was more efficient P-source than SP for enhancing nutrients uptake efficiency by plants grown under salinity stress.

Effects of the interaction between P-sources, and soil type or soil salinity levels on N concentrations and uptake in the aerial parts of wheat plants were detected (Table 3). Adding fertilizer P was shown to have more improving role in enhancing N contents and its uptake in wheat plant grown in the sandy and calcareous soils compared with the alluvial soil. Also, the beneficial effects of CM as organic P-source were more noticeable under the calcareous and sandy soils compared with the alluvial one.

Phosphorus

Data in Table 4 show that the concentrations of P in the aboveground biomass of wheat plants were strongly influenced by the experimental treatments. Soil type induced significant effect on P concentrations in shoot tissue, grains and amount taken up in grains and straw. The overall values of P concentrations and uptake by wheat plants grown on the alluvial soil were significantly higher than that grown on the sandy or calcareous soils. Again, this result was not sudden since it well known that the alluvial soil is more fertile compared with either sandy or calcareous soils. It is obvious that P concentrations in shoot tissue and straw of plants grown in sandy soil were slightly higher compared with that planted on the calcareous soil. Lime-induced nutrients deficiency especially P and Fe on many crops grown in calcareous soils has been reported by numerous workers (Marschner, 1995). Halajnia *et al.* (2009) reported that after P fertilizer is added to a calcareous soil, it undergoes a series of chemical reactions with soil components that decrease its solubility (a process referred to as P-fixation). The mechanisms of P-fixation are: phosphate adsorption on clay minerals and $CaCO_3$ surfaces and precipitation of Ca-phosphates.

The results also indicate that P concentrations and uptake in the different aerial parts of wheat plant depressed significantly ($p \leq 0.05$) by salt stress (Table 4). However, the depression in P concentrations in shoot and straw due to the adverse effects of salinity does not reach the significant value. Increasing salt stress (EC_e) from slight level (4 dS/m) to high level (12 dS/m) decreased grains P concentrations from 0.29% to 0.22% and hence decreased total P uptake in the aboveground biomass from 64 to 23 mg/pot, respectively.

Table 4. Phosphorus concentrations (%) in grains, straw and its uptake (mg/pot) in the total yield of wheat plants as affected by soil types, salinity levels and fertilizer-P sources

Soil type	Soil salinity (EC_e), dS/m	Fertilizer-P sources					Fertilizer-P sources					Fertilizer-P sources				
		Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean
		Grains P concentration					Straw P concentration					Total P uptake				
Alluvial	4	0.241	0.339	0.308	0.365	0.365	0.044	0.062	0.062	0.066	0.059	53	92	94	113	88
	8	0.219	0.313	0.316	0.348	0.348	0.042	0.053	0.055	0.054	0.051	34	65	68	73	60
	12	0.190	0.292	0.290	0.289	0.289	0.042	0.049	0.047	0.049	0.047	20	41	41	42	36
	Mean	0.216	0.314	0.304	0.334	0.334	0.043	0.055	0.055	0.056	0.052	36	66	68	76	61
Sandy	4	0.221	0.327	0.317	0.304	0.304	0.047	0.052	0.062	0.053	0.054	23	49	55	56	45
	8	0.197	0.286	0.297	0.318	0.318	0.041	0.049	0.068	0.065	0.056	5	19	21	21	16
	12	*-	*-	0.274	0.282	0.282	0.038	0.054	0.053	0.053	0.049	*-	*-	5	5	3
	Mean	0.139	0.204	0.296	0.301	0.301	0.042	0.052	0.061	0.057	0.053	9	23	27	27	21
Calcareous	4	0.187	0.295	0.294	0.302	0.302	0.035	0.049	0.057	0.051	0.048	31	64	66	70	57
	8	0.161	0.284	0.283	0.300	0.300	0.039	0.051	0.058	0.049	0.049	21	47	48	49	41
	12	0.152	0.281	0.272	0.311	0.311	0.035	0.052	0.053	0.059	0.050	11	32	31	37	28
	Mean	0.166	0.286	0.283	0.304	0.304	0.036	0.051	0.056	0.053	0.049	21	48	48	52	42
Grand means		0.174	0.258	0.294	0.313		0.040	0.051	0.057	0.055		22	46	48	52	
Means of soil salinity levels																
4 dS/m				0.292					0.054					64		
8 dS/m				0.277					0.052					39		
12 dS/m				0.219					0.049					23		
LSD at 0.05:														64		
ST				0.008					NS					2.8		
SS				0.015					NS					1.9		
PS				0.012					0.007					2.3		
ST×SS				0.026					NS					3.4		
ST × PS				0.021					NS					NS		
SS × PS				0.021					NS					NS		
ST × SS × PS				0.036					NS					NS		

SP hint at superphosphate, CM denote to cattle manure, and NS is abbreviation of non-significant. * Plants failed to form grains.

Phosphate availability is reduced in saline soils not only because of ionic strength effects that reduce the activity of orthophosphate ions ($H_2PO_4^-$ and HPO_4^{2-}) but also because P concentrations in soil solution are tightly controlled by sorption processes and by the low solubility of Ca-P minerals (Lindsay, 1979). Therefore, it is understandable that P concentrations in agronomic crops decreased as salinity increased (Grattan and Grieve, 1999 and Elgharably, 2008). In many cases, tissue P concentration was reduced between 20 and 50%, yet there was no evidence of P deficiency in the crops. When plants are P deficient, they may be more sensitive to salinity. This result consist with that of Naheed *et al.* (2008) who found that P-deficient plants were more sensitive to salinity than those with adequate P and that deficient plants had a lower cellular tolerance for the accumulated ions.

Shoot, grains and straw P concentrations increased significantly ($p \leq 0.05$) with P application compared with 0 P (Table 4). The difference between organic (CM), inorganic (SP) P-sources and their mixture (SP+CM) on P concentration in shoot or straw and its uptake in straw was non-significant. However, applying of SP+CM resulted in significant increases in P concentration and uptake in grains and biomass over that induced either by single application of SP or CM. Under medium and high salinity levels in the sandy and calcareous soil the ameliorative effect of organic P-sources on P contents of wheat plants was evident. Halajnia *et al.* (2009) found that application of CM along with inorganic P increased the recovery of applied P. In general, manure application had an appreciable and different impact on the chemical fractions of P particularly in calcareous soils as P from manure gradually turned into available forms over the time. Organic sources of P are known to increase P availability more than inorganic P fertilizers and enhance efficient use of applied P fertilizer. The synergistic effect of manure application along with P fertilizer on increasing soil test P concentration was due to decreases in the precipitation rate of poorly soluble Ca phosphate by organic amendments. Consequently, P availability to plants is controlled by the application rates and forms of soluble P and the dissolution and desorption of fixed P.

Potassium

The results presented in Table 5 appear significant ($P \leq 0.05$) differences among the three soils for their effect on K concentrations in shoot tissue and its uptake by the aboveground biomass of wheat plants. On the other hand, k concentration in grain and straw was non- significant. The plants grown on the alluvial soil had higher K contents than plants grown on the sandy or calcareous soils. Also, plants grown on the alluvial soil exhibited high K concentrations in grains and straw and hence high total K uptake. However, results demonstrated that the K status was almost the same for plants grown either on the sandy or calcareous soil. The differences among the studied soils in their effect on K status of wheat plants are specific differences that go back to their mineral fabric composition.

It is evident from Table 5 that K contents of wheat plants were significantly depressed with increasing EC_e from 4 to 8 dS/m. However, increase EC_e more than 8 dS/m did not induce additional significant decreases in K concentrations in shoot tissue, straw or grains. Increasing levels of salinity decreased wheat K contents perhaps due to antagonistic effect of Ca, Mg and Na on K.

It is seemed that phosphorus counteracted the adverse effects of salinity on K absorption, and thereby K contents of shoot, grains and straw (Table 5). The similar addition of SP and CM together found to be had the superior promoting effect on K concentration and uptake compared with solitary application. Again, this finding asserts that SP+CM is more suitable P-source for wheat growing under salt stress.

Data show non-significant interactions between soil type and soil salinity levels on K contents of wheat plants with some exceptions. This is a signal to the differential ability of the studied soils to overcome noxious effects of salinity conditions.

Zinc

Results summarized in Table 6 indicate that the tested soils differ greatly in their effects on Zn concentration and accumulation by wheat plants under salinity conditions. However, there was non-significant effect of soil type on Zn concentrations in straw. The alluvial soil significantly ($p \leq 0.05$) surpassed both the sandy and calcareous soils in their effects on

Table 5. Potassium concentrations (%) in grains, straw and its uptake (mg/pot) in the total yield of wheat plants as affected by soil types, salinity levels and fertilizer-P sources

Soil type	Soil salinity (EC_e), dS/m	Fertilizer-P sources					Fertilizer-P sources					Fertilizer-P sources				
		Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean
		Grains K concentration					Straw K concentrations					Total K uptake				
Alluvial	4	0.299	0.361	0.361	0.351	0.343	2.0	2.6	2.5	2.5	2.4	282	494	511	536	456
	8	0.268	0.303	0.342	0.319	0.308	1.7	2.0	1.9	2.2	1.9	179	298	299	330	276
	12	0.247	0.284	0.315	0.293	0.285	1.7	2.0	2.0	2.1	1.9	156	217	238	241	213
	Mean	0.271	0.316	0.339	0.321	0.312	1.8	2.2	2.1	2.3	2.1	206	336	349	369	315
Sandy	4	0.307	0.326	0.335	0.339	0.327	1.7	2.3	2.3	2.3	2.1	109	213	229	233	196
	8	0.254	0.290	0.308	0.303	0.289	1.4	2.3	2.2	1.8	2.0	47	128	119	107	100
	12	*-	*-	0.256	0.248	0.126	1.3	1.9	1.8	1.8	1.7	3	12	27	30	18
	Mean	0.187	0.205	0.300	0.297	0.247	1.5	2.2	2.1	2.0	1.9	53	118	125	123	105
Calcareous	4	0.300	0.326	0.350	0.330	0.327	1.3	1.9	2.5	2.3	2.0	122	292	336	312	265
	8	0.285	0.276	0.264	0.283	0.277	1.4	1.8	2.1	2.1	1.9	105	203	228	240	194
	12	0.234	0.264	0.247	0.250	0.249	1.3	1.5	2.1	1.7	1.6	61	129	162	148	125
	Mean	0.273	0.289	0.287	0.288	0.284	1.3	1.7	2.2	2.0	1.8	96	208	242	233	195
Grand means		0.244	0.266	0.309	0.302		1.5	1.9	2.2	2.1		118	221	239	242	
		Means of soil salinity levels														
4 dS/m				0.332					2.1					305		
8 dS/m				0.291					1.9					190		
12 dS/m				0.220					1.8					119		
LSD at 0.05:																
ST				NS					NS					5.3		
SS				0.021					NS					3.0		
PS				0.021					0.13					2.4		
ST×SS				0.031					NS					NS		
ST × PS				0.036					NS					4.2		
SS × PS				0.036					NS					4.2		
ST × SS × PS				0.063					NS					NS		

SP hint at superphosphate, CM denote to cattle manure, and NS is abbreviation of non-significant. * Plants failed to form grains.

Table 6. Zinc concentrations (ppm) in grains, straw and its uptake (mg/pot) in the total yield of wheat plants as affected by soil types, salinity levels and fertilizer-P sources

Soil type	Soil salinity (EC_e), dS/m	Fertilizer-P sources					Fertilizer-P sources					Fertilizer-P sources				
		Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean	Control	SP	CM	SP+CM	Mean
		Grains Zn concentration					Straw Zn concentrations					Total Zn uptake				
Alluvial	4	43	49	48	53	48	36	41	39	41	39	1.272	1.797	1.955	2.199	1.806
	8	56	53	51	71	58	33	42	38	42	39	1.065	1.506	1.457	1.891	1.480
	12	53	56	54	51	54	39	45	39	46	42	0.764	1.116	1.101	1.114	1.024
	Mean	51	53	51	58	53	36	43	39	43	40	1.033	1.472	1.504	1.734	1.436
Sandy	4	38	41	35	44	40	37	44	47	43	43	0.537	0.870	0.911	1.077	0.849
	8	40	44	43	41	42	40	55	52	46	48	0.188	0.507	0.503	0.457	0.414
	12	*-	*-	42	47	22	39	48	44	43	43	0.010	0.029	0.119	0.134	0.073
	Mean	26	28	40	44	35	39	49	48	44	45	0.245	0.469	0.511	0.556	0.445
Calcareous	4	47	42	55	48	48	35	31	36	42	36	0.929	1.203	1.486	1.458	1.269
	8	53	53	59	56	55	31	33	30	37	32	0.792	1.071	1.176	1.174	1.053
	12	52	59	58	57	57	38	50	51	45	46	0.490	0.930	0.931	0.925	0.819
	Mean	51	51	57	54	53	35	38	39	41	38	0.737	1.068	1.198	1.186	1.047
Grand means		43	44	49	52		37	43	42	43		0.672	1.003	1.071	1.159	
							Means of soil salinity levels									
4 dS/m				45					39					1.308		
8 dS/m				52					40					0.982		
12 dS/m				44					44					0.639		
LSD at 0.05:																
ST				6.4					NS					0.243		
SS				NS					NS					0.085		
PS				4.2					5.1					0.085		
ST×SS				NS					NS					NS		
ST × PS				7.2					NS					0.148		
SS × PS				7.2					NS					0.148		
ST × SS × PS				12.6					NS					NS		

SP hint at superphosphate, CM denote to cattle manure, and NS is abbreviation of non-significant. * Plants failed to form grains.

Zn concentrations in grains and uptake in biomass. This result confirmed the previous obtained results on concentration and uptake of N, P and K, and accurately reflected the superiority of the alluvial soil as optimum medium for plant growth. It is well known that soils differ greatly in response of their exchange phase (mineral and colloidal make up) to replenishment of solution phase with a nutrient. This means that the benefit of plants from the available nutrients which in turn affect the uptake will differ strongly with soil type (Lindsay, 1979; Bohn *et al.,* 2001 and Marschner, 1995).

Irrespective of soil type, augmentation of salinity (EC_e) level induced non-significant increases in the concentrations of Zn in shoot, grains and straw of wheat plants (Table 6). However, increasing EC_e from 4 dS/m to 12 dS/m significantly decreased Zn uptake in the aboveground biomass.

Application of CM either singly or combined with SP significantly increased Zn contents of wheat plants as compared with non-fertilized ones. Moreover the antagonism between P and Zn was not observed under conditions of this study may be due to low levels of initial available soil P and Zn and the added level of P (30 mg P_2O_5/kg soil) was not so high to attain such antagonism.

Data presented in Table 6 show that the interactions between soil types, salinity levels and P-sources were flocculated and not completely clear. However, it can be noted that the maximum amount of Zn taken up in the aboveground biomass 2.199 mg/pot was recorded in alluvial soil at 4 dS/m with P-source of SP+CM, whereas the lowest one 0.01 mg/pot was found in sandy soil at 12 dS/m without addition of P.

It can be concluded that the effects of soil type, salinity, and fertilizer P-sources on wheat plant growth and its composition were generally associated with their respective roles in dry matter production, and availability of N, P, K and Zn in soils and their uptake in plants. Synergic application of inorganic and organic P fertilizers can partly alleviated adverse effects of salt stress on plants.

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دور التسميد الفوسفاتي في تخفيف التأثيرات الضارة للملوحة على القمح النامي علي أنواع تربة مختلفة

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قسم علوم الأراضى – كلية الزراعة – جامعة الزقازيق

إن الإدارة المثلي للتسميد تقنيةُ مهمةُ لتخفيف التأثيرات الضارة للملوحة على النباتات. لهذا أجريت تجربة خلال ٢٠٠٧/٢٠٠٦ لتقييم الدور المفيد للاسمدة الفوسفاتية اللا عضوية والعضوية على القمح المنمي تحت إجهاد ملحي في ثلاثة ترب فقيرة أصلاً في محتواها من الفوسفور الميسر للنبات. فقد نميت نباتات القمح صنف سخا ٩٣ على ثلاثة ترب هي: رسوبية ورملية و جيرية، تحت ثلاث مستويات ملوحة (معبراً عنها كتوصيل كهربائي لمستخلص عجينة التربة المشبعة) هي: ٤ و ٨ و١٢ ديسيسيمنز/م، مع تسميدها بكمية ثابتة من الفوسفور هي ٣٠ ملليجرام فو٢أ٥/كجم تربة مصدرها إما: سوبر فوسفات احادي أو سماد ماشية أو خليط منهما بنسبة ١:١، بجانب معاملة مقارنة (كنترول) لم تسمد بالفوسفور.

أظهرت النتائج أن القمح النامى في التربة الرملية قد تأثرت بدرجة أشد بالتأثيرات الضارة للملوحة من تلك المزروعة على التربة الرسوبية، خصوصاً عندما لم تسمد بالفوسفور، بينما تأثرت القمح النامى فى التربة الجيرية بدرجة متوسطة. كما أثر نوع التربة علي محصول الحبوب والقش وتركيز وامتصاص النتروجين، الفسفور، البوتاسيوم، والزنك في أنسجة المجموع الهوائي (الأوراق والسوق)، القش، والحبوب بشكل ملحوظ، حيث سُجلت أعلى القيم تحت ظروف التربة الرسوبية تلتها التربة الجيرية. تناقص محصول القش والحبوب وتركيز وامتصاص النتروجين، الفسفور، والبوتاسيوم معنوياً بزيادة الملوحة من المستوي المنخفض (٤ ديسيسيمنز/م) إلى المستوى العالي (١٢ ديسيسيمنز/م). وبالعكس، زيادة الاجهاد الملحي لم تؤثر في تركيز الزنك في معظم الحالات، وفي حالات قليلة أحدثت زيادة طفيفة، إلا أنها سببت زيادة معنوية في كمية الزنك الممتصة في الأجزاء الهوائية لنباتات القمح. حَسّنَ الفسفور نمو القمح تحت ظروف التربة الملحية، ومقدار هذا التأثير المفيد كان أكبر تحت الملوحة المعتدلة والعالية. كما أن الزيادات التي أحدثها التسميد الفوسفاتي في الكميات الممتصة من النتروجين، الفسفور، البوتاسيوم، والزنك كانت أكثر وضوحاً في الترب الرملية والجيرية. وظهرت فروق معنوية بين مصادر الفوسفور اللا عضوية والعضوية وخليطهم في التأثيرعلى محصول القمح وتركيز وامتصاص النتروجين، الفسفور، والبوتاسيوم، والزنك، فعندما أُضيف المصدرين معاً في صورة خليط فاق تأثيره كلا المصدرين عندما أُضيف كلٍ علي حده، وكان هذا واضحاً في كل أنواع الترب ومستويات الملوحة المختبرة.