

Soil Salinity Impact on Phosphorus Forms of Some Soils of EI-Dakhla Oasis, Egypt

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ABSTRACT: Nine surface (0-30 cm) soil samples were collected based on their salinity levels from EI-Dakhla oasis, New Valley, Egypt to investigate the effect of soil salinity level on phosphorus (P) forms. The soil samples were divided into two levels based on their content of soil salinity to non-saline samples ($EC_e < 4$ dS/m) and saline ones ($EC_e > 4$ dS/m). Seven fractions of soil P (resin-P, $NaHCO_3$ -Pi, $NaHCO_3$ -Po, NaOH-Pi, NaOH-Po, HCl-P and Residual-P) were sequentially extracted from each soil sample using the modified Hedley method. The results indicated that relative to the total P, the mean percentages of resin-P, $NaHCO_3$ -Pi, NaOH-Pi, NaOH-Po and residual-P fractions were higher in the saline soil samples ($EC_e > 4$ dS/m) than those of the non-saline ones ($EC_e < 4$ dS/m). On the other side, the mean level of HCl-P fraction was lower in the saline soil samples. So, soil salinity tends to motivate levels of labile P (resin-P, $NaHCO_3$ -Pi, $NaHCO_3$ -Po), NaOH-Po and residual-P to increase on the charge of reducing the HCl-P level. Significant positive correlations were recorded between the $NaHCO_3$ -Pi, NaOH-Pi and NaOH-Po fractions and the EC_e , Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^{-} , Cl^- , SO_4^{-2} and SAR_e of these soil samples. However, the $NaHCO_3$ -Po, HCl-P and residual P fractions were negatively correlated to the EC_e , Na^+ , Cl^- and SAR_e .

Key words: Phosphorus forms, soil salinity, EI-Dakhla Oasis, P fractionation

INTRODUCTION

EI-Dakhla Oasis is located in the southwest of New Valley governorate, western desert of Egypt, EI-Dakhla Oasis. Environmental conditions, like high speed winds and temperatures as well as salinity and drought stresses affect the crop production of such areas. Groundwater is the only available water source for irrigation in this oasis. Shallow groundwater that occurs in many areas of oasis is of a poor quality and contains enough salts to make the soils to suffer from salinity which inhibit plant growth (Hasanien *et al.*, 2010).

Soil salinity is considered as a massive problem for the irrigated agriculture. It is one of the most devastating environmental stresses, which causes major reductions in cultivated land areas as well as the crop productivity and quality of crops (Shahbaz and Ashraf, 2013). In arid and semi-arid regions, such as in the western desert of Egypt most of the soils are saline with a low agricultural potential. Inappropriate irrigation management in such areas intensifies the problem leading to secondary salinization that affects about 20% of irrigated land worldwide (Glick *et al.*, 2007). Soil salinity effect results are the complex interactions among plants morphological, physiological, and biochemical processes including seed germination, plant growth, and nutrient uptake (Akbarimoghaddam *et al.*, 2011).

The availability of soil phosphorus (P) to plants depends upon the replenishment of labile phosphorus from other P forms. So, detection of P forms is

important to estimate its status and understand the soil chemical properties that affect its behavior in soils. Various soil P fractions have different solubilities and the amount of each form depends upon the soil characteristics, such as soil chemical, physical and genesis ones (McCray *et al.*, 2012; Adegbenro *et al.*, 2013). The available nutrient balance or dynamics differs in non-saline soils from saline ones. Also, plants may suffer from nutrient absorption due to having antagonistic effect with the constituents of saline water. The interaction between salinity and nutrient uptake, including P by plants is a complex task (Nasrin *et al.*, 2016). The soil available P in saline soils is affected by the concentration and type of salts (El-Gharably, 2008). In addition, phosphorus forms in soils may be influenced by soil salinity (Domínguez *et al.*, 2010). Soluble P decreases with increasing concentrations of Ca^{+2} , but it is not affected by Na^+ salts. Also, increased Na^+ and Ca^{+2} concentrations in the soil solution may cause an increase in the soil ionic strength which may decrease the availability and uptake of P by plants due to the reduced activity of phosphate ions in highly saline substratum (Prapagar *et al.*, 2012). Hassan *et al.* (1970) reported that available P slightly increased with increasing the soil salinity due to increasing the concentrations of Cl^- and SO_4^{2-} in soil solution and lowering soil pH. On the other hand, the solubility of phosphates increases, remains unaffected or decreases depending upon the nature and added amounts of salts and presence of lime (Paliwal and Maliwal, 1971). In Gharb El-Mahooob soils, El-Dakhla Oasis, Egypt, Abd El-Rahim *et al.* (2016) obtained negative correlations between the available P and EC_e , Ca^{+2} , Mg^{+2} , Na^+ and sodium adsorption ratio (SAR_e) of the saturated soil paste extract.

The study of soil P forms is important to determine the P behavior in soils. Phosphorus fractionation is a procedure which uses a series of chemical solutions which are ordered from the lowest to the strongest in the extraction power to extract various chemical P forms (Hedley *et al.*, 1982; Tiessen and Moir, 1993).

The objective of this study is to investigate the influence of soil salinity content on soil P forms of some soils collected from of El-Dakhla Oasis and their relationship with some soil chemical constituents of these soils.

MATERIALS AND METHODS

Location and soil sampling

El-Dakhla Oasis is located in the southwest of New Valley governorate, western desert of Egypt between longitudes of $28^\circ 30' 00''$ and $29^\circ 47' 00''$ E and latitudes of $25^\circ 20' 00''$ and $26^\circ 00' 00''$ N. Nine surface soil samples (0-30 cm) were collected from the soils of this oasis to investigate the effect of the existing soil salinity on phosphorus forms in these soils (Figure 1). All soil samples were air-dried, ground, sieved through a 2 mm sieve and kept for analyses. Some physical and chemical properties of these samples are present in Tables 1 and 2. The soil samples were divided based on their soil salinity content into non-saline samples ($\text{EC}_e < 4\text{dS/m}$) and saline ones ($\text{EC}_e > 4\text{dS/m}$) according to FAO (2006).

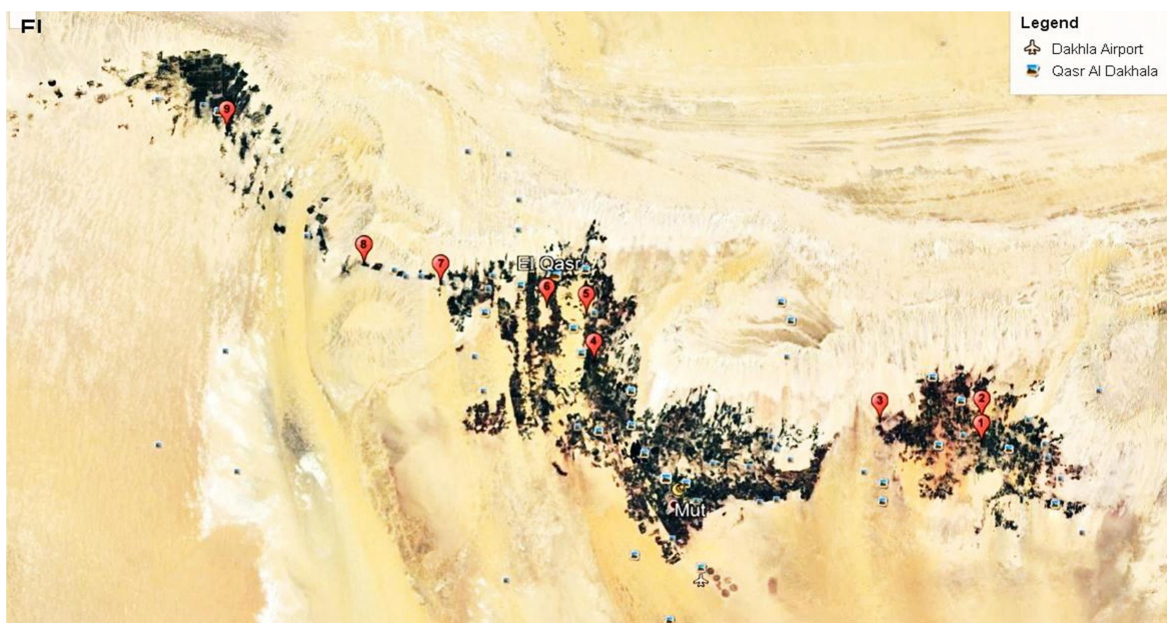


Fig. (1).A location map of the study area indicating the selected soil samples.

Table (1). Some physical properties of the tested soil samples

Sample No.	Particle-size distribution (%)			Texture*	Saturation percentage
	Sand	Silt	Clay		
1	18	13	69	C	90
2	88	3	9	LS	25
3	47	23	30	SCL	62
4	69	5	26	SCL	52
5	54	9	38	SC	76
6	52	10	38	SC	67
7	77	9	14	SL	40
8	23	54	23	SiL	93
9	40	36	24	L	77

*C=Clay, SCL=Sandy clay loam, SC=Sandy clay, SL=Sandy loam, SiL=Silt loam, L=Loam, and LS=Loamy sand.

Table (2). Some chemical properties of the tested soil samples

Sample No.	Soil pH	ECe (dS/m)	Soluble ions (mmol/kg)							CEC (cmol/kg)	CaCO ₃ (g/kg)	OM (g/kg)	SAR _e	Olsen P (mg/kg)
			HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺					
1	7.09	8.13	5.39	34.61	8.67	13.65	7.90	18.99	2.43	23.64	65.90	27.00	4.32	1.18
2	7.56	9.35	2.42	13.68	2.09	5.04	2.82	3.44	0.44	13.68	30.30	7.10	2.45	2.93
3	7.54	8.15	7.45	13.30	9.18	9.93	0.99	18.89	4.42	14.47	7.60	7.90	7.25	1.91
4	7.70	1.56	6.87	3.72	0.34	2.92	0.42	1.28	0.22	15.77	81.10	15.80	0.97	7.79
5	7.75	1.26	6.36	5.41	0.06	3.03	1.21	2.43	0.64	20.55	100.00	14.30	1.36	2.04
6	7.36	9.57	8.86	38.36	4.90	11.28	8.60	26.78	1.26	25.62	47.70	22.10	7.33	23.84
7	7.50	2.48	2.39	2.27	0.86	5.73	0.64	0.15	0.09	16.11	62.90	9.20	0.09	3.25
8	8.09	17.48	4.44	93.80	12.35	19.98	3.70	141.96	1.69	41.88	87.10	7.90	30.33	12.03
9	7.59	25.10	11.03	139	9.08	34.50	17.3	119	1.15	51.58	83.30	5.20	18.85	11.19

Soil analyses

The particle-size distribution and saturation percentage (SP) of these soil samples were estimated as described by Jackson (1973). Soil pH was measured in the suspension of soil paste using a pH meter with a glass electrode. Soil organic matter (OM) was determined using Walkley and Black method (Jackson, 1973). The calcium carbonate (CaCO_3) content was estimated using a volumetric calcium carbonate calcimeter (Nelson, 1982). The electrical conductivity of the saturated soil paste extract (EC_e) was determined using an electrical conductivity meter according to Jackson (1973). Soluble calcium (Ca^{+2}) and magnesium (Mg^{+2}) in the saturated soil paste extract were estimated using the titration method by EDTA (Ethyline-diamine tetra acetic acid) solution. However, soluble sodium (Na^+) and potassium (K^+) in this extract were determined by flame photometry method (Hesse, 1998). Also, soluble anions such as bicarbonate (HCO_3^-) and chloride (Cl^-) were determined using the titration with HCl acid (Richards, 1954) and silver nitrate solution (Jackson, 1973), respectively.

Meanwhile, soluble sulphate (SO_4^{2-}) was estimated by the turbidimetry method using a barium chloride solution (Baruah and Barthakur, 1997). The cation exchange capacity (CEC) of the soil samples was determined using the sodium acetate method as proposed by Jackson (1973). Sodium adsorption ratio (SAR_e) of the saturated soil paste extract was calculated according to Richards (1954). The soil available P was extracted using 0.5M NaHCO_3 at pH 8.5 as described by Olsen *et al.* (1954).

Soil Phosphorus Forms

A sequential extraction of soil phosphorus (P) forms was carried out on the soil samples that represent non- saline soils ($\text{EC}_e < 4$ dS/m) and saline soils ($\text{EC}_e > 4$ dS/m). The sequential fractionation of the soil P was operated using the modified Hedley method (Hedley *et al.*, 1982; Tiessen and Moir, 1993) with a minor modification for the final fraction (residual P). The sequential order of the solutions from the lowest to strongest extraction power was resin ionic exchange (Resin-Pi), 0.5 M NaHCO_3 buffered at pH 8.5 (NaHCO_3 -Pi and-Po), 0.1 M NaOH (NaOH-Pi and-Po) and 1.0 M HCl. The total P in the soil samples was extracted through the digestion with a mixture of concentrated HNO_3 and HClO_4 acids followed by adding HF to get rid of silicates as described by Krudsen *et al.* (1982). The residual P fraction was estimated from the difference between the total P and the sum of other fractions.

RESULTS AND DISCUSSION

Soil physical and chemical properties play an important role in translocation and behavior of nutrients among their various forms in soils (Abd El-Rahim, 2016). Soil phosphorus is considered as a potential nutrient in many arid and semiarid regions. In most cases, saline soils occur in arid and semiarid regions where the climate encourages the soluble salts to accumulate in soils. Phosphorus forms may

be affected by some soil properties, such as soil salinity (Adegbenro *et al.*, 2013). Therefore, it is vital to investigate the salinity content effect of El-Dakhla Oasis soils on the various phosphorus forms and pools that occur in these soils to evaluate its P nutrition status. The P distribution of different P fractions and its percentage of the total P in the non-saline (<4 dS/m) and saline (> 4 dS/m) soil samples are shown in Tables 3 and 4, respectively, and illustrated in Figure 2.

On the average basis, the non-saline soil samples exhibit P levels of the resin-P, NaHCO₃-Pi, NaHCO₃-Po, NaOH-Pi, NaOH-Po, HCl-P and residual P fractions of 2.64, 4.97, 4.18, 9.52, 15.46, 563.41 and 1119.17 mg/ kg soil, respectively. These respective fractions have mean P levels representing 0.16, 0.32, 0.21, 0.64, 0.81, 30.68 and 67.18% of the mean total P (1719.33mg/kg soil). Therefore, the P level of the non-saline soil samples could be ranked in the descending order of Residual P > HCl-P > NaOH-Po > NaOH-Pi > NaHCO₃-Pi > NaHCO₃-Po > Resin-P fractions. On the other side, the mean P levels of the resin-P, NaHCO₃-Pi, NaHCO₃-Po, NaOH-Pi, NaOH-Po, HCl-P and residual-P fractions of the saline (>4 dS/m) soil samples are 4.30, 7.70, 3.01, 31.46, 20.53, 269.08 and 1103.59 mg/ kg soil, respectively. The mean level P percentages of these respective P fractions of the saline soil samples are 0.32, 0.58, 0.22, 2.44, 1.56, 19.23 and 75.65% of the mean total P (1439.67 g/ kg soil). It decreases in the order of residual P > HCl-P > NaOH-Pi > NaOH-Po > NaHCO₃-Pi > Resin-P > NaHCO₃-Po fractions.

It is clear that the residual P fraction dominates in these soil samples that illustrate the soil salinity status and it represents, on the mean basis, about 67 to 76% of the total P. It is followed by the HCl-P fraction that depicts approximately 19 to 31% of the total P. The other P fractions assign very low level of the total P. Each of these fractions contributes about less than 2.5% of the total P. The mean concentration of the resin-P increases from 2.64 mg/kg (0.16% of the mean level of total P) in the non-saline samples to 4.30 mg/kg (0.32% of the mean total P) in the saline soil samples. It means that the soil salinity could result in an increase in the resin-P. The resin-P level is significantly positively correlated to the EC_e of these soil samples ($r=0.750^{**}$). In addition, it is significantly and positively correlated to Ca⁺², Mg⁺², Na⁺, K⁺, HCO₃⁻, Cl⁻, and SO₄⁻² ions as well as SAR_e with r values of 0.729^{**}, 0.612^{**}, 0.677^{**}, 0.501^{**}, 0.552^{**}, 0.692^{**}, 0.785^{**} and 0.699^{**}, respectively (Table 5). High soil salinity means high concentrations of anions such as HCO₃⁻, Cl⁻ and SO₄⁻² that are able to replace phosphate anions on the soil exchange sites (Helyar *et al.*, 1976). Also, high Na⁺ ions and SAR_e values can result in high solubility of sodium phosphates. Sodium ions that dominate in the soil solution of the saline soils can replace the exchangeable Ca⁺² on the soil particle surfaces allowing P to bind to these surfaces to release in soil solution (Curtin *et al.*, 1992). The double layer of the clay particles may expand in the soil solution of high Na⁺ concentrations leading to block phosphate anions from approaching clay surfaces and limit P sorption (Rimmer *et al.*, 1992). Amin (2008) showed significant, positive correlations between the resin-P of the surface layer in Assiut soils and Ca⁺², HCO₃⁻, and Olsen-P with r values of 0.287^{*}, 0.397^{**} and 0.640^{**}, respectively. On the mean basis, the Pi level extracted with NaHCO₃ increases

from 4.97 mg/kg in the non-saline soil samples to 7.70 in saline samples (Table 3). It increases from 0.32% of the mean total P in the non-saline samples to 0.58% in the saline ones (Table 4). However, the mean $\text{NaHCO}_3\text{-Po}$ decreases from 4.18 mg/kg in the non-saline samples to 3.01 mg/kg in the saline ones. Meanwhile, as percentage of the mean total P, it is not affected by the soil salinity (Figure. 2).

Significant positive correlations were found between the $\text{NaHCO}_3\text{-Pi}$ and the EC_e , Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , Cl^- , SO_4^{-2} and SAR_e values of these soil samples with r values of 0.858**, 0.910**, 0.742**, 0.887**, 0.401**, 0.908**, 0.783** and 0.837**, respectively (Table 5). However, the $\text{NaHCO}_3\text{-Po}$ is insignificantly and negatively correlated to the EC_e , Na^+ , Cl^- and SAR_e with r values of -0.081, -0.201, -0.089 and -0.233, respectively. The $\text{NaHCO}_3\text{-Pi}$ of surface soil samples of Assiut governorate was found to vary from 3.60 to 86.00 mg/kg with an average of 30.16 mg/kg, representing 0.21 to 3.49% with an average of 0.55% of the total P. It was significantly and positively correlated to the EC_e , HCO_3^- and Ca^{+2} with r values of 0.325**, 0.412** and 0.369**, respectively (Amin, 2008). On the other hand, the $\text{NaHCO}_3\text{-Po}$ of Assiut soils differed from 0.03 to 4.27% of the total P but it was significantly and positively correlated to the soluble Ca^{+2} content (Amin, 2008). Cross and Schlesinger (2001) found that the $\text{NaHCO}_3\text{-Po}$ of grassland soils was positively correlated to Ca^{+2} , SO_4^{-2} and Cl^- ($r=0.258$, 0.254 and 0.400 , respectively). In shrub land soils, it was negatively correlated to Ca^{+2} , Mg^{+2} and Na^+ ($r=-0.280$, -0.078 and $r=-0.197$, respectively) and positively correlated to Cl^- and SO_4^{-2} ($r=0.488$ and 0.062 , respectively).

Concerning the mean labile P (resin-P, $\text{NaHCO}_3\text{-Pi}$ and $\text{NaHCO}_3\text{-Po}$), it increased from 11.79 mg/kg (0.23% of the mean total P) in the non-saline soil samples to 15.01 mg/kg (0.37% of the mean total P) in the saline samples. Although, the amount of labile P in these samples increases with the soil salinity, Domínguez *et al.* (2010) reported that the salinity might affect the P form and dynamics in soils. Curtin *et al.* (1992) also indicated that the labile P increased with increasing Na^+ concentration in soil solution. Helyar *et al.* (1976) found that HCO_3^- and Cl^- were the only anions that might compete with orthophosphate anions for the soil adsorption sites. Both mean values of NaOH-Pi and Po of these soils increase from 9.52 and 15.46 mg/kg, respectively, in the non-saline (< 4 dS/m) samples to 31.46 and 20.53 mg/kg, respectively, in the saline (>4 dS/m) ones (Table 3). As percentages of the mean total P, these respective P fractions increase from 0.64 and 0.81%, respectively, in the non-saline samples to 2.44 and 1.56%, respectively, in the saline ones (Table 4).

The NaOH -extractable inorganic P is positively correlated to the EC_e , Ca^{+2} , Mg^{+2} , Na^+ , K^+ , HCO_3^- , Cl^- , SO_4^{-2} and SAR_e values with r values of 0.871**, 0.930**, 0.774**, 0.831**, 0.452*, 0.631*, 0.887**, 0.867** and 0.790**, respectively. Also, the NaOH-Po is positively correlated to the EC_e , Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , Cl^- , SO_4^{-2} and SAR_e with r values of 0.518*, 0.617**, 0.650**, 0.471, 0.362*, 0.283*, 0.554*, 0.710** and 0.450*, respectively (Table 5).

Table (3). Distribution of various P fractions and the total P in the non-saline (<4 dS/m) and saline (> 4 dS/m) of investigated soil samples

EC _e (dS/m)	Sample No.	Texture	EC _e (dS/m)	P fraction (mg/kg)							Residual- P	Total P (mg/kg)
				Resin- P	NaOH- Po	NaOH- Pi	NaHCO ₃ - Po	NaHCO ₃ - Pi	HCL- P			
<4	4	SCL	1.56	3.25	5.28	6.27	11.02	29.54	848.21	1135.64	2039.21	
	5	SC	1.26	2.53	4.82	5.54	6.36	13.33	634.29	1404.04	2070.91	
	7	SL	2.48	2.14	4.81	0.73	11.18	3.51	207.72	817.83	1047.92	
	Mean		1.77	2.64	4.97	4.18	9.52	15.46	563.41	1119.17	1719.35	
>4	1	C	8.13	2.87	6.81	3.40	56.57	43.59	276.85	828.67	1218.76	
	2	LS	9.35	4.09	5.68	4.16	10.27	1.50	353.20	1922.22	2301.12	
	3	SCL	8.15	4.41	5.08	4.65	15.71	11.82	324.94	949.63	1316.24	
	6	SC	9.57	6.03	9.16	1.71	42.71	44.40	269.53	1149.77	1523.31	
	8	Silt L	17.48	4.36	10.09	1.23	33.72	12.68	149.98	1004.15	1216.21	
	9	L	25.10	4.05	9.37	2.89	29.77	9.19	239.98	767.08	1062.33	
	Mean		12.96	4.30	7.70	3.01	31.46	20.53	269.08	1103.59	1439.67	

Table (4). Distribution of various P fractions as percentages of the total P in non-saline (EC_e < 4 dS/m) and saline (EC_e >4 dS/m soil samples.

EC _e (dS/m)	Sample No.	Texture	EC _e (dS/m)	P fraction (%)						
				Resin- P	NaOH-Po	NaOH-Pi	NaHCO ₃ - Po	NaHCO ₃ -Pi	HCL-P	Residual-P
<4	4	SCL	1.56	0.16	0.26	0.31	0.54	1.45	41.6	55.68
	5	SC	1.26	0.12	0.23	0.27	0.31	0.64	30.63	67.8
	7	SL	2.48	0.2	0.46	0.07	1.07	0.33	19.82	78.05
	Mean		1.77	0.16	0.32	0.21	0.64	0.81	30.68	67.18
>4	1	C	8.13	0.24	0.56	0.28	4.64	3.58	22.71	67.99
	2	LS	9.35	0.18	0.25	0.18	0.45	0.07	15.35	83.52
	3	SCL	8.15	0.34	0.39	0.35	1.19	0.9	24.69	72.14
	6	SC	9.57	0.4	0.6	0.11	2.8	2.91	17.69	75.49
	8	Silt L	17.48	0.36	0.83	0.1	2.77	1.04	12.33	82.57
	9	L	25.10	0.38	0.88	0.27	2.8	0.87	22.59	72.21
	Mean		12.96	0.32	0.58	0.21	2.44	1.56	19.23	75.66

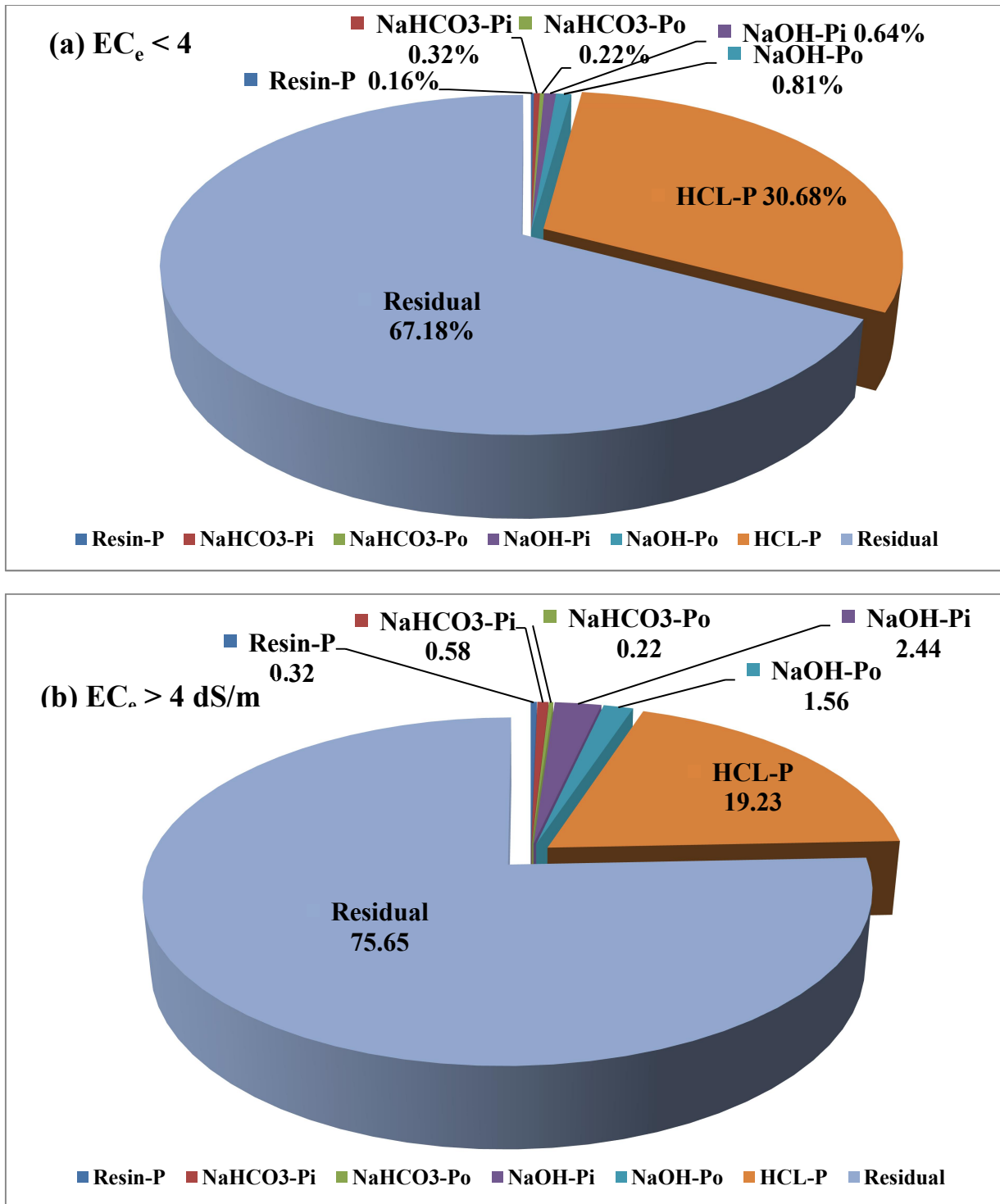


Fig (2). Distribution of various P fractions as a mean percentage of the mean total P in non- saline (<4 dS/m) (a) and saline (> 4 dS/m) (b) studied soil samples

Table (5). Correlation coefficients (r) of soil phosphorus fractions with soil salinity (EC_e), soluble ions, and sodium adsorption ratio (SAR_e) of the soil samples

Property	EC _e	Ca ⁺²	Mg ⁺²	Na ⁺	K ⁺	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	SAR _e
Resin-P	0.750**	0.729**	0.612**	0.677**	0.501**	0.552**	0.692**	0.785**	0.699**
NaHCO ₃ -Pi	0.858**	0.910**	0.742**	0.887**	0.186	0.401**	0.908**	0.783**	0.837**
NaHCO ₃ -Po	-0.081	0.003	0.035	-0.201	0.457*	0.455*	-0.089	0.047	-0.233
NaOH-Pi	0.871**	0.930**	0.774**	0.831**	0.452*	0.631*	0.887**	0.867**	0.790**
NaOH-Po	0.518*	0.617**	0.650**	0.471	0.362*	0.283*	0.554*	0.710**	0.450*
HCL-P	0.000	0.113	0.339	-0.036	0.289	0.322	0.058	0.297	-0.019
Residual	-0.510	-0.361	-0.259	-0.441	-0.142	0.298	-0.379	-0.498	-0.497
Total P	0.401	0.213	0.077	0.345	0.027	-0.423	0.252	0.315	0.405*

Amin (2008) found no correlations between both NaOH-Pi and NaOH-Po and the salinity (EC_e) of Assiut soils. However, the NaOH-Po was only positively correlated to the Ca⁺² concentration (r=0.314**) of these soils. Cross and Schlesinger (2001) recorded a positive correlation between the NaOH-Po and Ca⁺², Mg⁺² and Na⁺ with r values of 0.314, 0.212 and 0.460, respectively and a negative correlation with Cl⁻ (r=-0.220) in grassland soils. However, in shrubland soils, they found that the NaOH-Po was negatively correlated to Ca⁺², Mg⁺² and Na⁺ (r=-0.532, -0.275 and -0.300, respectively) and positively correlated to Cl⁻ (r=0.387). However, Curtin *et al.* (1992) showed that Na⁺ concentrations did not affect the moderately labile P (NaOH-extractable P) in soil.

The mean level of HCl-extractable P decreases from 563.41 mg/kg in the non-saline soil samples to 269.08 mg/kg in the saline ones (Table 3). Meanwhile, it increases from 30.38% of the mean total P in the non-saline soil samples to 19.23% in the saline ones (Figure 2). The results show that the HCl-P is not significantly correlated either to the EC_e or other ions of these soil samples. Similar results were reported by Amin (2008) in soils of Assiut. However, Bayoumi *et al* (1997) indicated that the Ca-P content increased with increasing the soil solution salinity and sodicity. This effect may be as a result of dissolution of other P forms due to the salinity. The mean level of non-occluded P (NaOH-Pi, NaOH-Po and HCl-P) of the studied samples decreases from 588.39 mg/kg in the non-saline samples to 321.07 mg/kg in the saline ones. At the same time, it decreases from 32.13% of the mean total P in the non-saline samples to 23.23% in the saline samples.

The average level of residual (occluded) P of the investigated soils slightly decreases from 1119.17mg/kg in the non-saline samples to 1103.59 g/kg in the saline ones (Table 4). Relative to the mean total P, it increases from 67.18% in the non-saline samples to 75.65% in the saline ones. Insignificantly negative correlations are found between the residual P and the EC_e, Ca⁺², Mg⁺², Na⁺, K⁺, Cl⁻, SO₄⁻² and SAR_e with r values of -0.510, -0.361, -0.259, -0.441, -0.142, -0.379, -

0.498 and -0.497, respectively. However, the residual P is positively correlated to HCO_3^- ($r=0.298$).

The mean total P of these soils decreases from 1719.35 mg/kg in the non-saline samples to 1439.67mg/kg in the saline ones. Soil salinity may cause some P forms to be solubilized and lost by leaching resulting in lower total soil P levels. The mean total P is negatively correlated to HCO_3^- ($r=-0.423$). However, it was positively correlated to the EC_e , Ca^{+2} , Mg^{+2} , Na^+ , K^+ , Cl^- , SO_4^{-2} and SAR_e with r values of 0.401, 0.213, 0.077, 0.345, 0.027, 0.252, 0.315 and 0.405, respectively. In general, soil salinity causes an increase in levels of labile P (resin-P, $\text{NaHCO}_3\text{-Pi}$ and $\text{NaHCO}_3\text{-Po}$), NaOH-Pi , NaOH-Po and Residual-P on the charge of decreasing the HCl-P level.

CONCLUSION

It is concluded that the mean levels of resin-P, $\text{NaHCO}_3\text{-Pi}$, NaOH-Pi , NaOH-Po and residual P fractions of the tested soil samples were higher in the saline soil samples ($\text{EC}_e > 4$ dS/m) compared to those of the non-saline ones ($\text{EC}_e < 4$ dS/m). On the other side, the mean level of the HCl-P fraction was lower in the saline soil samples. Significant positive correlations were obtained between the $\text{NaHCO}_3\text{-Pi}$, NaOH-Pi and NaOH-Po and the EC_e , Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , Cl^- , SO_4^{-2} and SAR_e of these soil samples, while $\text{NaHCO}_3\text{-Po}$, HCl-P and Residual P fractions were negatively correlated with EC_e , Na^+ , Cl^- and SAR_e . The mean total P of these soils decreases from 1719.35mg/kg in the non-saline samples to 1439.67mg/kg in the saline ones.

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المخلص العربي

تأثير ملحية التربة على صور الفوسفور في بعض أراضي واحة الداخلة - مصر

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تم جمع تسع عينات تربة سطحية (صفر - 30 سم) من أراضي واحة الداخلة بالوادى الجديد وفقا لمستوى ملوحة التربة ، لدراسة تأثير مستوى ملوحة التربة على صور الفوسفور في التربة. تم تقسيم عينات التربة تبعاً لمحتواها من الأملاح الى مستويين (أراضي غير ملحية $EC_e < 4$ dS/m وأراضي ملحية $EC_e > 4$). كما تم إجراء استخلاص متعاقب لسبعة صور من الفوسفور في هذه العينات وهي: $NaHCO_3-Pi$ ، $NaHCO_3-Po$ ، $Resin-P$ ، $NaOH-Pi$ ، $NaOH-Po$ ، $HCl-P$ ، $Residual-P$ وذلك تبعاً لطريقة Hedley المعدلة. أوضحت النتائج ان مستويات صور $NaHCO_3-Pi$ ، $Resin-P$ ، $NaOH-Pi$ ، $NaOH-Po$ ، $Residual-P$ كانت أعلى في العينات الملحية عنها في العينات غير الملحية. وعلى الجانب الأخر كانت الصورة $HCl-P$ منخفضة في العينات الملحية مما يدل على أن ملوحة التربة تؤدي الى زيادة مستويات الصور $NaHCO_3-Pi$ ، $Resin-P$ ، $NaOH-Pi$ ، $NaOH-Po$ ، $NaHCO_3-Po$ ، $Residual-P$ ، $HCl-P$ وذلك على حساب خفض مستوى صور $HCl-P$. كما أوضحت النتائج أنه يوجد ارتباط معنوي موجب بين صور $NaOH-Pi$ ، $NaOH-Po$ ، $NaHCO_3-Pi$ ومحتوى التربة من الأملاح (EC_e) ونسبة الصوديوم المدمص وكذلك ايونات الكالسيوم والماغنسيوم والصوديوم والبيكربونات والكلوريد والكبريتات ، بينما يوجد ارتباط معنوي سالب بين صور $HCl-P$ ، $NaHCO_3-Po$ ، $Residual-P$ وملوحة التربة (EC_e) و SAR_e و ايونات الصوديوم والكلوريد.