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Available Phosphorus Assessment of Gharb El-Mawhoob Soils, El-Dakhla Oasis, Egypt

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Abstract

Thirty-four soil samples were collected from Garb El-Mawhob soils, northwest of El-Dakhla oasis, New Valley governorate, Egypt to evaluate the soil available phosphorus and its relation with the properties of these soils. These samples were taken from the surface (0-30 cm) and subsurface layers (30- 60 cm) of 17 soil profiles covered the study area. Most of the soil samples had a texture of loamy sand, sandy clay loam and clay. In most cases, the studied soils showed mild alkaline pH (7.4 to 7.8) values. The electrical conductively (EC_e) and $CaCO_3$ of these soils varied from low to high levels and ranged from 1.05 to 163 dS/m and from 2.2 to 57.58%, respectively. The soil organic matter content differed from 0.08 to 2.27%. Also, the soluble cations and anions in most of the studied soils followed the order of Ca^{+2} >Na^{+}> Mg^{+2} > K^{+} and Cl^{-} > $SO_4^{=}$ > HCO_3^{-}, respectively. The cation exchange capacity (CEC) and sodium adsorption ratio (SAR_e) of these soils were ranged from 6.58 to 57.49 cmolc⊕/kg and from 0.11 to 45.18%, respectively.

The $NaHCO_3$-extractable soil phosphorus of these soils varied from 2.25 to 65.35 mg/kg in the surface layer and from 3.34 to 24.49 mg/kg in the subsurface one. In general, about 50% of the studied soil samples had a low level of available P (< 6 mg/kg), 24% of them showed a medium level (6 -10 mg/kg) and 26% of them contained a high level of available P (>10 mg/kg). Moreover, the studied soil samples that had clay and clay loam textures contained a high level of available P than those having other textures. The available P showed highly significant positively correlation, with some soil properties, such as OM, HCO_3^{-}, CEC and silt contents, while it was negatively correlated with EC_e, Na^{+},$CaCO_3$ and Ca^{+2}.

Keywords: Available phosphorus, soil physical-chemical properties, El-Dakhla soils.

1. Introduction

Phosphorous (P) is one of the most important macronutrients. It is often the potential limiting nutrient in many arid and semiarid regions (Zhao *et al.,* 2008). Plants absorb phosphorus mainly as the phosphate forms of $H_2PO_4^{-}$ and HPO_4^{2-}. However, soil solution contains very low levels of these forms in spite of the great soil total content of P. The large number of methods to evaluate the available phosphorus indicates the complexity of this nutrient in the soil, mainly due to the strong interaction with soil colloids and other elements which are present in soil solution (Silva and van Raij, 1999). Phosphorus adsorbed on soil colloids also represents a readily extractable form that held on the surface of soil components. It is considered a part of the P pools in soils. It is in an equilibrium with P in the soil solution and can be readily transferred to the soil solution when P concentration in the latter is lowered due to P uptake by plant roots (Sanyal *et al.,* 2015). The availability of soil phosphorus is governed by large number of soil and crop factors, such as soil pH, calcium carbonate ($CaCO_3$), salinity (EC) and soil organic matter content (SOM), as well as soil physical properties and biological activities which also affect soil fertility (Abd El-Galil and Ibrahim, 2001; Khalil *et al.,* 2004). The available P in arid and semi-arid soils can be fixed as calcium phosphate form duo to presence of Ca^{2+} and $CaCO_3$ in high amounts. Soil pH can affect P availability through the competition between OH^- and $H_2PO_4^{-2}$ or HPO_4^- for bonding sites, greater microbial activity at neutral pH levels and Ca-P mineral precipitation at pH levels above 7. The solubility of phosphorus is restricted by reactions with aluminium (Al) and iron (Fe) oxides/hydroxides at low pH and calcium (Ca) and magnesium (Mg) compounds at high pH. The ideal soil pH values for P availability are between 6 and 7.5, while pH values below 5.5 and between 7.5 to 8.5 limit P availability to plants due to the fixation by these elements (Follett *et al.*, 1981; Tisdale *et al.,* 1997). Chad *et al.* (1991) reported that the available P significantly decreased with increasing of soil pH but it increased with an increase in the organic carbon, cation exchange capacity (CEC) and clay content.

Organic carbon is the main electron donor which it influences the release of P during organic matter decomposition by micro organisms (Scalenghe *et al.,* 2002). Moreover, some scientists observed that P availability increased with adding organic matter to calcareous soils. Organic acids that are produced from organic matter decomposition help to dissolve the rock phosphate and increases its availability (Lotfollahi *et al.,* 2001).

This study aims to estimate the available P in Gharb El-Mawhoob soils, El-Dakhla oasis, New valley governorate, Egypt as well as its relations with the properties of those soil.

2- Materials and Methods

2.1 Study area

The study area is located in Gharb El-Mawhoob region (longitude 28º 19` 42‟and 28º 59` 23‟E and latitude 25º 45` 06‟ and 25º 53`34‟N) northwest of El-Dakhla oasis, New Valley governorate, Egypt. Nine transects containing 17 soil profiles were designated to represent the study area (Fig. 1). Each soil profile was situated using the Global Position System (GPS) as shown in Table (1). The distance between each two consequent transect profiles was 5 to 7 km.

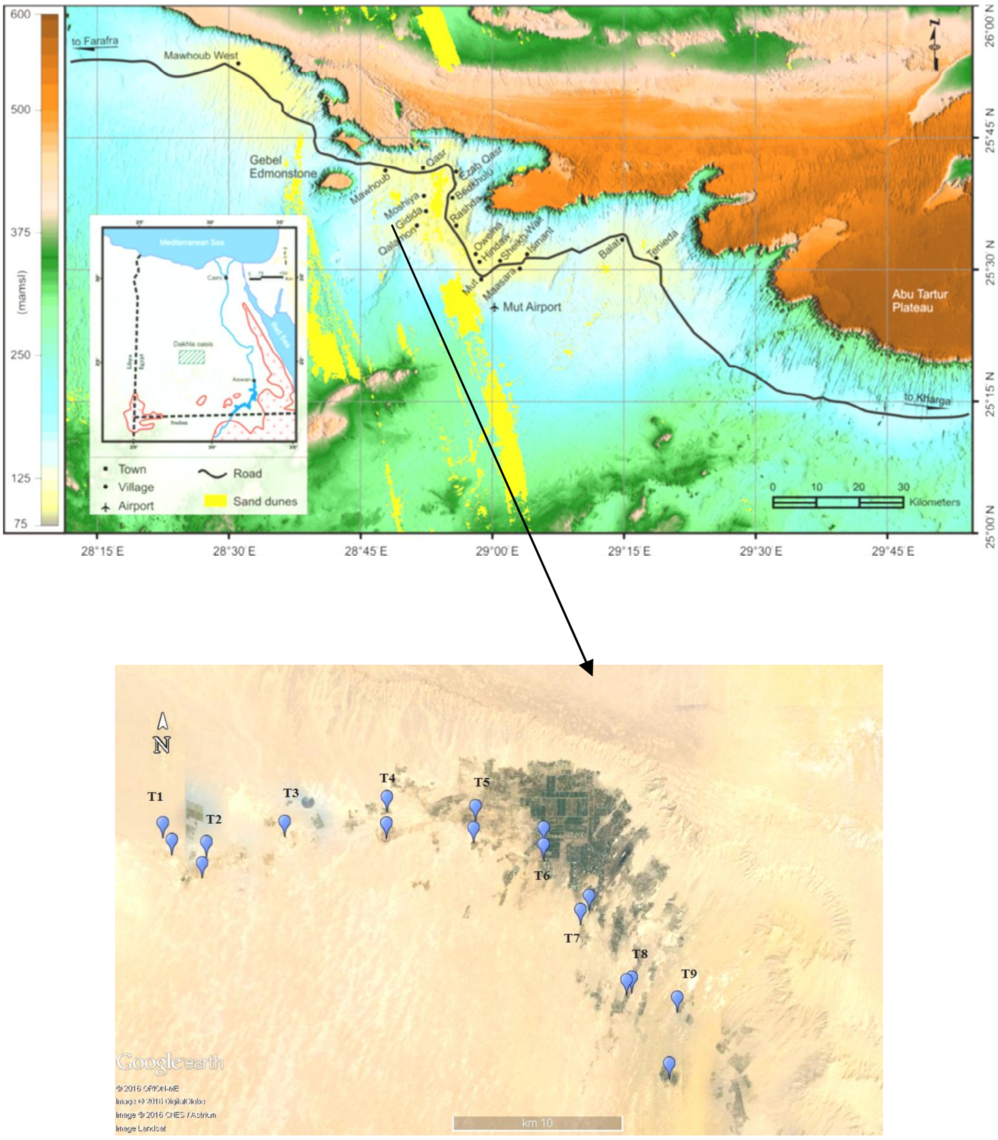

Figure 1: A location map of the study area indicating the selected transects.

Table 1. Location and land use of the studied soil profiles

Transect	Profile	Depth (cm)	Location Latitude N	Location Longitude E	Land use
T1	1	0 - 30	25° 52′ 44″	28° 19′ 23″	Clover
		30 - 60			
	2	0 - 30	25° 52′ 12″	28° 19′ 42″	Lemon and Orange orchards with hard band in the subsurface layer
		30 - 60			
T2	3	0 - 30	25° 51′ 28″	28° 20′ 46″	Date palm orchard with hard band in the subsurface layer and died trees
		30 - 60			
	4	0 - 30	25° 52′ 58″	28° 20′ 55″	Non cultivated area with salts on the soil surface
		30 - 60			
T3	5	0 - 30	25° 52′ 47″	28° 23′ 40″	Clover with shell layer in the subsurface layer and groundwater down 22m
		30 - 60			
T4	6	0 - 30	25° 53′ 34″	28° 27′ 16″	Wheat + Clover
		30 - 60			
	7	0 - 30	25° 53′ 44″	28° 27′ 15″	Non-cultivated
		30 - 60			
T5	8	0 - 30	25° 53′ 17″	28° 30′ 23″	Date palm orchard and clover
		30 - 60			
	9	0 - 30	25° 52′ 35″	28° 30′ 19″	Wheat
		30 - 60			

Table 1. Continued

Transect	Profile	Soil depth (cm)	Location Latitude N	Location Longitude E	Land use
T6	10	0 - 30	25° 52′ 36″	28° 32′ 47″	Clover
		30 - 60			
	11	0 - 30	25° 52′ 04″	28° 32′ 47″	Date palm orchard and clover
		30 - 60			
T7	12	0 - 30	25° 50′ 26″	28° 34′ 23″	Wheat
		30 - 60			
	13	0 - 30	25° 49′ 59″	28° 34′ 05″	Non cultivated
		30 - 60			
T8	14	0 - 30	25° 47′ 50″	28° 35′ 53″	Clover
		30 - 60			
	15	0 - 30	25° 47′ 45″	28° 35′ 42″	Wheat
		30 - 60			
T9	16	0 - 30	25° 47′ 12″	28° 37′ 29″	Clover + Wheat
		30 - 60			
	17	0 - 30	25° 45′ 06″	28° 37′ 12″	Date palm and Clover
		30 - 60			

2.2 Soil sampling

Thirty-four soil samples were collected from these soil profiles involving surface (0-30 cm) and subsurface (30-60 cm) soil layers to assess the available P level in these soils and show the relationship with the properties of these soils. Most of these samples were taken from cultivated soils. All soil samples were air-dried, ground, sieved through a 2 mm sieve and then, kept for analyses.

2.3 Soil analyses

The particle size distribution of the soil samples was determined by the international pipette method (Jackson, 1973). The saturation percentage (SP) was estimated as described by Hesse (1998). Soil pH was measured in a 1:2.5 of soil to water suspension using pH meter with a glass electrode. Soil organic matter was determined using Walkley and Black method (Jackson, 1973). Total calcium carbonate was estimated using a volumetric calcium carbonate calcimeter (Nelson, 1982). Electrical conductivity (EC_e) was measured in the saturated soil paste extract using an electrical conductivity meter according to Jackson (1973). Soluble calcium (Ca^{+2}) and magnesium (Mg^{+2}) in the saturated soil paste extract were determined using the titration method by EDTA (ethylinediamine tetra acetic acid) solution. Soluble sodium (Na^+) and potassium (K^+) in this extract were determined by flame photometry method (Hesse, 1998). Soluble bicarbonate (HCO_3^-) was determined titrimetrically using HCl acid according to Richards (1954). Soluble chloride (Cl^-) was titrated using a silver nitrate solution (Jackson, 1973). Soluble sulphate (SO_4^{2-}) was estimated by the turbidimetry method using a barium chloride solution (Baruah and Barthakur, 1997). Cation exchange capacity (CEC) was determined using the sodium acetate method as proposed by Jackson (1973). Sodium adsorption ratio (SARe) of the saturated soil paste extract was calculated using the following equation:

$$SAR_e = \frac{[Na]}{\sqrt{\frac{[Ca]+[Mg]}{2}}}$$

Where: Na^+, Ca^{+2}, and Mg^{+2} are concentrations in the saturated soil paste extract in m mol per litter (mmol/l).

The soil available P was extracted using 0.5M $NaHCO_3$ at pH 8.5 as described by Olsen *et al.* (1954), and calorimetrically determined using the chlorostanous phosphomolybdic acid method (Jackson, 1973).

3- Results and Discussion

3.1 Characterization of the studied soils.

Some physical and chemical properties of the investigated soil samples are present in Tables (2) and (3).

Particle size distribution

About 41.2% of the soil samples had a clay content that was higher than 30%. The highest clay content (48, 46%) was recorded in soil profiles 16 and 17 of transect 9 in both surface and subsurface layers (Table 2). On the other hand, the lower clay content (6-16%) was found in profiles 1, 2, 4, 6, 7 and 8. Furthermore, the clay content often increased with depth. Generally, some soil profiles (10, 11, 12 and 13) possessed a relatively high silt content. So, the texture class of these soils varied from loamy sand to clay. Different texture classes were present including loamy sand, sandy loam, loam, sandy clay loam, clay loam, sandy clay and clay. In most of the studied soil profiles (11 of 17 profiles), the soil texture did not change with depth. These results may be attributed to the nature of the soil parent materials which are sedimentary rocks (Adeloju *et al.,* 2016).

Table 2. Some physical and chemical properties of studied soil samples

Transect	Profile	Depth (cm)	Particle-size distribution (%)			Soil texture	Saturation percentage (%)	pH (1:2.5)	$CaCO_3$ %	Organic matter %
			Sand	Silt	Clay					
T1	1	0 - 30	86	7	7	Loamy Sand	29	7.45	2.20	0.28
		30 - 50	82	8	9	Loamy Sand	28	7.79	21.29	0.45
	2	0 - 30	85	6	8	Loamy Sand	28	7.85	17.27	0.28
		30 - 60	83	8	10	Loamy Sand	33	7.90	15.91	0.28
T2	3	0 - 30	62	17	20	Sandy Clay Loam	49	7.63	18.94	0.42
		30 - 60	59	16	25	Sandy Clay Loam	50	7.50	18.56	0.72
	4	0 - 30	74	11	16	Sandy Loam	34	7.56	36.36	1.29
		30 - 60	73	22	6	Sandy Loam	54	7.96	50.15	0.35
T3	5	0 - 30	75	7	18	Sandy Loam	36	7.53	36.36	0.82
		30 - 60	49	20	31	Sandy Clay Loam	49	7.65	57.58	0.21
T4	6	0 - 30	83	10	7	Loamy sand	46	7.58	17.73	1.60
		30 - 60	81	12	7	Loamy Sand	37	7.53	22.65	0.25
	7	0 - 30	80	10	10	Sandy Loam	31	7.78	19.92	0.21
		30 - 60	80	12	8	Loamy Sand	41	7.88	21.52	0.21
T5	8	0 - 30	81	10	9	Loamy Sand	37	8.03	39.39	0.11
		30 - 60	86	7	7	Loamy Sand	34	7.93	43.48	0.55
	9	0 - 30	58	14	28	Sandy Clay Loam	65	7.80	20.00	0.82
		30 - 60	54	14	32	Sandy Clay Loam	65	7.91	18.03	0.38

Table 2. **Continued**

Tran-sect	Profile	Depth (cm)	Particle-size distribution (%)			Soil texture	Saturation percentage (%)	pH (1:2.5)	$CaCO_3$ (%)	Organic matter (%)
			Sand	Silt	clay					
T6	10	0 - 30	37	33	30	Clay Loam	96	7.80	9.55	2.03
		30 - 60	17	38	45	Clay	92	7.80	10.61	1.23
	11	0 - 30	43	30	27	Clay Loam	111	7.64	7.73	1.60
		30 - 60	37	27	36	Clay Loam	115	7.44	3.79	2.17
T7	12	0 - 30	35	33	32	Clay Loam	90	7.80	6.82	1.12
		30 - 60	23	33	44	Clay	94	7.64	7.73	0.69
	13	0 - 30	40	36	24	Loam	77	7.59	8.33	0.51
		30 - 60	34	36	29	Clay Loam	71	7.52	8.18	0.62
T8	14	0 - 30	46	24	30	Sandy Clay Loam	67	7.42	7.50	1.30
		30 - 50	46	22	32	Sandy Clay Loam	68	7.50	6.89	0.68
	15	0 - 30	48	14	37	Sandy Clay	77	7.46	6.44	1.30
		30 - 60	50	16	34	Sandy Clay Loam	78	7.72	7.20	0.85
T9	16	0 - 30	32	27	41	Clay	85	7.52	7.58	1.33
		30 - 60	30	21	48	Clay	71	7.45	8.71	1.09
	17	0 - 30	26	28	46	Clay	96	7.60	6.89	2.27
		30 - 60	35	23	42	Clay	89	7.53	7.65	0.72

Table 3. The electrical conductivity (EC_e), soluble ions, cation exchange capacity (CEC), sodium adsorption ratio (SAR_e) and Olsen P (mg/kg) of the studied soil samples

Transect	Profile	Depth (cm)	EC_e (dS/m)	Soluble ions (mmol/kg)							CEC ($cmol^+$/kg)	SAR_e	Olsen P (mg/kg)
				Ca^{+2}	Mg^{+2}	Na^+	K^+	HCO_3^-	CL^-	$SO_4^=$			
T1	1	0 -30	4.36	4.35	1.55	0.75	0.12	3.88	14.33	2.49	13.16	0.44	4.11
		30- 60	42.12	12.92	8.23	75.08	0.92	5.87	21.65	5.47	15.43	23.09	5.60
	2	0 -30	20.60	7.91	2.26	26.47	0.17	8.36	1.33	4.17	14.79	9.61	7.45
		30 -60	35.70	11.44	4.44	86.37	0.44	7.94	1.57	6.88	19.67	30.65	7.83
T2	3	0 -30	99.60	60.74	37.46	77.87	1.49	4.49	40.03	5.64	27.54	22.53	6.78
		30 -60	100.60	101.55	45.13	238.34	2.02	5.91	56.82	3.48	24.19	27.83	4.31
	4	0 -30	163.00	85	84.30	450.92	4.48	3.70	647.63	0.73	14.93	49.01	6.92
		30 -60	34.00	25.14	11.68	77.87	1.27	5.86	215.54	10.26	20.49	18.15	4.77
T3	5	0 -30	6.87	7.67	1.62	4.30	0.17	3.88	12.33	2.94	16.16	2.35	8.94
		30 -60	10.84	7.22	5.62	12.02	0.25	5.87	21.65	6.70	18.12	4.80	8.53
T4	6	0 -30	2.65	9.14	0.57	0.58	0.27	8.36	1.33	3.19	26.58	0.28	28.98
		30 -60	2.58	7.08	0.90	0.36	0.21	7.94	1.57	3.69	14.95	0.21	3.34
	7	0 -30	19.58	7.28	2.55	22.86	0.29	4.49	40.03	5.79	19.52	13.06	3.91
		30 -60	24.20	9.08	2.52	45.21	0.27	5.91	56.82	9.15	24.33	20.72	8.33
T5	8	0 -30	1.05	1.62	1.62	0.20	0.05	2.21	1.13	1.29	6.58	0.22	4.72
		30 -60	1.64	2.02	2.69	0.85	0.23	3.15	2.35	0.83	16.29	0.24	7.79
	9	0 -30	5.47	9.92	6.97	13.11	0.30	7.85	9.34	11.26	26.78	3.94	3.02
		30 -60	10.92	14.06	19.90	17.67	0.19	6.21	9.24	15.44	27.18	3.77	4.23

Table 3. Continued

Transect	Profile	Depth (cm)	EC_e (dS/m)	Soluble ions (mmol/kg)							CEC ($cmol^+$/kg)	SAR_e	Olsen P (mg/kg)
				Ca^{+2}	Mg^{+2}	Na^+	K^+	HCO_3^-	CL^-	$SO_4^=$			
T6	10	0 -30	1.71	7.06	1.57	6.16	0.35	6.88	6.83	3.66	54.89	2.15	62.07
		30- 60	3.11	7.57	8.70	5.18	0.66	5.54	10.54	6.58	57.49	1.29	42.49
	11	0 -30	1.57	6.85	2.28	6.49	2.97	13.36	6.36	2.58	55.52	2.03	65.35
		30 -60	4.81	18.33	9.87	26.69	2.66	11.00	19.64	13.38	52.17	4.69	23.76
T7	12	0 -30	1.11	5.56	1.11	3.05	0.29	7.59	3.87	3.37	52.22	0.53	3.84
		30 -60	4.68	12.30	7.30	18.63	0.75	7.88	6.69	13.39	46.43	30.90	5.81
	13	0 -30	25.10	34.54	17.27	118.70	1.15	11.03	138.88	9.08	51.58	18.85	11.19
		30 -60	31.10	44.82	18.79	121.64	0.27	6.77	163.15	7.85	42.90	18.16	11.70
T8	14	0 -30	2.67	11.24	0.54	1.26	0.17	4.82	2.87	2.55	37.21	0.45	3.08
		30 -60	4.59	10.33	3.81	0.61	0.40	4.89	2.91	7.85	38.84	0.20	3.93
	15	0 -30	4.72	12.32	3.70	17.25	0.31	5.54	7.70	10.00	37.32	4.92	2.25
		30 -60	9.37	16.25	1.87	51.71	0.81	4.68	10.02	17.85	35.21	13.77	3.93
T9	16	0 -30	3.18	12.28	6.82	5.48	0.65	7.16	7.30	5.99	41.11	1.36	5.01
		30 -60	5.30	12.01	3.43	9.91	0.67	6.00	10.21	8.69	37.6	2.98	5.84
	17	0 -30	3.72	15.29	3.82	13.34	1.62	8.03	8.19	8.09	48.00	3.12	22.91
		30 -60	6.18	14.24	7.12	27.23	1.38	6.41	36.85	12.97	41.4	6.25	10.04

Soil saturation percentage (SP)

The soil saturation percentage of the studied soils ranged from 28% in profiles 1 and 2 to 115 % in profile 11 (Table 2). In most cases, the SP of the investigated soils increased with increasing the clay content. Likewise, the highest SP value (115%) was recorded only for profile 11 that due to the high content of expanded clay minerals. (El-Desoky and Ragheb, 1993; Amin, 2008).

Soil pH

The pH of the investigated soil samples ranged from 7.42 to 8.03 and 7.44 to 7.96 in the surface and subsurface layers, respectively (Table 2). According to Brady and Weil (1999), about 79.4% of the studied soil samples were mildly alkaline (Mi 7.4 to 7.8) and 20.6% were moderately alkaline (Mo 7.9 to 8.4). This probably results from prevailing the base (Na^+ and K^+) and earth base (Ca^{+2} and Mg^{+2}) cations as well as calcium carbonate. These results agree with those reported by El-Desoky and Ghallab (1997).

Calcium carbonate content ($CaCO_3$)

The calcium carbonate ($CaCO_3$) content of the investigated soils varied from 2.2 to 57.58% (Table 2). It differed from lows to high depending up on some soil characteristics such as soil texture, soil pH, and organic matter. The high value (57.58%) of $CaCO_3$ was recorded in the subsurface layer of profile 5, but the lowest one (2.20%) was obtained in the surface layer of profile 1. The high content of $CaCO_3$ in some of these soils may be attributed to the limestone nature that dominates in the plateau which surrounds the study area. In most situations, the $CaCO_3$ content is higher in loamy sand and sandy clay loam soils than clay and clay loam soils. Also, it increased with depth. These results coincide with those of Abdel-Kareim (1999), Abd Allah (2002), Khalil *et al.* (2004), Selmy (2005) and Abd El-Rhman (2016).

Organic matter content

Soil organic matter can be maintained or increased by returning crop residues to the soil. It is a source of P and other nutrients for crops. The organic matter content of these soils ranged from 0.11% in the surface layer of profile 8 to 2.27% in the surface layer of profile 17 (Table 2). In most cases, the lower organic matter content is related to the coarse soil texture, while the higher one is attached to the fine soil texture, as well as to the addition of organic amendments to soils, especially from crop residues (El-Desoky, 1993; Negim, 2003; Khalil *et al*, 2004 and Selmy, 2005). In most of the studied soils, the surface layer showed a high organic matter content compared to the subsurface one.

Electrical conductivity (EC_e)

The electrical conductively of the saturated soil paste extract (EC_e) varied from 1.05 dS/m in the surface layer of profile 8 to 163.00 dS/m in the surface layer of profile 4 (Table 3). About 68% of the soil samples had an EC_e value above 4.0 dS/m, while only 32% of them were less than 4.0 dS/m. According to Abrol *et al.* (1988), about 14.70% of the studied soils were non-saline (EC_e<2 dS/m), 17.64% were very slightly saline (EC_e 2 - 4 dS/m), 26.47% were slightly saline (EC_e 4 - 8 dS/m), 8.82% were moderately saline (EC_e

8-16 dS/m) and 32.35% of them were strongly saline (EC_e >16 dS/m). In all studied profiles except profile 4, the EC_e is higher in the subsurface than in the surface layer. The highest EC_e value of the surface layer of profile 4 may be attributed to the drip irrigation system that is used in this area which encourages the soluble salts to stay in and not to be leached downward. It may be also related to the saline nature of the parent material of these soils. The high content of soluble salts of the studied soils in the subsurface layers could be attributed to the effect of surface irrigation water on the movement of soluble salts from the surface layer downward to stop in the subsurface one (Negim *et al*., 2003; Khalil *et al*., 2004; Selmy, 2005; Abd Alla *et al*., 2007).

Soluble ions

Concentrations of soluble ions differed from a soil profile to another and between the surface and subsurface layers in each profile (Table 3). In the studied soil samples, soluble sodium, calcium, magnesium and potassium cations ranged from 0.20 to 450.92, 1.62 to 101.55, 0.54 to 84.52 and from 0.05 to 4.48 mmol/kg soil, respectively. Generally, concentrations of the soluble cations in the saturated soil paste extracts of the studied soils followed the order of Na^+ > Ca^{+2} > Mg^{+2} > K^+ . Levels of soluble anions, also varied in the studied soil samples. They ranged from 1.33 to 647.63, 0.072 to 17.85 and from 3.70 to 13.36 mmol/kg soil, for Cl^-, $SO_4^=$ and HCO_3^-, respectively. The highest level (647.63mmol/kg soil) of soluble Cl^- that was recorded in the surface layer of profile 4 may be due to the highest values of EC_e (163 dS/m), Na^+ concentration (587.92 mmol/kg), and Ca^{+2} concentration (85 mmol/kg) in this layer. Levels of soluble anions in all studied soils had the order of Cl^- > $SO_4^=$ > HCO_3^-. Moreover, in most of studied soil profiles, levels of soluble cations and anions increased with depth. This may be attributed to the movement of these ions with irrigation water downwards the soil profile. These results are in a harmony with those of Khalil *et al.* (2004) and Selmy (2005).

Cation exchange capacity (CEC)

The CEC of the examined soil samples ranged from 6.58 to 57.49 cmol$^{\oplus}$/kg (Table 3). A soil of a high CEC value is attributed to high levels of clay content, soil pH and organic matter content (Foth, 1988). High soil pH values cause an increase in numbers of negative sites on soil colloids and so, the CEC value. High contents of both organic matter and clay result in high values of CEC. They have a large number of negative sites on their surfaces which retain cations (Foth, 1988; Tomašić *et al*., 2013).

Sodium adsorption ratio (SAR_e)

The sodium adsorption ratio of the saturated soil paste extract (SAR_e) of the studied soils varied from 0.20 to 49.01 (Table 2). According to Bohn *et al.* (2001), about 28.13% of the investigated soil samples had a SAR_e value that was greater than 13% (sodic soils). These soil samples included the subsurface layers of profiles 1, 2, 3 and 7 and both layers of profiles 4 and 13. However, about 71.87% of the studied samples showed a SAR_e value that was lower than 13 (normal soils). Moreover, the SAR_e decreased with depth in most of the studied soil samples. This may be attributed to the increased solubility of sodium salts as a result of irrigation effect.

Soil available phosphorus

The $NaHCO_3$ – extractable P or Olsen P is the fraction of total P in soil that is readily available for the absorption by plant roots. The $NaHCO_3$ - extractable soil phosphorus of Garb El-Mawhoob soils ranged from 2.25 to 65.35 mg/kg in the surface layer and from 3.34 to 42.49 mg/kg in the subsurface layer (Table 3). According to Tomas and Peaslee (1973), about 50% of the studied soil samples had a low level of available P (< 6 mg/kg), 24% of them showed a medium level (6 -10 mg/kg) and 26% of them contained a high level of available P (>10 mg/kg). The available P varied from 1.7 to 8.7 mg/kg in the semi-arid regions (Bennoah *et al.,* 1995). In some soils of Toshka region Behiry *et al*. (2003) found that the $NaHCO_3$ – extractable P 0.5M ranged from 3.00 to 21.20, 2.90 to 19.50 and from 2.50 to 18.90 mg/kg in the surface, subsurface and deeper layers, respectively. The soil samples that had clay and clay loam textures contained the highest level of available P. With having the same P saturation index, the fine-textured soils tend to release more soil available P with water extraction than the coarse-textured ones (Pellerin *et al.,* 2006). The highest levels of available P in these soils were recorded for the surface and subsurface layers of profiles 10 and 11, as well as the surface layers of profiles 6 and 17. The high available P level may be attributed to the high organic matter and clay contents as well as the high levels of phosphate fertilization of these soils. It is clear that some New Valley soils contain high levels of phosphate minerals that may raise the level of available P in these soils (Abdel-Aal *et al.,* 1978b). In some Egyptian soils, Abd Alla, *et al.* (2007) found that the soil available P is affected by clay and calcium carbonate content. On the other hand, the lowest level (2.25 mg/kg) of the available P was recorded for the surface layer of profile 15. The low contents of available P in these soils may be attributed to the P fixation of P by calcium and calcium carbonate that are found in high amounts in these soils. The solubility of P decreases as the concentration of Ca^{+2} in soil solution increases (Curtin *et al.,* 1993; Uzoho and Oti, 2004). Also, the available P is affected by the soil pH. Phosphate ions, $H_2PO_4^-$ and $HPO_4^=$, are soluble and readily available for plant roots in a narrow soil pH range of 6.0 to 6.6. Below this pH range, phosphate ions are precipitated as iron and aluminum phosphate while above that, they are fixed as calcium phosphate (Tisdale *et al.,* 1997).

3. 3. Correlations between soil available P and soil properties

The correlation coefficients of the soil available P and some properties of the investigated soil samples are present in Table 4. Highly significantly positive correlations were found between the available soil P and the OM, CEC, HCO_3^- and silt contents of the studied soils with r values of 0.602**, 0.468**, 0.500** and 0.457**, respectively. Similar results were reported by El-Desoky and Ragheb (1993) in sandy calcareous soils of Assiut and by Amin, (2008). On the other side, negative correlations were obtained between the available P and $CaCO_3$, EC_e, Ca^{+2}, Mg^{+2}, Na^+ and SAR_e of these soils with r values of -0.219, -0.194, -0.142, -0.126, -0.134 and -0.171, respectively. Increasing Na^+ and Ca^{+2} concentrations in the soil solution can lead to increased soil ionic strength which may affect P availability and P uptake by plants (Curtin *et al.,* 1993). Phosphorus is also very reactive with lime. It can be precipitated with $CaCO_3$ as Ca-P form (Mehmood *et al.,* 2010). Moreover, in calcareous soils, the Ca-saturation clay contents will exhibit low solution P levels, since P can readily be precipitated or adsorbed (Tisidale *et al.,* 1997; Bai *et al.,* 2013). Abd Alla *et al.,* (2007) reported that the available P was affected by clay and calcium carbonate contents in some Egyptian soils. Meanwhile, a negative correlation is also found between the available P and the sand content. However, the correlation between the available P and soil pH was not significant (r=0.037). Moreover, the negative correlation between the available P and soil organic matter was not significant but it was negative (r = -0.039). Qian and Schoenau, (2000) found that the addition of manure did not increase the most labile P in soil instead the initial fate of the P from the manure was mainly moderately labile and stable fractions such as calcium phosphate and organic P forms.

Table 4. Correlation coefficients of soil available P and some properties of the studied soils

Character	Correlation coefficients	Character	Correlation coefficients
Sand	-0.324	Ca^{+2}	-0.142
Silt	0.457**	Mg^{+2}	-0.126
Clay	0.188	Na^+	-0.134
$CaCO_3$	-0.219	K^+	0.272
OM	0.602**	HCO_3^-	0.500**
pH (1:2.5)	0.037	CEC	0.468**
EC_e	-0.194	SAR	-0.171

** = High significant

Conclusions

The soils of Garb El-Mawhoob varied in their chemical and physical properties depending upon the variations in formation conditions and parent material as well as the complex reactions among soil components. Moreover, in most studied soils, the available soil P content differed from one profile to another. The surface layer showed a high content of available P than the subsurface one that it is attributed to the low organic matter content of these soils. In addition, 50% of the studied soils contained low levels of available P and 24% of them had medium levels. On the other side, only 26% of these soils exhibited a high level. So, it is recommended to raise the available P level and improve the physical and chemical properties of these soils through additions of organic materials and manure or phosphate fertilizers, especially to the newly reclaimed ones.

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تقييم الفوسفور الميسر في أراضي غرب الموهوب واحة الداخلة- مصر

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الملخص

تم جمع أربع وثلاثون عينة تربة من أراضي غرب الموهوب، واحة الداخلة محافظة الوادي الجديد– مصر لتقييم الفوسفور الميسر في هذه التربة وعلاقته بخصائصها. وقد أخذت هذه العينات من الطبقة السطحية (٠–٣٠ سم) والطبقة تحت السطحية (٣٠– ٦٠ سم) من ١٧ قطاع أرضي تمثل منطقة الدراسة. كانت معظم عينات التربة ذات قوام رملي طمي، وطمي طيني رملي وطيني. أظهرت التربة قلوية خفيفة (٧.٨– ٧.٤ pH). في حين تباينت قيم التوصيل الكهربي (EC_e) وكربونات الكالسيوم $CaCO_3$ لهذه العينات من المستويات القليلة إلى المرتفعة وتراوحت ما بين ١.٠٠٥إلي ١٦٣ ديسيمنز/متر ومن ٢.٢ إلي ٥٧.٥٨٪ على التوالي. وكان محتوى التربة من المادة العضوية متباين حيث تراوحت قيمتها ما بين ٠.١١ إلي ٢.٢٧٪. كما تناقصت الكاتيونات والأنيونات الذائبة في معظم الأراضي المدروسة كالأتي: الكالسيوم > الصوديوم > المغنيسيوم > البوتاسيوم وكذلك الكلوريد > الكبريتات > البيكربونات، على التوالي. وتراوحت السعة التبادلية الكاتيونية (CEC) ونسبة إدمصاص الصوديوم (SARe) لهذه الأراضي من ٦.٥٨ إلي ٥٧.٤٩٪ سينتيمول$^{\oplus}$/كجم تربة ومن ٠.١١ إلي ٤٥.١٨ علي التوالي.

تباينت قيم الفوسفور المستخلص بواسطة بيكربونات الصوديوم في الطبقة السطحية لهذه الأراضي من ٢.٢٥ إلي ٦٥.٣٥ مللجرام/كجم ومن ٣.٣٤ إلي ٤٢.٤٩ مللجرام/ كجم في الطبقة تحت السطحية. وعموماً، فإن حوالي ٥٠٪ من العينات المدروسة ذات مستوى منخفض من الفوسفور الميسر (<٦ مللجرام/كجم)، ٢٤٪ من العينات المدروسة ذات مستوى متوسط (١٠ – ٦ مللجرام/ كجم)، وإحتوت ٢٦٪ منها علي مستوى مرتفع من الفوسفور الميسر (> ١٠ مللجرام/ كجم). كما أظهرت الأراضي ذات القوام الطيني والطمي الطيني أعلي مستوي للفوسفور الميسر. أظهرت النتائج أيضاً وجود إرتباط معنوي موجب للفوسفور الميسر مع بعض خواص التربة، مثل المادة العضوية، والبيكربونات والـ CEC ونسبة السلت، في حين ارتبطت قيم الفوسفور الميسر سلبا مع قيم التوصيل الكهربي، وكربونات الكالسيوم وكلاً من الكالسيوم والصوديوم الذائب.