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Available Potassium Evaluation of Gharb El-Mawhoob Soils, El-Dakhla Oasis, Egypt

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Abstract

In Garb El-Mawhob area, northwest of El-Dakhla Oasis, New Valley governorate, Egypt, nine transects (≈ 5km away between two consecutive ones) containing 17 soil sites were designated to evaluate the available potassium (K)and its relation with some soil properties. Surface (0-30) and subsurface (30-60) soil samples were collected from each profile, air-dried, ground, sieved and then, kept for some physical and chemical analyses.

The obtained results indicated that about 56, 65 and 41% of the total soil samples contained sand, silt and clay respectively of more than 60, 10 and 30%, respectively. The saturation percentage (SP) varied from 25 to 110% and increased whenever the clay or organic matter content increased. The organic matter content differed from 0.01 to 2.48 % and decreased with soil depth. The $CaCO_3$ content of these soils varied from 2.20 to 59.24%. The pH values ranged from 7.44 to 8.03.The electrical conductivity of the soil paste extract (EC_e) differed from 0.71 to 171.30 dS/ m with an average value of 20.33dS/ m. The soluble anions could be arranged in the descending order of Cl> SO_4 > HCO_3. The soluble cations could be arranged in the descending order of Na >Ca> Mg > K . The sodium adsorption ratio of the soil paste extract (SAR_e) ranged from 0.31 to 85.20. Cation exchange capacity (CEC) values ranged from 6.58 to 62.56 $cmol^{(+)}$/ kg with a mean value of 29.44 $cmol^{(+)}$/ kg and it increased with soil depth.

The available K ranged from 148.98 to 944.12 mg/ kg with an average value of 451.81 mg/ kg. About 47.06% of the studied soil samples contained a very high level of available K (> 450 mg/ kg),20.56% had a high K level (251-450 mg/ kg), 29.41% showed a moderate K level (151-250 mg/kg) and only 2.94% exhibited a low K level (86-150 mg/ kg). The available K was found to be positively correlated to silt content, clay content, SP, EC_e, SAR_e and CEC as well as soluble Na, Mg, HCO_3 and SO_4. However, it was negatively correlated to both sand and $CaCO_3$ contents.

Keywords: *Available Potassium, soil physical-chemical properties, Gharb El-Mawhoob, El-Dakhla Oasis, Egypt.*

Introduction

Potassium (K) is considered one of the most critical nutrient for plant growth. Plant development is seriously limited when Kis inadequate in the soil solution. Plants take up K from soil solution as an ionic form (K^+) Moreover, K element which remains in the ionic form in planttissues. It plays an important role in several physiological processes in plants. In addition, potassium has a great effect of many enzymes of primary metabolism that are responsible for energy transfer and formation of sugars, starch and protein which are affected by potassium presence in the plant (Carminati and Vetterlein, 2013.). It also promotes photosynthesis, controls stomata opening, improves N utilization and encourages assimilate transport to increase crop yields. Moreover, it influences the microbial population in the rhizosphere (Solanki and Chavda, 2012 and Sumithra *et al.,* 2013). Potassium has a diverse role for Na resistance in plants. Therefore, to improve crop performance on Na-affected soils the K fertilization is advisable (Wakeel, 2013).

The content of K in the earth crust is about 2.3% but a small part of it is available for plant uptake. Levelsof soil K are influenced by soil properties such as CEC, clay minerals and wet conditions. It is electrostatically held at the edge and surface sites of minerals and humus colloids that have permanent charge and/or pH dependent charges.(Fotyma, 2007).Soils with large amounts of vermiculite or mica and high organic matter content are high in available K content. This K pool is considered exceedingly bioavailable as long as the soil moisture is adequate. Potassium ions held by surface charge might be released into soil solution by the exchange with other ions in solutions when the soil solution has a low K^+ activity (Hosseinpur *et al.,* 2014). Thus, the exchangeable K is the essential source of K for plant nutrition (Thompson and Ukrainczyk, 2002). In addition the available K level is higher in surface soil layer compared to the subsurface one due to the biological activity and weathering processes (Grodnitskaya *et al.,* 2010; Zharikova and Kostenkov, 2014).

Soil K may be classified according to their availability to plants into relatively unavailable, readily available and slowly available or exchangeable K forms. However, 90-98% of soil K occur in minerals as a relatively unavailable form. The readily available K form constitutes only 1-2% of the total soil K. The readily available soil K exists as water soluble K in the soil solution and as exchangeable K held on soil colloidal surface (Hoeft *et al*., 2000).

In Egyptian soils, K levels are subjected to exhausting as consequence of escalated development and intensive agriculture (Shaaban and Abou El-Nour, 2012). Theavailable potassium level varied from 250 to 500 mg/kg, 105 to 358 mg/kg and

100 to 300 mg/kg in clay, sandy and calcareous sandy soils respectively (AbdEl-Hady, 2004).Moreover, there is a wide variation in the cumulative K release among calcareous soils that it ranges from 169 to 199 mg/kg. Sandy soils that contain very low levels of clays often have low plant available K (Rahman *et al.,* 2014)

This study aims to assess the levels of the available K in Gharb El-Mawhoob soils, and their relations to the properties of these soils.

Materials and Methods

1. Study area

The study area is located at Gharb El-Mawhoob, northwest El-Dakhla Oasis, New Valley governorate, Egypt between longitude 28° 19` 23“to 28° 37` 12“E and latitude 25° 52` 44“to 25° 45`06“N. Nine transects (≈ 5km away between two consecutive ones) containing 17 soil sites were designated to represent the study area (Fig.1). Each soil site was situated using the Global Position System (GPS) as shown in Table (1).

2. Soil sampling and analyses

Surface (0-30cm) and subsurface (30-60cm) soil samples were collected from each site, air-dried, ground, sieved through a 2-mm sieve and then, kept for some physical and chemical analyses. Soil particle-size distribution was determined by the international pipette method according to Jackson (1973) and the saturation percentage (SP) was estimated as described by Hesse (1998). Soil pH was measured in a 1:2.5 ratio of soil to water suspension using Beckman pH meter with a glass electrode. The soilorganic matter content was determined using the Walkley and Black method (Jackson, 1973).The total calcium carbonate content was estimated by Collin’s calcimeteraccording to Nelson (1982). The electrical conductivity of the saturated paste extract (EC_e) was measured using an electrical conductivity meter according to (Jackson, 1973).Soluble bicarbonates (HCO_3^-) and Chloride (Cl^-) were determined by the titration method using standard HCl acid and standard silver nitrate solution, respectively (Richards, 1954 and Jackson, 1973). Soluble sulfate was determined by turbidity method (Baruah and Barthakur, 1997).

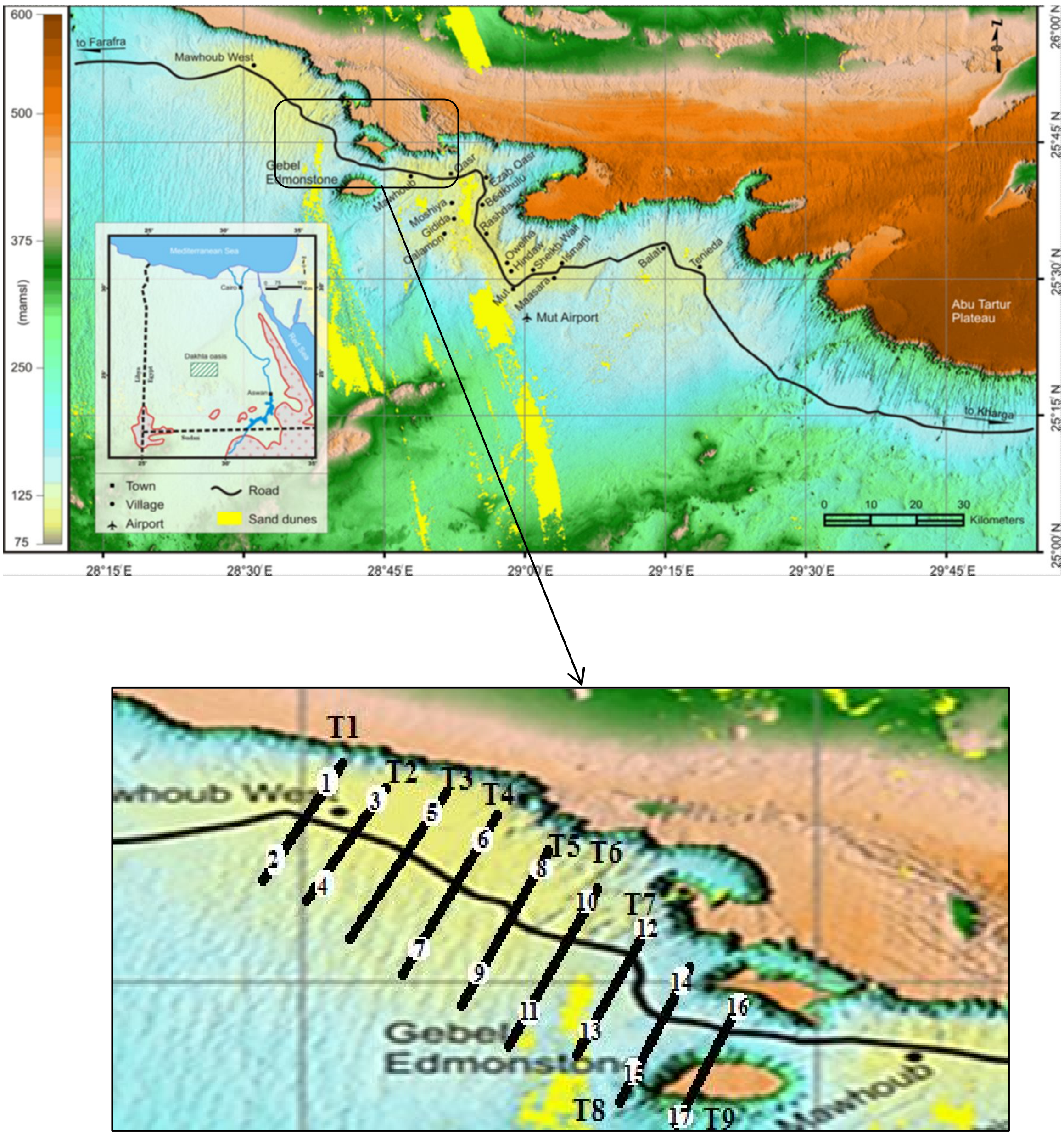

Fig 1: A location map of the study area and soil sites.

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

Transect No.	Profile No.	Location		Land Use
		Longitude E	Latitude N	
T1	1	28° 19′ 23″	25° 52′ 44″	Clover
	2	28°19′ 54″	25° 52′ 51″	Citrus
T2	3	28° 20′ 55″	25° 51′ 58″	Date palm
	4	28° 20′ 54″	25° 52′ 46″	Wheat
T3	5	28° 23′ 40″	25° 52′ 47″	Clover
T4	6	28° 27′ 15″	25° 53′ 44″	Uncultivated
	7	28° 27′ 21″	25° 53′ 01″	Uncultivated
T5	8	28° 30′ 22″	25° 52′ 59″	Uncultivated
	9	28° 30′ 11″	25° 52′ 37″	Fruitful olive trees
T6	10	28° 32′ 36″	25° 52′ 17″	Wheat
	11	28° 32′ 46″	25° 51′ 56″	Date palm
T7	12	28° 34′ 23″	25° 50′ 26″	Wheat
	13	28° 34′ 28″	25° 50′ 33″	Wheat
T8	14	28° 37′ 37″	25° 47′ 33″	Wheat
	15	28° 37′ 11″	25° 45′ 13″	Clover
T9	16	28° 37′ 29″	25° 47′ 12″	Clover and wheat
	17	28° 37′ 12″	25° 45′ 06″	Date palm and Clover

Soluble calcium (Ca^{+2}) and magnesium (Mg^{+2}) in the saturated soil paste extract were determined by the EDTA method (Jackson, 1973). However, soluble sodium (Na^{+}) and potassium (K^{+}) in these extract were determined by flam photometry method (Hesse, 1998). The sodium adsorption ratio (SAR_e) was calculated according to the formula of Richerds (1954). The cation exchange capacity (CEC) of the soil was determined using sodium acetate method proposed by Jackson (1973). Soil available K was extracted using 1NNH_4OAc at pH 7 described by Carson (1980).

Results and Discussion

1. Characteristics of the studied soils

The results inTable 2reveal that about 56, 65 and 41% of the total soil samples had sand, silt and clay contents,respectively, of more than 60, 10 and 30%, respectively. In general, the sand fraction of these soils decreased with depth while, in most cases, the clay fraction increased downward. This might be attributed to the movement of sand dunes over the surface of these soils as well as to the clay movement downward with irrigation water (Ismeal, 2015). Therefore these soils showed different texture classes including loamy sand, sandy loam, sandy clay loam, clay loam and clay. In most of the investigated soil sites, the soil texture changed with depth. It was noticed that soil texture became coarser towards the west direction.

The saturation percentage (SP) of the studied soils varied from 25 to 110 %it increased whenever the clay or organic matter content increased (Table 2). It was noticed that the average SP value of the coarse-textured soils (transects 1 to 5, west direction) was 35.5%while it was 84% for the fine-textured soils (transects 6 to 9, east direction). The soils that contain high amount of smectiteclay minerals have the ability to increase their volume by 30% as a result of wetting process (Brady and Weil, 2008). The soil organic matter content (SOM) of these soils differed from 0.01 to 2.48% (Table 2). It decreased with soil depthshowing the same trend as the saturation percentage the high SOM content is found in the soils that are often cultivated or have organic fertilizers as well as crop residues are added (El-Desoky, 1993; Negim, 2003; Khalil *et al.,* 2004; Selmy, 2005).

The total calcium carbonate ($CaCO_3$) content of the investigated soils ranged from 2.20 to 59.24% (Table 2). Generally, it increased with depth. According to the classification proposed by FAO (1973), 2.94% of thetotal soil samples were non-calcareous ($CaCO_3$ content < 5%) and 50.0% of them were slightly calcareous in nature ($CaCO_3$ content between 5 to 15%) However, the rest of these samples (47.06%) were calcareous in nature ($CaCO_3$ content > 15%). It was recognized that the total $CaCO_3$ content was higher than 15% in western part of the study area (transects 1 to 5) indicating that these soils are calcareous. This sites are close to the lime stone Edmon mountain. In most situations, the sandy loam and loamy sand soils contained higher levels of $CaCO_3$than the clay and clay loam soils. These results coincidewith those obtained by Khalil *et al.* (2004) and Selmy (2005).

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

Transect	Profile	Depth (cm)	Particle-size distribution (%)			Soil texture	Saturation percentage (%)	Organic matter (%)	$CaCO_3$ (%)	pH (1:2.5)
			Sand	Silt	clay					
T1	1	0 - 30	86	7	7	Loamy Sand	29	0.28	2.20	7.45
		30 - 60	82	8	9	Loamy Sand	28	0.45	21.29	7.79
	2	0-30	84	10	6	Loamy Sand	26	0.45	14.32	7.77
		30-60	84	7	9	Loamy Sand	25	0.62	17.27	7.60
T2	3	0 - 30	62	17	20	S.C. Loam	49	0.42	18.94	7.63
		30 - 60	59	16	25	S.C. Loam	50	0.72	18.56	7.50
	4	0 - 30	76	18	6	Sandy Loam	42	0.62	53.79	7.59
		30 - 60	68	26	5	Sandy Loam	49	0.45	59.24	7.60
T3	5	0 - 30	75	7	18	Sandy Loam	36	0.82	36.36	7.53
		30 - 60	49	20	31	S.C. Loam	49	0.21	57.58	7.65
T4	6	0 - 30	86	7	7	Loamy Sand	29	0.01	23.41	7.84
		30 - 60	75	12	13	Sandy Loam	41	0.35	35.76	7.87
	7	0 - 30	83	6	10	Loamy Sand	33	1.02	21.14	7.49
		30 - 60	81	5	14	Sandy Loam	27	0.55	17.27	7.55
T5	8	0 - 30	78	11	11	Sandy Loam	36	1.19	16.21	7.44
		30 - 60	72	12	15	Sandy Loam	31	1.09	21.06	7.53
	9	0 - 30	86	5	9	Loamy Sand	26	0.35	15.76	8.03
		30 - 60	77	9	13	Sandy Loam	33	0.79	14.24	7.93
T6	10	0 - 30	31	35	34	Clay Loam	110	2.48	9.85	7.78
		30 - 60	33	24	43	Clay	93	0.79	9.39	7.53
	11	0 - 30	78	9	13	Sandy Loam	46	1.13	15.30	7.56
		30 - 60	20	30	50	Clay	92	0.86	6.97	7.98
T7	12	0 - 30	35	33	32	Clay Loam	90	1.13	6.82	7.8
		30 - 60	23	33	44	Clay	94	0.69	7.73	7.64
	13	0 - 30	29	32	39	Clay Loam	99	1.29	6.67	7.52
		30 - 60	20	37	43	Clay	105	1.09	6.82	7.6
T8	14	0 - 30	27	29	44	Clay	78	1.16	8.03	7.55
		30 - 50	30	29	41	Clay	80	0.89	8.11	7.46
	15	0 - 30	61	10	29	S.C. Loam	62	1.63	9.09	7.53
		30 - 60	62	11	26	S.C. Loam	54	0.89	9.77	7.6
T9	16	0 - 30	32	27	41	Clay	85	1.33	7.58	7.52
		30 - 60	30	21	48	Clay	71	1.09	8.71	7.45
	17	0 - 30	26	28	46	Clay	96	2.27	6.89	7.6
		30 - 60	35	23	42	Clay	89	0.72	7.65	7.53

The pH of the investigated soil samples differed from 7.44 to 8.03 (Table 2). In most soil sites, the soil pH increased with depth. According to Kumar *et al.,*(2009)17.65% of the total soil samples were neutral (pH of 7.00 to7.50), while 82.35% of them were slightly alkaline (pH of 7.50 to 8.00). It was recognized that the high pH values were related tothe high calcium carbonate levels. This may be due to the partial hydrolyzed calcium carbonate to bicarbonate and hydroxide ions resulting in high soil pH. In addition, the relative high soil pH values may be attributed to the presence of a high degree of base saturation, especially exchangeable sodium (Kumar *et al.,* 2013 and Singh *et al.,* 2014). These results agree with those reported by El-Desoky and Ghallab (1997).

The electrical conductivity of the saturated soil paste extract (EC_e) of the studied soil samples varied from 0.71 to 171.30 dS/m with an average value of 20.33dS/ m (Table 3). Almost, half of the total soil samples (47.05 %) showed normal values of soil salinity (EC < 4 dS/m). According to Abrol *et al.,* (1988), 20.58% of the tested soil samples were non-saline (EC_e< 2 dS/m), 26.47% were slightly saline (EC_e 2-4dS/m).

Table 3. Some chemical properties of the studied soil samples

Transect	Profile	Depth (cm)	EC_e (dS/m)	Soluble ions (mmol/kg)							SAR_e	CEC ($cmol^{(+)}$/kg soil)	Available K^+ (mg/kg soil)
				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	37.14	2.49	0.44	13.16	267.28
		30 - 60	42.12	12.92	8.23	75.08	0.92	5.87	1657.14	5.47	23.09	15.43	943.53
	2	0 - 30	54.60	17.38	6.93	35.84	0.60	4.37	827.49	2.75	20.16	12.15	619.19
		30 - 60	171.30	44.59	19.58	140.00	1.15	2.70	1960.25	1.71	49.43	10.92	732.09
T2	3	0 - 30	99.60	60.74	37.46	77.87	1.49	4.49	40.03	5.64	22.53	27.54	530.20
		30 - 60	100.60	101.55	45.13	238.34	2.02	5.91	56.82	3.48	27.83	24.19	571.87
	4	0 - 30	13.66	13.26	3.96	10.86	0.28	4.03	16.32	3.64	5.71	18.49	244.95
		30 - 60	5.01	15.47	0.60	5.42	0.40	4.70	4.44	3.68	2.73	17.04	154.69
T3	5	0 - 30	6.87	7.67	1.62	4.30	0.17	3.89	12.33	2.94	2.35	16.16	187.75
		30 - 60	10.84	7.22	5.62	12.02	0.25	5.87	21.65	6.70	4.80	18.12	163.05
T4	6	0 - 30	40.30	11.77	6.06	41.33	1.10	4.18	32.35	4.27	25.70	11.58	537.26
		30 - 60	71.00	19.33	5.88	193.71	2.60	7.38	82.40	9.99	85.20	19.25	698.22
	7	0 - 30	3.39	6.09	1.62	0.53	0.12	6.73	1.09	3.17	0.47	16.34	201.41
		30 - 60	2.92	4.32	1.77	0.28	0.06	2.92	0.41	2.89	0.31	14.91	148.98
T5	8	0 - 30	2.89	4.43	2.95	0.71	0.13	5.62	0.75	3.49	0.61	18.51	228.40
		30 - 60	3.61	4.83	2.80	0.59	0.08	2.98	0.82	3.68	0.54	15.53	192.86
	9	0 - 30	1.05	1.60	1.60	0.20	0.05	2.18	0.29	1.15	0.31	6.58	159.64
		30 - 60	1.65	2.03	2.71	0.70	0.22	3.17	0.77	0.67	1.54	16.29	295.45
T6	10	0 - 30	1.00	5.86	3.71	5.41	0.78	9.24	5.20	1.72	1.49	59.56	783.10
		30 - 60	3.11	5.34	4.18	13.73	1.01	7.81	3.72	9.64	1.40	56.58	696.38
	11	0 - 30	0.96	0.57	0.60	2.83	0.19	3.86	0.92	1.09	0.68	17.42	269.97
		30 - 60	4.35	11.69	13.67	15.84	0.94	8.83	8.43	17.39	3.84	56.44	584.62
T7	12	0 - 30	1.11	5.56	1.11	3.50	0.29	7.59	3.87	3.37	0.53	52.22	492.64
		30 - 60	4.68	12.30	7.30	18.63	0.76	7.90	6.69	13.39	30.90	46.43	485.11
	13	0 - 30	5.31	8.93	26.03	16.24	1.14	8.32	11.25	16.55	7.37	62.56	517.58
		30 - 60	7.51	12.92	57.42	14.64	1.50	12.60	18.84	21.49	15.10	49.90	676.17
T8	14	0 - 30	2.78	3.74	3.17	9.98	0.40	4.68	3.49	4.82	1.37	44.64	436.84
		30 - 60	3.75	1.92	8.80	13.44	0.54	6.72	8.28	5.55	3.55	39.29	445.34
	15	0 - 30	0.71	0.50	0.34	1.98	0.16	4.46	1.09	0.54	0.39	28.55	341.30
		30 - 60	1.73	2.59	0.54	2.16	0.12	3.89	1.24	0.64	0.48	27.06	207.57
T9	16	0 - 30	3.18	12.28	6.80	5.46	0.65	7.16	7.30	5.99	1.36	41.11	442.03
		30 - 60	5.30	12.01	3.43	9.91	0.66	6.00	10.21	8.69	2.98	37.60	462.86
	17	0 - 30	3.72	15.29	3.82	13.34	1.62	8.03	8.19	8.09	3.12	48.00	944.12
		30 - 60	6.18	14.24	7.12	27.23	1.38	6.41	36.85	12.97	6.25	41.40	699.25

26.47% were moderately saline (EC_e 4-8 dS/m) and only 5.88% were saline (EC_e 8-16 dS/m). However, 20.58% ofthese samples were strongly saline (EC_e> 16 dS/m). Thewesternpart of the study area (transects 1 to 5) exhibited very high soil salinity since its average EC_e was 36.96 dS/m indicating that this part is considered salt-affected soils. On the other hand, the easternpart of the investigated area has normal soils since its average EC_e value was 3.46 dS/m. Most of the studied soil profiles showed an increase in thesoil salinity with depthreflecting the effect of irrigation process on leaching the soluble salts from surface layers downward to the subsurface ones, especially in light-textured soils (Sharma *et al.,* 2008). The high EC_e values may be ascribed to the marine sediment or nature parent material that dominates in these soils (Khalil *et al.,* 2004 and Selmy, 2005).

Table (3) alsoshowsthat the concentrations of soluble ions in the saturated soil paste extract varied widely from one soilprofile to another andbetween surface and subsurface layers.In each profile Bicarbonate (HCO_3^-) ions ranged from 2.18 to 12.60 mmol/kg with an average value of 5.72mmol/kgand showed an irregular trend with soil depth. Soluble chloride (Cl^-) levels in the saturated soil paste extract differed from almost 0.29 to 1960.25mmol/ kg with an average value of 143.76 mmol/kg and displayed a variable trend with soil depth. The variability in Cl concentrations coincided with ofbicarbonates through the different transects. Soluble sulfate (SO_4^{-2}) levels in soils also differed from 0.54 to 21.49mmol/kg with an average value of 5.87mmol/kg and exhibited an irregular trend with soil depth .In general, the soluble anions in these soils could be arranged in the descending order of Cl> SO_4≈ HCO_3.

The obtained results revealed that soluble calcium ions (Ca^{+2}) in these soils ranged from 0.50 to 101.55 mmol/kg with an average value of 13.69 mmol/kg (Table 3). In most cases, there were random variations in soluble Ca distribution with depth. In general, soluble magnesium (Mg^{+2}) was less than soluble calcium (Table 3). It varied from 0.34 to 57.42 mmol/kg with an average value of 8.94mmol/kg. There were no constant distribution trends of the soluble Mg with depth. Soluble sodium (Na^+) in the investigated soils differed from 0.20 to 238.34mmol/kg with a mean value of 29.79mmol/kg(Table3). Its distribution showed an irregular trend with depth. Soluble potassium (K^+) of the studied soils varied from 0.05 to 2.60mmol/kgwith an average value of 0.70mmol/kgand showed variable trend with depth (Table 3). In general, the soluble cations could be ranked in the descending order of Na >Ca> Mg > K.

The sodium absorption ratio (SAR_e) of the saturated soil past extract extended from 0.31 to 85.20 with a mean value of 9.57 (Table 3). In most cases, it increased with depth. The lowest SAR_e value (0.31) and the highest one (85.20) were recorded for the subsurface layer of profiles6and 7,respectively. According to Bohn *et al.,* (2001), 20.59% of the investigated soil samples are considered sodic (SAR_e> 13) while the rest (79.41%) are normal soils (SAR_e<

13).The high SAR_evalues were compatible with the high soil salinity (High EC_e values).These results are in harmony with those obtained by Abd El-Rahim *et al.*(2016).

The cation exchange capacity (CEC) of the studied soil samples ranged from 6.58 to 62.56cmol$_c$/kg (Table 3). It increased with soil depth. The lowest and highestCEC values (6.58 and 62.56 cmol$^{(+)}$/kg soil),respectively were recorded for the surface layer of soil profiles 9 and 13, respectively. High contents of both organic matter and clay result in high values of CEC.This soil components have a large number of negative sites on their surfaces which retain cations(Tomašić *et al.,* 2013). Negative sites on soil colloids are also produced due to high pH dependent charges resulting in high CEC values (Bohn *et al.,* 2001).

3. Available potassium

The available potassium (K) of the investigated soils ranged from 148.98 to 944.12 mg/kg with an average value of 451.81 mg/kg (Table 3). Most of the soil profiles showed that the availableK decreased withdepth. According to Bashour (2001), 47.06% of the studied soil samples contained very high levels of available K (> 450 mg/kg), 20.56% of these samples had high K level (251-450 mg/kg), 29.41% of them possessed moderate K levels (151-250 mg/kg) and only 2.94% of them retained low K levels (86-150 mg/kg). It was noticed that the available K decreased towardswest direction. The average available K level was 382.05mg/kg in the westernpart of the studied area (transects 1 to 5) but it was 530.31 mg/kg in the eastern-part (transects 6 to 9). These findings coincided well with the texture of these soils since it became coarser towards the west direction.Fixed (non-exchangeable) potassium in interlayers of some clay minerals such as micas could be released to soil solution with reducing K^+ activity in soil solution and clay particle size as well as with wetting-drying cycles and adding chelating agents. On the other hand, vermiculite tends to fix the available K in the interlayers as a result of potassium fertilization and it turns to mica (Fanning *et al.,* 1989). Moreover,K ions become trapped in the siloxane cavity and held by medium force energy, and when the interlayers sequentially contract and expand, either adsorption or desorption becomes possible, depending on K concentration gradient. In addition, silt fraction may rapidly release a part of the non-exchangeable K and becomes available for plant nutrition. However,K that is present in the clay fraction is adsorbed with medium force energy in the vermiculite and smectite interlayers and may serve as a medium-term K source to plants as long as the available contents available are not excessively high (Barré *et al.,* 2008a & b).

4. Correlations between available K and some soil properties

The correlations coefficient of the soil available K and some properties of the investigated soils are present in Table 4. Highly significant positive correlations were recorded between the available K and saturation percentage (SP), soil salinity (EC_e), soluble Mg, soluble Na, soluble K, soluble HCO_3, soluble SO_4 and cation exchange capacity (CEC) with r values of. (0.451^{**}, 0.422^{**}, 0.448^{**}, 0.425^{**}, 0.751^{**}, 0.463^{**}, 0.424^{**} and 0.474^{**}, respectively). However, the available K was significantly positively correlated to silt content, clay content and SAR_e with r values of 0.381^{*}, 0.377^{*} and 0.380^{*}, respectively. On the other hand, significantly negative correlations were found between the available K and both of sand and calcium carbonates contents with r values of -0.398^{*} and -0.370^{*}, respectively. Similar results were reported by Abd El-Rahim *et al.*(2016).

Table 4. Correlation coefficients (r) of the available K and some properties of the studied soils

Character	Correlations coefficient(r)	Character	Correlations coefficient(r)
Sand	-0.398^{*}	Mg^{+2}	0.448^{**}
Silt	0.381^{*}	Na^{+}	0.425^{**}
Clay	0.377^{*}	K^{+}	0.751^{**}
SP	0.451^{**}	HCO_3^{-}	0.463^{**}
SOM	0.269	Cl^{-}	0.145
$CaCO_3$	-0.370^{*}	$SO_4^{=}$	0.424^{**}
pH	0.203	SAR_e	0.380^{*}
EC_e	0.422^{**}	CEC	0.474^{**}
Ca^{+2}	0.246	-	-

*Significant ** Highly significant

Also the results showed the available K was affected by soil texture (Fig 2). The available K decreased as the soil texture descended in the order of clay loam > clay > loamy sand > sand clay loam > sandy loam with average values of 597.8, 587.3, 494.3, 362.8 and 269.00, respectively. These results are in agreement with those obtained by Rausell *et al.* (1965); Fanning *et al.* (1989); Rahman *et al.*(2014) and Abd El-Rahim *et al.* (2016).

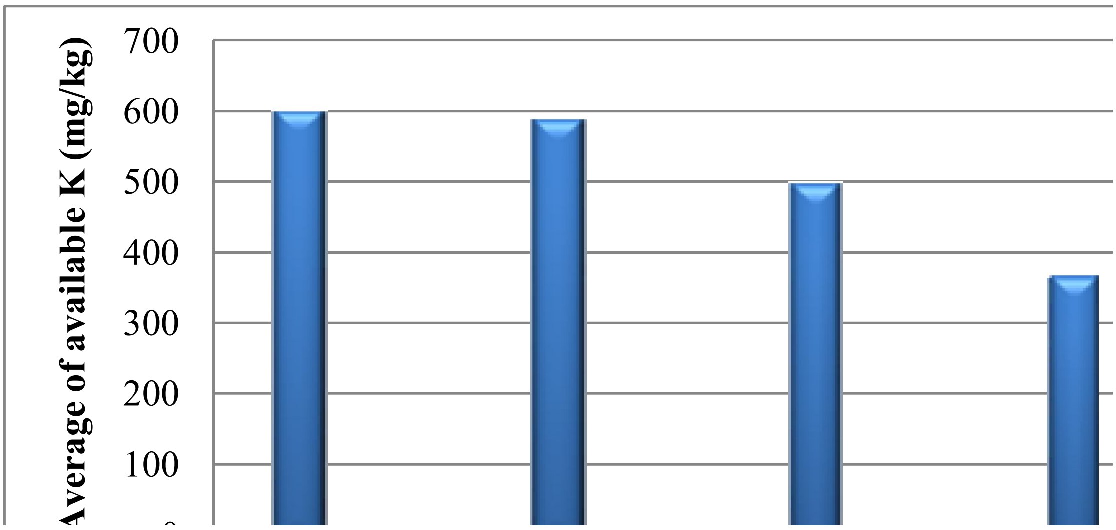

Fig. 2. Relation between soil texture and available potassium

Conclusions

Soils of Garb El-Mawhoob area have variations in their physical and chemical characteristics that are attributed to the differences in their formations and nature of parent material. About 58.82% of the studied soil samples contained very high levels of available K (> 450 mg/kg), 11.76% had high K levels (251-450 mg/kg), 26.47% exhibited moderate K levels (151-250 mg/kg) and only 2.94% showed low K levels (86-150 mg/kg). These findings confirm that most of Garb El-Mawhoob soils contain surplus amounts of available K to meet their high potential use in agriculture.

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تقييم البوتاسيوم الميسر في أراضي غرب الموهوب، واحة الداخلة- مصر

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الملخص

أجرى هذا البحث فى منطقة غرب الموهوب شمال غرب واحة الداخلة، محافظة الوادى الجديد، مصر. تم إختيار ٩ محاور عرضية تفصل بين كل محور والذى يليه مسافة ٥كم تقريبا. وأحتوت الدراسة على ١٧ قطاعا أرضياتم أخذ من كل منها عينات تربة سطحية (٠-٣٠ سم) وتحت السطحية (٣٠- ٦٠ سم) ثم جففت العينات هوائياوتم طحنها ونخلها ثم أجريت عليها بعض التحليلات الطبيعية والكيميائية المطلوبة.

أوضحت النتائج أن حوالى ٥٦، ٤١،٦٥% من إجمالى عدد عينات التربة كان محتواها من الرمل والسلت والطين على التوالى أكثر من ٦٠،١٠،٣٠ % وقد تراوحت قيم السعة التشبعية من٢٥إلى١١٠% مع زيادتها بزيادة محتوى التربة من الطين أو المادة العضوية و تراوح محتوى العينات من المادة العضوية من ٠,٠١ إلى ٢,٤٨% مع تناقصها بالعمق. إختلف محتوى كربونات الكالسيوم فى هذة العينات بين ٢,٢٠ و ٥٩,٢٤% بينما إنحصرت قيم الرقم الهيدروجينى بين ٧,٤٤ و ٨,٠٣ كما تراوحت قيم التوصيل الكهربى لمستخلص عجينة التربة المشبعة من ٠,٧١ إلى ١٧١,٣٠ ديسيمنز/ م بمتوسط ٢٠,٣٣ ديسيمنز/ م. كان ترتيب تركيز الأنيونات الذائبة فى العينات كالتالى : كلوريد □ كبريتات □ بيكربونات. وكانتركيز الكاتيونات فكان ترتيبها كما يلى:صوديوم□ كالسيوم□ ماغنسيوم □ بوتاسيوم.أما نسبة إدمصاص الصوديوم فى محلول عجينة التربة المشبعة (SAR_e) فتراوح من٠,٣١ إلى ٨٥,٢٠ مع زيادتها بالعمق.كما تراوحت السعة التبادلية الكاتيونية (CEC) لهذة العينات بين ٦,٥٨ ،٥٩,٥٦ سينتيمول$^{(+)}$/كجم تربة.

تباينت قيم البوتاسيوم الميسر فى هذة الأراضى من ١٤٨,٩٨ إلى ٩٤٤,١٢ مللجرام/كجم بمتوسط ٤٥١,٨١مللجرام/ كجم .واظهرت النتائج أيضا أن٤٧,٠٦% من العينات المدروسة كانت تحتوى على مستوى مرتفع جدا منالبوتاسيوم الميسر (□ ٤٥٠ مللجرام/كجم)،٢٠,٥٦% من العينات بها مستوى مرتفع من البوتاسيوم الميسر (٢٥١-٤٥٠ مللجرام/كجم)،٢٩,٤١% من العينات المدروسة ذات مستوى متوسط من البوتاسيوم الميسر (١٥١-٢٥٠ مللجرام/ كجم)، ٢,٩٤ % فقط من العينات المدروسة بها مستوى منخفض من البوتاسيوم الميسر (٨٦ - ١٥٠ مللجرام/ كجم). كما وجد أن البوتاسيوم الميسر مرتبط إرتباطا موجبا مع محتوى التربة من السلت والطين ، السعة التشبعية ، التوصيل الكهربى ونسبة الصوديوم المدمص فى مستخلص عجينة التربة المشبعة ومع السعة التبادلية الكاتيونية وكذلك تركيز أيونات البوتاسيوم والماغنسيوم والصوديوم والبيكربونات والكبريتات بينما أظهرت النتائج أن البوتاسيوم الميسر إرتبط إرتباطا سالبا مع محتوى التربة من كل من الرمل وكربونات الكالسيوم.