Evaluation of Potassium Quantity-Intensity in some Soils of El-Dakhla Oasis, New Valley, Egypt

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ABSTRACT

The current research was carried out in 2016 to evaluate potassium Quantity-Intensity parameters and the relation of these parameters to the characteristics of some agricultural soils of El-Dakhla Oasis, New Valley, Egypt. Six surface soil samples (0-30 cm) were collected from different sites in El-Dakhla Oasis. The values of equilibrium activity ratio of potassium (AR^k_o) ranged between 0.0071 (soil 3) to 0.0320 $(mol/L)^{1/2}$(sample no. 1). The labile K ($-\Delta K^0$) values also, varied from 0.020 (sample no. 4) to 0.412 (cmol/kg soil (sample no.1).The values of the potassium potential buffering capacity (PBC^K) of soil ranged from 0.964 to 12.86 [(Cmol kg^{-1}/(mol $L^{-1})^{0.5}$]. Generally, the highest value of AR^k_o, ΔK^0, PBC^K parameters were related in soil sample no. 1[(0.032 $(mol/l)^{0.5}$, 0.412 cmol/kg, and 12.86 [(cmol kg^{-1}/(mol $L^{-1})^{0.5}$], respectively. The AR^k_o was a negatively significant correlated with exchangeable potassium (r=-0.822), Organic matter (-0.633) and available K (-0.444). A positive highly significant correlation was obtained between the labile K ($-\Delta K^0$)and both exchangeable Ca and Mg (r=0.936 and 0.941, respectively). The PBC^K showed a positive significant correlation with clay content, available K and cation exchangeable capacity (CEC), and negative significant correlations with soil pH (r=-0.795) and $CaCO_3$ (r=-0.633).

Key words: Quantity/Intensity parameters, Potassium kinetics, El-Dakhla Oasis.

INTRODUCTION

Potassium (K) is considered an essential macronutrient which is required relatively large amounts for plant growth . The soil potassium content can be classified into three categories; (1) the readily available form (soluble and exchangeable potassium), (2) the slowly available one (the non-exchangeable potassium), and (3) the unavailable form that includes the potassium in the structure of silicate minerals such as feldspars and micas (Brady, 1984). The availability of K in the soil solution, and the capacity of soil to buffer this concentration are among the important parameters that determine the effective available K for plants (Raheb and Heidari, 2012). The forms and dynamics of soil potassium are affected by changes in vegetative cover and biomass production (Awdenegest et al., 2013). The quantity/intensity (Q/I) ratio of potassium has been vastly disseminte in the scientific works to assess the K status in the soils. In this approach, immediate available K is related to the intensity factor, the reserve of the non-exchangeable K is referred to the quantity factor and the renewal capacity is applied to the buffering capacity (Royet al., 1991; Hamdan et al., 1999; Wang et al., 2004). The same time different soil having same equilibrium activity ratio of potassium (AR_e^k) values may not possess the capacity for keeping AR_e^k when soil K is decreased (Diattaet al., 2006). The potassium potential buffering capacity (PBC^K) describe soil capacity to resist changes in the content of available potassium under the impact of natural and anthropogenic factors (Zharikova, 2004). Several endeavors have been made to describe the relationship between the intensity of K and the buffering capacity of soil K content. Evangelou et al. (1994) reported that the high value of labile K indicates an increased release of K in the soil solution as a result of a greater pool of soil potassium. The high value of the potential buffering capacity of potassium (PBC^k) implies that the availability of K is good, while the low value of PBC^k indicates that K fertilization is required. This study aims to evaluate the quantity/intensity parameters of soil potassium and their relationship between these parameters and some soil properties in El-Dakhla Oasis.

MATERIALS AND METHODS

Locations: Soil samples were collected from different sites represented the agricultural soils of Dakhla Oasis, that is located in the middle of the Western Desert of Egypt between latitudes 25^o 29′ to 25^o 55′ N and longitudes 28^o 30′ to 29^o 32′ E (Fig 1). The soil samples were air-dried, crushed, passed through a 2 mm sieve and kept for analysis. The soil particle-size distribution was determined by the pipette method according to Jackson, (1969). The saturation percentage was measured as described by Hesse (1998). Organic matter was determined by the Walkley-Black method outlined in Jackson, (1973). Soil pH was determined in 1:2.5 of a soil deionized water suspension by Jackson, (1973). Total calcium carbonate was estimated using a manometric calcimeter (Nelson, 1982).

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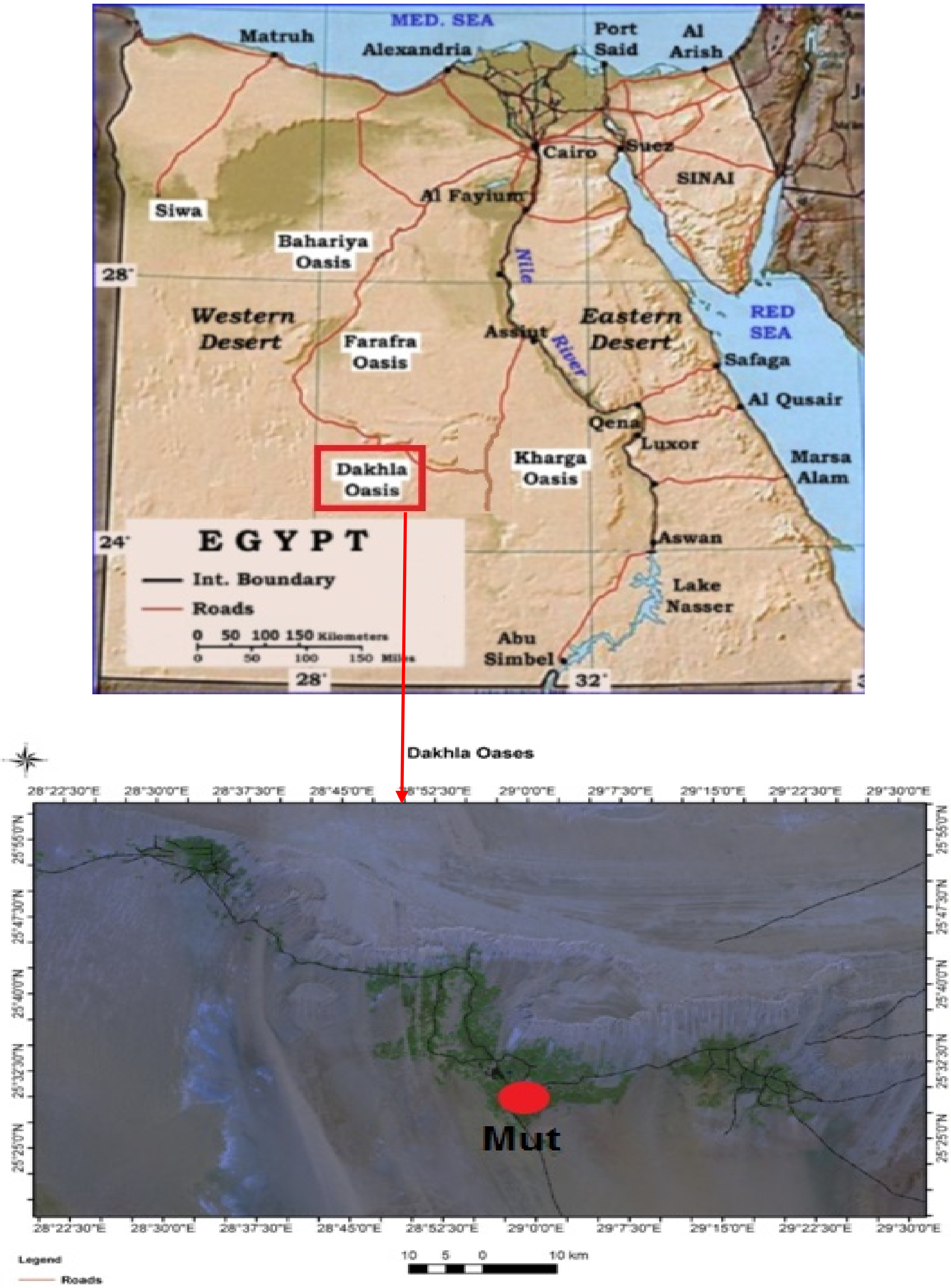

Figure 1. General map of Egypt and location of El-Dakhla Oasis map

The electrical conductivity (EC) was determined in a 1:2.5 of a soil to water extract using an electrical conductivity meter (Hesse, 1998). The cation exchange capacity (CEC) and the exchangeable cations (Ca, Mg and K) of the soil sample were determined according to Baruah and Barthakur, (1997). Available P was determined by 0.5 M $NaHCO_3$ extract at pH of 8.5 as described by Olsen et al.(1954).

Quantity/Intensity of potassium:

The quantity/intensity of potassium was detrimined by adding 50 ml of 10 mM $CaCl_2$ solutions containing various concentrations of potassium (0, 0.2, 0.4, 1, 2 and 4 mmol/l from KCl) to 5.0 g of the soil sample in bottles. The soil suspensions in the bottles were shaken for 2 hours, then left for overnight (24 hours) to complete equilibrium and centrifuged at 4000 rpm from 5 min. The suspension of soil samples was filtered and the supernatants were construe for potassium using flame photometer (PFP7), calcium, and magnesium. Potassium in equilibrium solutions was measured using the flame photometer while calcium plus magnesium was determined by the titration using ethyline-diamine tetra acetic acid (EDTA) solution. The factor of K quantity (ΔK) was computed from the difference in K concentration between the initial and equilibrium solutions. The activity coefficient of an ionic species was measured by using the Davies equation given by (Sposito, 1989) as:

$$\text{Log}\ \gamma = -0.512\ Z^2\ [(I^{0.5}/1+I^{0.5})-0.3I]$$

Where Z = the charge of *i* ionic species and *I* = the ionic strength that was calculated as follows:

$$I = ½\ \Sigma C_i Z_i^2$$

Where C_i is the concentration of *i* species in mmol/L

A plot of ΔK on the ordinate axis and activity ratios of K (AR^K) on the abscissa axis was constructed for each treatment to obtain the Q/I curve. Equilibrium activity ratios of K (AR_0^K) were extrapolated from x-intercepts of the Q/I plots at zero level of ΔK. The value of $-\Delta K^0$ (labile K) was extrapolated from y-intercept of the Q/I plots. The potential buffering capacity for K (PBC^K) is the slope of the Q/I curve (Usman and Gameh, 2008).

RESULTS AND DISCUSSION

Soil properties:

The soil physico-chemical properties are shown in Table 1. The results indicate that the soil samples have different soil texture. The clay content in soil 1 is relatively high, suggesting its ability to retain K. On the other hand, the soil 4 and 5 contained a relatively high sand fraction. The soil organic matter (OM) varied from 0.60g/kg (soil 4) to 15.5g/kg (soil 1). The high value of OM in soil 1 and 3 may be due to the high of clay and loam contents in these soils. Soil pH ranged from 7.58 (soil 1) to 8.85 (soil 4). So, most of the soils studied were slightly alkaline except soil 4 that is considered strongly alkaline. The soil salinity ranged from 2.02 dS/m (soil 5) to 9.17 dS/m (soil 4). The high level of EC may be due to the high content of chlorides of sodium, magnesium, and calcium sulfate. The cation exchange capacity (CEC) varied between 9.63 to 39.7 cmol kg^{-1}. The exchangeable potassium (K_{ex}) ranged from 0.08 to 0.46 cmol kg^{-1}; exchangeable Ca varied from 1.74 to 29.31 cmol kg^{-1}soil, exchangeable Mg differed from 1.06 to 17.61 cmol kg^{-1} soil. The K saturation is considered a value that expresses mobility parameters. K saturation was low in all soil samples except soils 2 and 6 which showed a relatively high potassium concentration (Yawson et al., 2011). Also, the content of $CaCO_3$ ranged from 28.70 to 268.40 g/kg andSoil available K ranged from 46.2 to 139.3 mg/kg. The high content of available Kin some soils may be attributed to the high content of clay and organic matter in these soils.

Quantity-Intensity (Q/I) Parameters

Equilibrium activity ratio of potassium (AR^k_o):

The Equilibrium activity ratio of K (AR^k_o) is obtained to measure the intensity of a labile K in the soil (Intensity factor) and represents the K that is instantly available to crop roots (Yawson et al., 2011). The values of AR^k_o ranged between 0.0071 and 0.0320 $(mol/L)^{0.5}$ (Table 2 and Figure 2). The soil 1 showed a higher AR^k_o value compared to the rest of soils. On the other hand, a lower (AR^k_o) value was recorded for the soil 3. The higher values of AR^k_o may be due to smaller exchangeable K percentage (EKP) as well as to potassium fertilization (Schneider, 1997). Sparks and Liebhardt, (1981) suggested that the adsorbed K was held at planer positions wherever the AR^k_o values were $>0.01(mol/L)^{0.5}$. Also, the low values of exchangeable Ca and Mg which increase the AR^k_o values (Lalitha and Dhakshinamoorthy, 2015). In the current study, the AR^k_0 values were higher than those reported by Wang et al.(2004), they found that the soils that have low values of K_{ex}, and their AR^k_o ranged from 0.001 to 0.010 $(mol/l)^{0.5}$.

The labile K ($-\Delta K^0$):

The labile K ($-\Delta K^0$) represents the available amount of K capable of ion exchange during the equilibrium between soil solids and solution (Lalitha and Dhakshinamoorthy, 2015). It has to maintain a balance between K on the soil colloids and K in soil solution by ionic exchange.

Table1. Some physical and chemical properties of the selected soils

Soil	Particle-size distribution (g/kg)			Texture	OM (g/kg)	pH (1:2.5)	EC (1:2.5) dS/m	$CaCO_3$ (g/kg)	Exchangeable bases (cmol kg^{-1})			CEC (cmol kg^{-1})	EKP (%)	Available K mg kg^{-1}
	Sand	Silt	Clay						Ca	Mg	K			
1	350	240	410	Clay	15.5	7.58	3.57	46.5	29.31	17.61	0.26	39.72	0.28	139.3
2	380	350	270	Loam	11.5	7.74	6.59	28.70	2.52	1.31	0.21	33.23	4.24	112.2
3	320	360	320	Clay loam	14.5	7.78	2.18	37.60	5.12	2.43	0.46	29.21	0.51	213.1
4	870	50	80	Sand	0.60	8.85	9.17	268.40	1.74	1.08	0.08	9.63	0.94	46.2
5	670	160	170	Sandy loam	1.10	8.03	2.02	93.10	2.10	1.06	0.13	27.69	0.58	82.3
6	52	23	25	Sandy clay loam	10.8	7.66	2.45	69.80	2.43	1.29	0.22	25.36	5.44	119.1

OM= Organic matter, $CaCO_3$= Total calcium carbonate and CEC=Cation exchange capacity, EKP= Exchangeable potassium percentage

Table 2. The quantity-intensity (Q/I) parameters of the experimental soils

Soil No.	Linear equation	R^2	AR_0^k $(mol/l)^{0.5}$	$-\Delta K^0$ (cmol kg^{-1})	PBC^K $[(cmol\ kg^{-1}/(mol\ l^{-1})^{0.5}]$
1	y = 12.86x - 0.412	0.994	0.0320	0.412	12.86
2	y = 6.495x - 0.125	0.988	0.0192	0.125	6.495
3	y = 4.493x - 0.032	0.978	0.0071	0.032	4.493
4	y = 0.964x - 0.02	0.643	0.0207	0.020	0.964
5	y = 3.286x - 0.067	0.982	0.0204	0.067	3.286
6	y = 9.043x - 0.127	0.947	0.0140	0.127	9.043

x= Activity ratio and y= Labile K

The labile K values of the soil samples varied from 0.020 to 0.412 cmol kg^{-1} soil (Table 2 and Figure 2). The highest value of labile K was recorded in soil 1 (0.412 cmol kg^{-1}). This high value of labile K may be attributed to the high CEC values and amount of loosely bound K^+ ions present in exchangeable site (Samadi, 2006). Also, the high values of labile K due to a greater K release into the soil solution, resulted in an increase in availability of K. Also, K fertilizer may be increase the labile K in the soil (Yawson et al., 2011). On the other hand, the lowest labile K value of soil 4 (0.020 cmol kg^{-1}) was due to the more retention of K because of the presence of montmorillonite clay mineral (Lalitha and Dhakshinamoorthy, 2015). In generall , most of the potassium added through mineral fertilizer or released from organic amendments in the calcareous or sandy soils (soil 4) are susceptible to leaching due to their lower CEC or clay content compared to high clay content in soil 1, that maintains a great amount of K on the clay exchange sites. On the other hand, the lowest labile K value of the studied soil sample 4 (0.020 cmol kg^{-1}) may be related to the low clay content and CEC. Also, most of the potassium added through mineral fertilizer or released from organic amendments in the calcareous or sandy soils (soil 4) released to the soil solution due to their lower CEC and clay content compared to high clay content in soil 1 that maintains a great amount of K exchanged on its clay particles. Moreover, some clay minerals such as vermiculite can fix the labile K between their layers which could be considered non-exchangeable form (Fanning et al., 1989).

Potential buffering capacity of potassium (PBC^K):

The PBC^K is the ability of a soil to maintain the intensity of K in soil solution. The PBC^K values of selected soil samples varied from 0.964 to 12.86 cmol kg^{-1}. All soil samples except soil 4 had high values of PBC^K (Table 2 and Figure 3). The PBC^k values are divided into very low (20 cmol kg^{-1} $(molL^{-1})^{½}$) and high (> 200 cmol kg^{-1} $(molL^{-1})^{½}$) (Zharikova, 2004). The variations in the PBC^K values of the study soil samples could be attributed to the variations in the texture, parent material, addition of crop residues and mineralogy of the soils (Al-Zubaidi et al., 2008). The high soil PBC^k value is an indication of good K availability, whereas a low PBCk soil would suggest a need for frequent K fertilizer application (LeRoux and Sumner, 1968).The high PBC^K values of the soils indicate a greater capacity for maintaining K concentration, but they enable a low K intensity. However, soil 4 which had a low PBC^K value would not maintain a given supply of potassium (Yawson et al., 2011). The low values of $PBC^K$are caused by the few sites of soluble K it is shown in Q/I isotherms of low buffering capacity. Moreover, the low PBC^K values in the soil samples mean that the potassium fertilization should be added frequently for optimum crop yield (Sparks and Liebhardt, 1981 and Ldigbor et al., 2009). The high K-buffering capacity also implies the high ability of the soil to maintain K and resist to potassium level change (Al-Zubaidi et al., 2008).

The Correlations Coefficients among Quantity-Intensity Parameters and Some Soil Properties

The activity ratio (AR_k^0) has significantly negative correlation with organic matter, CEC, exchangeable potassium, and available K (r=-0.633**, r=-0.289*, r=-0.822**, and r=-0.444*, respectively (Table 3). AR_k^0 was positively and significantly correlated with Ca (r=0.709**) and Mg (r=0.731**).However, AR_k^0 correlations with pH, clay, EC, $CaCO_3$, and CEC were not significant. Labile K ($-\Delta K^0$) was positively correlated with clay, Ca_{ex}, Mg_{ex}, (r= 0.742**, r= 0.936**, r=0.941**), respectively, but it was positively and non-significant with available K (r=0.166).The $-\Delta K^0$of the studied soil samples was significant and negatively correlated with pH, EC, $CaCO_3$ and K_{ex}. On the other hand, the $-\Delta K^0$ was positively correlated with clay content (0.742**), OM (0.567*), CEC (0.712**), Ca_{ex} (0.936**) and Mg_{ex} (0.941**). Also, the correlation coefficients between the potential buffering capacity (PBC^K) and the clay content, silt, OM, CEC, Ca and Mg of the studied soils was positively significant and were r=0.844**, r=0.410*, r=0.762**, r=0.775**, r= 0.770** and 0.768**, respectively.

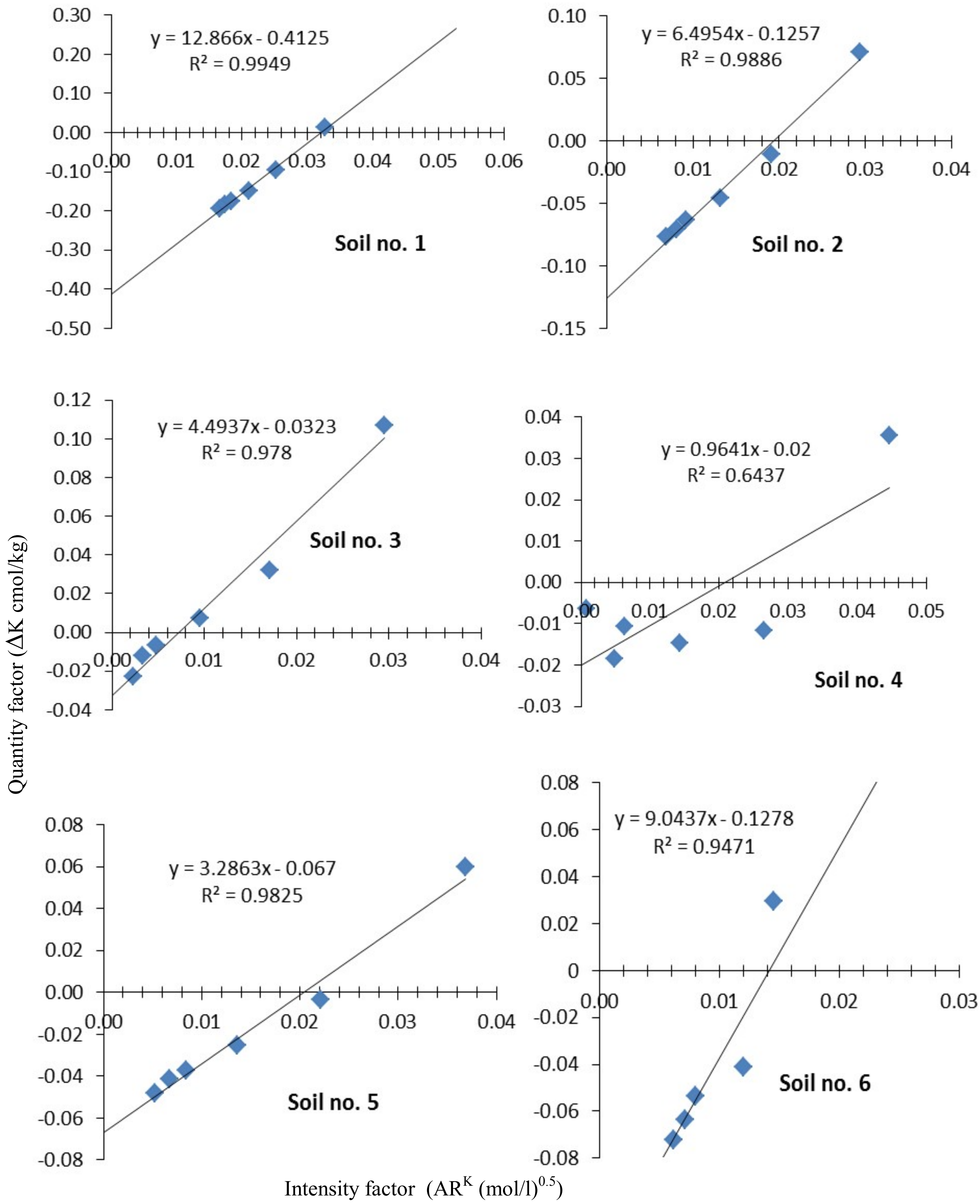

Figure 2. The K quantity-intensity (Q/I) isotherms of the studied soil samples

Table 3. The correlation coefficients between potassium quantity-intensity parameters and some soil properties

Soil property	Ar_k^0	$-\Delta K^0$	PBC^K
Clay(%)	0.179	0.742**	0.844**
Silt (%)	-0.371	0.161	0.410*
pH	0.013	-0.555	-0.795**
EC d/Sm	0.254	-0.187	-0.396
$CaCO_3$(%)	0.122	-0.407*	-0.633**
OM(%)	-0.633**	0.567*	0.762**
CEC	0.289*	0.712**	0.775**
Ca_{ex}	0.709**	0.936**	0.770**
Mg_{ex}	0.731**	0.941**	0.768**
K_{ex}	-0.822**	-0.334	0.027
Available K	-0.444*	0.166	0.381

* $p<0.05$ and ** $p<0.01$

These results may be explained by the competitive relation existing between the activity of K and the activity ratio of Ca^{+2} and Mg^{+2} content (Abaslou and Abtahi, 2008). and Yeledhalli et al., 2011). Also,they reported that the PBC^K had a significant positive correlation with the clay content (r=0.9944) indicating that the clay is responsible for the replenishment of soil solution K^+. Also, the PBC^K was significantly and negitively correlated with soil pH (r=-0.795**) and $CaCO_3$ (-0.633**). These relationships deserve more exploration to further understand potassium dynamics in soils and to ease modeling and prediction of K behavior in soils.

CONCLUSION

The studied soil samples showed variation in the physical-chemical properties, texture, EC, pH, organic carbon, $CaCO_3$, and exchangeable K. In this study, some soils had a high K intensity and lower in PBC^K. So, these soil samples will require frequent K fertilization. Generally, AR_o^k, $-\Delta K_o$ and PBC^k levels were increased with increasing the clay content and CEC of the studied soil samples. It is recommended that application of organic amendments to these soils, especially the sandy ones, can improve the potassium status, and Q/I parameters of potassium.

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الملخص العربي

تقييم شدة وكمية البوتاسيوم فى بعض أراضى واحة الداخلة بالوادى الجديد – مصر

مهدى حسن حامد، أبوالعيون أبو زيد أمين

أجريت هذه الدراسة فى عام ٢٠١٦ بهدف تقييم مقاييس الشدة والكمية للبوتاسيوم وعلاقة هذه المقاييس ببعض صفات التربة للأراضى المنزرعة فى واحة الداخلة بالوادى الجديد–مصر. حيث تم جمع ستة عينات تربة من الطبقة السطحية (صفر–٣٠ سم) من اماكن مختلفة من واحة الداخلة (موط). وأظهرت النتائج أن قيم نسبة النشاط البوتاسى عند الاتزان (AR_o^k) تراوحت من ٠,٠٠٧١ (التربة رقم ٣) الى ٠,٠٣٢٠ (مول/لتر)^{٠,٥} (التربة رقم ١).كذلك تراوحت قيم البوتاسيوم المتغير ($-\Delta K^0$) من ٠,٠٢٠ (التربة رقم ٣) الى ٠,٤١٢ سنتيمول/كجم تربة (التربة رقم ١). قيم السعة التنظيمية للبوتاسيوم (PBC^k)لعينات التربة تحت الدراسة تراوحت من ٠,٩٦٤ الى ١٢,٨٦ (سنتيمول كجم$^{-١}$ /مول لتر$^{-١}$)$^{-٠,٥}$. عموماً كانت أعلى قيمة لنسبة النشاط البوتاسى عند الاتزان والبوتاسيوم المتغير والسعة التنظيمية للبوتاسيوم فى عينات التربة تحت الدراسة بالعينة رقم ١ {(٠,٠٣٢٠ مول/لتر، ٠,٤١٢ سنتيمول/كجم ، ١٢,٨٦ (سنتيمول كجم$^{-١}$ /مول لتر$^{-١}$)$^{-٠,٥}$ }على التوالى. أعطت نسبة النشاط عند الاتزان علاقة معنوية سالبة مع البوتاسيوم المتبادل (r=-0.822) والمادة العضوية (r=-0.633) والفوسفور الميسر (r=-0.444). كذلك أعطى البوتاسيوم المتغير علاقة معنوية مع كل من الكالسيوم والماغنسيوم المتبادل والمادة العضوية والبوتاسيوم الميسر. أيضا أعطت السعة التنظيمية للبوتاسيوم علاقة معنوية موجبة مع محتوى الطين والبوتاسيوم الميسر والسعة التبادلية الكاتيونية، بينما أعطت علاقة معنوية سالبة مع رقم الحموضة(r=-0.795) وكربونات الكالسيوم (r=-0.633).