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POTASSIUM STATUS IN SOILS WITH DIFFERENT CONTENT OF CLAY

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Abstract

Potassium (K) is a vital nutrient for crop growth in soil. The parameters (quantity- intensity (Q/I) relationships provide some useful information for understanding K availability in calcareous soils. In this study was evaluated the K status, in some calcareous soil content different rate of calcium carbonate and clay particles using Q/I for better K fertilizer recommendation. The results showed the activity ratio of potassium ranged from 60×10^{-4} to 86×10^{-4}. The free energy ($-\Delta F$) values varied from (- 3027.36 calmol^{-1}) to (-2819.06 cal mol^{-1}) and all soils were classified as medium in supplying power of K. The potential buffering capacity (PBC^{K}) values varied from 317.38 cmol kg^{-1} mol L^{-1} to 381.77 cmol kg^{-1} mol L^{-1} and all soils category as high in PBC^{K}. The higher values of PBC^{K} indicate that soils could be have higher adjusted power to change in K through growing season. Therefore, the result of Q/I parameters should be taken in consideration when potassium fertilizer recommendation is made.

Key words : Potassium, Soils, Clay.

Introduction

Potassium (K) is a vital nutrient for crop growth in soil (Prajapati, Kalavati., and Modi, 2012). Potassium exists in soil as in four different forms: mineral or structural K, non-exchangeable K, exchangeable K and K in soil solution, all these forms are in equilibrium (Adesanwo *et al.,* 2015). Moreover, soil potassium can be divided into three forms depended on its availability for plant which is; unavailable =mineral or structural K, slowly available = non exchangeable K and readily available = K in soil solution or exchangeable K (Rao and Srinivas, 2017).

The evaluation K available for making K fertilizer recommendation for plant growth are depended on K exchangeable values were determined by traditional method (e.g. NH_4OAc) in soil (Islam *et al.,* 2017). However, studies showed this method was not a good indicator for K available uptake by plant during the season of growth (Islam *et al.,* 2017). On the other hand, many studies have used quantity- intensity relationship (Q/I) to make K fertilizer recommendation due to its provide good information on K availability in soil (Lalitha and Dhakshinamoorthy, 2015; Abu Zied Amin, 2016; Panda and Patra, 2018; Bilias and Barbayiannis, 2019; Das *et al.,* 2019).

The parameters, quantity- intensity (Q/I), potential buffering capacity (PBC^{K}), potassium activity, activity ratio and free energy of potassium help to understand availability of K in calcareous soils (Jalali, 2007; Hosseinpur and Tadayon, 2013). Potassium status can be affected by physical, chemical and mineralogy properties of soil (Bilias and Barbayiannis, 2019). Calcareous soils are speared in semiarid and arid soil regions. Calcareous soils are defined as soils having quantities of calcium carbonate ($CaCO_3$) which affect the soil physical properties (e.g. soil-water relation, soil crusting) or chemical properties (e.g. availability of nutrients for plants) to plant growth (Taalab *et al.,* 2019). Study showed that the removal of calcium carbonate from the soils led to increase the amount of fixed potassium (Edan and AI-Zubaidi, 1992). The results of study by Al-Zubaidi and AI-Rabai, 2001 showed that the thermodynamic parameters were varied despite the similarity in exchangeable K and they concluded the thermodynamic parameters better expressed the K supplying power of these soils with varying texture and

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mineralogy than did exchangeable K. Some works have been completed on the K status in calcareous soil in Iraq but there is little information on the effect of different rate of soil calcium carbonate content on status of K, thus the need for this research effort. Therefore, the aim of this study is to evaluate the K status, in some calcareous soil content different rate of calcium carbonate and clay particles using Q/I isotherms for better K fertilizer recommendation.

Materials and Methods

Soil characterization

Five soil samples were sampled from a 0-30 cm depth depended on their clay content. The global positioning system points of sampling places were 467046 N and 3742860 E, 467335 N and 3741690 E, 468202 N and 3757410 E, 468466 N and 3758770 E, 467461 N and 3740480 E for samples 1, 2, 3, 3, 4 and 5, respectively. The samples were dried, ground and sieved with a 2 mm sieve. The physiochemical properties of the soils are summarized in Table 1. Soil pH and electrical conductivity (EC) were determined using a deionized water with a 1:1 (soil: water) ratio. Cation exchange capacity (CEC) was measured using ammonium acetate according to Black (1965). Organic matter was estimated according to Walkley and Black method (Nelson and Summers, 1982) (Wang *et al.,* 2004). Calcium carbonate ($CaCO_3$) was determined by calculating losing weight using HCl (3N) according Drouineauand Galet (1972). Soil particle size was measured followed pipped method (Gee and Bauder, 1986).

Quantity/Intensity Experiment

Quantity/Intensity (Q/I) relationships were carried out according to beckett (1964). Soil samples (5 g) in duplicate were set up in to 100-mL polyethylene centrifuge tube and 50 mL of $CaCl_2 + MgCl_2$ (0.002 M) containing KCl concentration (0, 0.63, 1.25, 2.5, 3.8, 5.0, 6.4 mmol L^{-1}) were added. The prepared soil suspensions were shaken for 3 h, allowed to equilibrate for 24 h. The samples were centrifuged for 5 min at 1500 rpm. Then, the filtered supernatants were measured for Ca and Mg by titration using Na_2EDTA and K by flame photometry (Black, 1965). The electrical conductivity (EC) was measured in all supernatants. Ionic strength (I) was determined according to relationship suggested by Griffin and Jurinak (1973) using EC values as equation 1.

$$I = EC \times 0.031 \qquad .... (1)$$

Activity coefficient for Ca, Mg and K were calculated according to equation of Debye and Huckle (Lindsay, 1979) as equation 2.

$$\text{Log } fi = -AZ^2\sqrt{I} \;/\; 1+Bdi\sqrt{I} \qquad .... (2)$$

The quantity factor (“K) for K was calculated from the differences between initial and equilibrium K concentration in solution. Meanwhile, activity ratio (AR^k) was used to describe the K intensity as equation 3.

$$AR^k = \frac{aK}{\sqrt{aCa + aMg}} \qquad .... (3)$$

where *a*K, *a*Ca and *a*Mg are activity of potassium, calcium and magnesium in equilibrium solution, respectively.

The results for ΔK and AR^k w are drawn according to Beckett (1964) as (Fig. 1). The labile potassium and (PBC^K) values were got from the intercept and slope of straight-line equation.

The potassium free energy of replacement (-Δ F) was calculated as equation 4.

$$-\Delta F = 2.303\ RT \log AR^K \qquad .... (4)$$

where T and R are absolute temperature and gas constant, respectively.

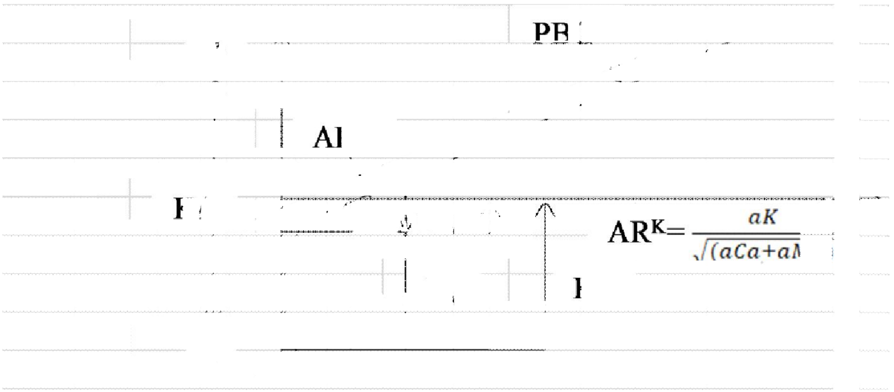

Fig. 1: A typical (Q/I) plot, A^{RK} = potassium activity ratio; K_L = labile K; K_x = specific K; $-\Delta K_0$ = nonspecific K; PBC^K = potential buffering capacity for potassium.

Results and Discussions

Soil properties

The results of selected physiochemical properties of the soil samples were shown in table 1. The soils pH were neutral to slightly alkaline with EC values ranged from 1.3 to 5.6 dS m^{-1} with low organic matter. The $CaCO_3$ varied from 142 to 340 g kg^{-1} and CEC ranged from 17 to 24 $cmol_+kg^{-1}$. In general, all soil samples were characterized as medium in CEC values. The clay fractions varied from 96 to 301.2 g kg^{-1} the texture of soil was silty loam, loam and clay.

Potassium Q/I Relationships

The Q/I parameters of potassium are shown in Table 2. The potassium activity coefficient values ranged from 0.78 in soil no. 1 to 0.87 in soil no. 3 and 4 that means 13% to 22% of soluble K^+ in soil solution is exit in inactive status. Conversely, the high values of activity coefficient indicate that the most K^+ in soil is exist in solution as in active form due to the ionic strength values of soils are low (Table 2).

The activity ratio of potassium ranged from 60×10^{-4} in soil no. 2 to 86×10^{-4} in soil no. 1. The activity ratio values reflect the chemical potential; the greater values mean that more K is available for uptake by plant (Al-Zubaidi *et al.,* 2008)and high values are generally associated with K fertilization (Becket 1964; Sparks and Liebhardt 1981)or naturally high exchangeable K levels (Jimenez and Parra 1991; Evangelou, Wang, and Philips 1986). According to Van Schouwenburg and Schuffelen (1963), $> 100\times10^{-4}$ refers to that the K exchanged during equilibration was adsorbed on planar sites; whereas, $K<10\times10^{-4}$ refers to that the K comes from more specific wedge and edge sites. In this study, the values were less than 100×10^{-4} but much more than 10×10^{-4}, referring that apart from edge and wedge sites, planar K also took ration in exchange reactions with Ca and Mg.

The free energy of replacement (- Δ F) values varied from (- 3027.36 cal mol^{-1}) of soil No. 2 to (-2819.06 cal mol^{-1}) of soil No.1 (Table 2 and Fig. 2). According to Woodruff (1955) the supplying power of soils classified the (- Δ F) values to: Soil with high supplying power of K has (-Δ F) less than -2500 cal mol^{-1}, and that of (-ΔF) -2500 to - 3500 cal mol^{-1} has medium K supplying power, while soil that has (-ΔF) value that is lower than - 3500 cal mol^{-1}, is poor in supplying potassium. The Fig. 2, shows that all soils have medium in supplying power of K. It is important to point out here that despite of differences in values of AR^K table 2 but all soils have a medium power for supplying K and plants may not respond to potassium fertilization

Soil buffering capacity and labile K

The values of activity ratio in the equilibrium solutions were plotted against the change in exchangeable potassium values, a series of linear curves were obtained with high significant correlation coefficient values (r = 0.99), in present studied soils (Fig. 3). The linear curves obtained with differ in intercepts and slopes, it's more likely to attribute to the variation soils in their contents in clay particles, and $CaCO_3$ (Table 2). This data show that the values of PBC^K vary from 317.38 cmol kg^{-1} mol L^{-1}in soil no. 3 to 381.77 cmol kg^{-1} mol L^{-1} for soil no. 5 (Table 3). This differentiation could be attributed to the variance in the texture, $CaCO_3$ and CEC of the studied soils. Al-Zubaidi *et al.*, (2008) found that there is a significant positive correlation between CEC values and PBC^K of

Table 1: Physiochemical properties of soil samples.

Soil sample	CEC $cmol_+$ kg^{-1} soil	pH	ECdS m^{-1}	O.M	$CaCO_3$	Sand	Silt	Clay	Texture
				g kg^{-1}					
1	20	7.8	5.6	7.6	142	456.0	342.4	201.6	Loam
2	21	7.9	2.8	7.2	340	176.0	642.4	181.6	Silty Loam
3	18	7.8	1.3	6.4	209	376.3	421.3	202.4	Loam
4	17	7.9	1.3	9.3	291	298.5	605.5	96.0	Silty Loam
5	24	8.2	3.7	5.7	340	316.6	382.2	301.2	Clay

Table 2: Thermodynamic parameters of K in soil samples.

Soil sample	Ionic Strength (mol L^{-1})	Activity coefficient	K-activity (mol L^{-1})	Activity Ratio	ΔF(cal mol^{-1})
1	0.073	0.78	76×10^{-5}	86×10^{-4}	-2819.06
2	0.036	0.83	46×10^{-5}	60×10^{-4}	-3027.36
3	0.017	0.87	38×10^{-5}	65×10^{-4}	-2979.84
4	0.017	0.87	38×10^{-5}	66×10^{-4}	-2971.72
5	0.048	0.81	65×10^{-5}	82×10^{-4}	-2845.41

Table 3: Potential buffering capacity and labile potassium in soil samples.

Soil sample	Potential buffering capacity (PBC) (cmol kg^{-1} / mol L^{-1})	Labile potassium (cmol kg^{-1})	R^2
1	347.45	1.37	0.98
2	347.84	0.86	0.98
3	317.38	1.06	0.98
4	354.62	1.08	0.95
5	381.77	0.78	0.98

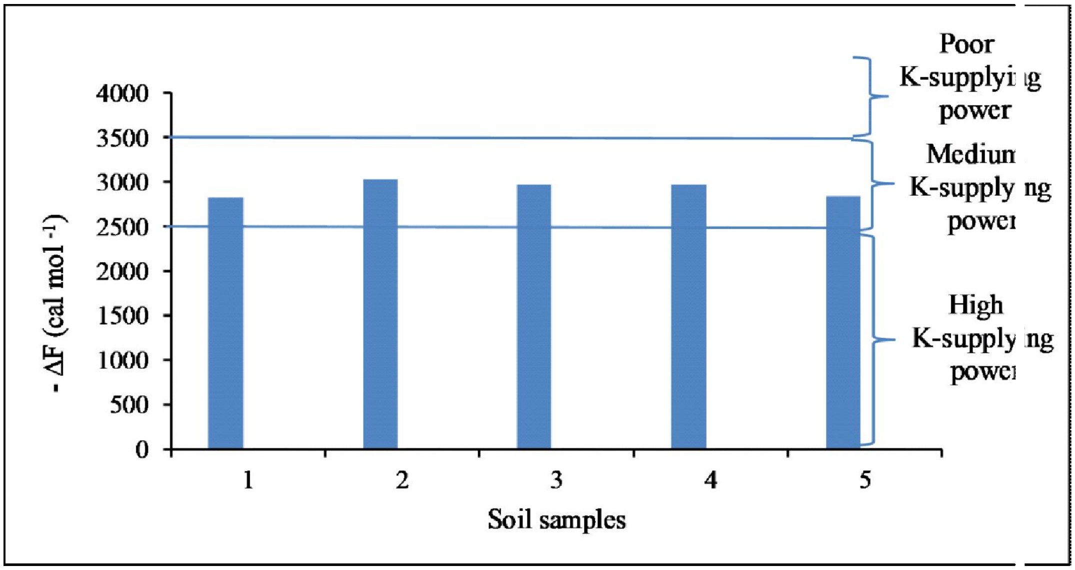

Fig. 2: The free energy (-ΔF) classified potassium according to woodruff classification.

soils in their study on some Lebanese soils.

The soils with higher values of PBC^K refer to have higher adjusted power to change in K through the growing season. Therefore, PBC^K values could help us to plan how to manage K fertilization. Zharikova (2004) classified the values of PBC^K into two categories; very low (20 cmol kg^{-1} $(molL^{-1})^{½}$) and high (> 200 cmol kg^{-1} $(molL^{-1})^{½}$). According to this classification, all soils of the present study category as high in PBC^K. The high value of PBC^K for soil is an suggestion of worthy K availability, however the soil with low PBC^K could propose a necessary for repeat K fertilizer application (LeRoux and Sumner, 1968).

Table 3 shows the labile potassium values in the present studied soils, this terms refer to the part of potassium adsorbed on unspecific sites which is ready to be released for uptake by root of plant through growth season. The values of labile potassium varied from 0.78 cmol L^{-1} in soil no. 5 to 1.37 cmol L^{-1} in soil no. 1 (Table 3). The higher labile K value refer to the higher amount of lightly bonded K^+ ions existing in exchangeable site. The lower value of labile K is due to the presence of clay minerals that lead to retain higher potassium.

Conclusions

Quantity – intensity isotherms give a good information of potassium dynamic in soil. The soil properties ($CaCO_3$, clay particles content and CEC) were more effected on K status. Soil with higher clay particles content was higher potential buffering capacity. This result should be considerable when potassium fertilizer recommendation is made.

Conflict of interest

The authors declare that no conflict of interest in present study.

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