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## Potassium Quantity-Intensity Parameters and its Correlation with Selected Soil Properties in Some Soils of Iran

H. Abaslou and A. Abtahi

Department of Soil Science, College of Agriculture, Shiraz University, Shiraz, Iran

**Abstract:** Potassium exchange-equilibrium were obtained from quantity-intensity (Q/I) isotherms, i.e., K equilibrium activity ratio ( $AR_0^k$ ), K labile ( $K_{lab}$ ), equilibrium potential buffering capacity for k ( $PBC_{equ}^k$ ), free energy of k replishment ( $-\Delta G_{equ}^k$ ), the Gapon selectivity coefficient ( $k_G$ ), least soil exchangeable potassium (Emin) and initial equilibrium concentration solution potassium ( $C, k_0$ ). Characterization of these relations provides general information on the nature of K equilibrium and serve as a good index of K supplying power of soil. Plant availability of soil potassium is controlled by dynamic interactions among its different pools. Misunderstanding of these dynamics leads to mismanagement of soil fertility. These relationships were investigated in some selected soils of Fars province, Iran. K equilibrium activity ratio ( $AR_0^k$ ) ranged between 1.74 to 19.90 ( $\text{mmol dm}^{-3}$ )<sup>0.5</sup>, labile K values fluctuated within the range 1.28 to -9.78 meq 100 g<sup>-1</sup> soil. And equilibrium potential buffering capacity ( $PBC_{equ}^k$ ) fluctuated from 31.14 to 100.64 meq 100 g<sup>-1</sup> ( $\text{mmol dm}^{-3}$ )<sup>0.5</sup>. Potassium was significantly controlled by soil properties. Potassium activity was controlled more by silt ( $r = 0.80^{**}$ ), Mn-BCD ( $r = 0.67^*$ ), Mn-OX ( $r = 0.73^*$ ) and the  $-\Delta G_{equ}^k$  values had significantly correlated with silt ( $r = 0.79^*$ ), Mn-BCD ( $r = 0.68^*$ ) Mn-OX ( $r = 0.71^*$ ). This result implies that studies of potassium dynamics of soils should additionally consider the level of Fe and especially Mn, as well. The Q/I parameters provide useful information for understanding K<sup>+</sup> availability in calcareous soils and can be used for K<sup>+</sup> fertilizer recommendations.

**Key words:** Potassium quantity-intensity isotherms, activity ratio, labile K, potential buffering capacity, free energy of replenishment, gapon selectivity coefficient, Iran

### INTRODUCTION

In spite of the fact that the total potassium of most soils is high but a small portion of this element is accessible for plants (Woodruff, 1955).

Availability of K to plants depends on its intensity, capacity and removal rate of soils. Intensity is the total amount of k in solution, capacity consists mainly of exchangeable k but may also includes some fixed k and k related from easily weathered minerals and renewal rate is a kinetic factor describing the k transfer rate from capacity to intensity (Woodruff, 1955).

It has been suggested that the activity ratio

$$\gamma K_{equ} / \sqrt{(\gamma Ca + \gamma Mg)_{equ}} \text{ or } AR_{equ}^k,$$

in a solution equilibrium with a soil provides a satisfactory measurement of their availability or the potential of potassium.  $AR_{equ}^k$  is a measure of the intensity of labile K in the soil. Different soils exhibiting the same value of  $AR_{equ}^k$  may not possess the same capacity for maintaining  $AR_{equ}^k$  while K is removed by plant roots (Diatta *et al.*, 2006). So, to describe the K status of a soil we must specify not only the current potential of K in the labile

pool but also the form of the quantity-intensity relation (Q/I relation) or the way in which the potential depends upon the quantity of labile k present.

The amount of measured exchangeable K with  $NH_4OAc$  (1 N) is used extremely as a way for evaluation of soil adsorbable k status ( $K_{ads}$ ) and determination of plant requirement to k fertilizers.

Soils of rich mica minerals, maintained much of its K with high energy because of specific barrier of k adsorption. A portion of k is released during extraction with  $NH_4OAc$  (Hoseinpour and Kalbasi, 2000). Likely that's way, is weak correlation between extracted K with  $NH_4OAc$  and plant response to K fertilizer in these soils (Hoseinpour and Kalbasi, 2000; Beckett, 1964). In recent years, it has been attempted to finding another suitable methods for plant requirement evaluation to k fertilizer in enrichment soils of mica minerals such as use of exchangeable relation of K<sup>+</sup> with  $Ca^{2+} + Mg^{2+}$  (Al-Kanani *et al.*, 1984). Matthews and Beckett (1962) have showed a method for describing relations between exchangeable and soluble k, which is called potassium quantity-intensity relations.

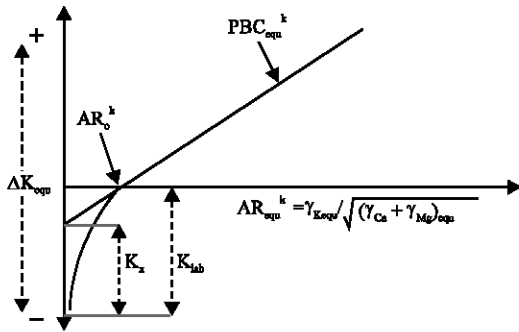


Fig. 1: A typical quantity/intensity (Q/I) plot.  $\Delta K$ : quantity by which the soil gains or loses k in reaching equilibrium or the quantity factor,  $AR_{eq}^k$ : activity ratio for K or the intensity factor,  $AR_0^k$ : equilibrium activity ratio for K or the intensity factor,  $PBC_{eq}^k$ : Equilibrium potential buffering capacity for potassium at  $AR_0^k$ ,  $K_{lab}$ : labile K,  $K_{ex}$ : specific K sites (a measure of edge sites)

Various efforts have been made to determine the relationship between intensity and capacity of soil k or soil k buffering characteristics (Arnold, 1978; Sparks and Liebhardt, 1981; Al-Kanani *et al.*, 1984; Roy *et al.*, 1991; Alafifi, 1996; Wang and Scott, 2001; Diatta *et al.*, 2006; Samadi, 2006; Jalali, 2007). It was reported that higher values of labile K indicated a greater K release into soil solution resulting from a larger pool of soil K. A higher potential buffering capacity for potassium ( $PBC_0^k$ ) value is indicative of a good K availability while a low  $PBC_0^k$  soil would suggest a need for potassium fertilization (Wang *et al.*, 2004). Potassium, calcium and magnesium equilibrium in the soil solution and solid phase may be described also by using the modified Gapon equation (1933) as a graph of  $K_{ex}/CA_{ex} + Mg_{ex}$  against  $\gamma K_{ex}/\gamma CA_{ex} + \gamma Mg_{ex}$ . However in most field soils  $K_{ex} \ll Ca_{ex} + Mg_{ex}$ . If so, small changes in  $K_{ex}$  may be accompanied by only insignificant changes in  $Ca_{ex} + Mg_{ex}$  and the isotherm may be represented as a graph of  $K_{ex}$  versus  $\gamma K_{ex}/\gamma CA_{ex} + \gamma Mg_{ex}$ .

Therefore, in this form, the isotherm directly relates the quantity factor to the intensity factor of soil K. A typical K quantity-intensity relation is demonstrated (Fig. 1). This relationship implies that the ability of a soil system to maintain a certain concentration of a cation in solution is determined by the total amount of the cation present in intensity by which it is released into the soil solution (Beckett, 1964).

In recent years, use of k fertilizer is started and is increasing in Iranian soils. In this case, it is necessary to aware of soil fertility based on K amounts. Since plant growth is not directly limited by the amounts of

exchangeable soil K, therefore, it should be necessary to elucidate this phenomenon on the basis of equilibrium studies in order to test the immediate power of soils to supply K to plants. This approach needs the use of equilibrium (Q/I) concept.

Such imprehensive studies are intended to outline some specific information which should clearly determine the capacity of soils for K supply and replenishment.

The objectives of the present study are to evaluate potassium dynamics of some selected Fars agricultural soils, by applying the quantity-intensity (Q/I) concept and evaluation the relationship of soil properties with potassium quantity-intensity parameters (Fig. 1).

### MATERIALS AND METHODS

**Soil samples and properties:** Nine soil samples representing 5 soil orders (Entisols, Inceptiso, Aridisols, Vertisols, Alfisols) from agricultural lands of the Bakhtegan lake marginal region (29° 17.2' N, 57° 53' E, Fars province, Iran) were selected. All soil series were studied and classified according to USDA soil taxonomy (Soil Survey Staff, 2006). Soil samples were air dried and passed through a 2 mm sieve, prior to chemical analysis. Particle size was determined by hydrometer method (Bouyoucos, 1951). Organic carbon was determined by dichromate oxidation and the Cation Exchange Capacity (CEC) of the soils was obtained by  $NH_4OAC$  (pH = 7) method. Exchangeable K ( $K_{ex}$ ) was measured by the method of  $NH_4OAC$  (1 M) buffered at pH = 7 (Page *et al.*, 1992) K saturation (K%) can be estimated from the following equation (Mustcher, 1995).

$$K\% = \frac{K_{ads}(\text{cmol.kg}^{-1})}{CEC(\text{cmol.kg}^{-1})}$$

Soil pH was potentiometrically measured in water and 1 M KCl extracts at soil to solution ratio of 1: 25 and  $\Delta PH (= pH_{KCL} - pH_{H_2O})$  and calculated as reported by Arnold (1978).

**Potassium exchange isotherms [Quantity-intensity relations (Q/I)]:** The Q/I curves were determined as follows:

Eleven soil suspensions were prepared for each selected soil sample. Six of them were containing 2.5 g soil and 25 mL of  $CaCl_2$  (0.002 M) with 0, 0.1, 0.2, 0.4, 0.8 and 1.6 mmol KCl concentrations. Other suspensions were made by application soil to solution ratio: 13.5, 20, 40, 80, 200 using  $CaCl_2$  (0.002 M) without KCl. The prepared soil suspensions were shaken for 1 h at 298°K, allowed to

equilibrate for 16 h, centrifuged and then the supernatants were analyzed for K by flame photometry. Concentrations of Ca and Mg in the solution were measured by titration using EDTA. Activity ratios were calculated with the Davis equations (Davis, 1962). The amount of gained or lost ( $\Delta K$ ) by the soil was calculated from the difference between the amounts of K added or removed in the final solution. Releasing and adsorption curves of Q/I potassium were drawn by variation of potassium activity ratio ( $AR^k$ ) versus variation of extracted exchangeable potassium with  $NH_4OAc$  1M (Ef) and versus the amount of K gained or lost ( $\Delta K$ ), respectively. The adsorption curves are typical plots of Q/I. The intercept of the Q/I curve on the  $AR^k$  axis gave the equilibrium AR for K,  $AR^0$ , which denotes the soil solution K activity relative to the Ca + Mg at equilibrium. The linear part of the curve was extrapolated to intercept the  $\Delta K$  axis; this represents the amount or readily exchangeable K held in the soil ( $\Delta K^0$ ).

The free energy of K replenishment ( $-\Delta G_{equ}^k$ ) was computed from the following equation as reported by Beckett (1964).

$$-\Delta G_{equ}^k = 2.303 RT \log AR_0^k$$

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

Gapon (1933) has suggested an equilibrium coefficient  $K_G$  relating  $K_{ex}$ ,  $Ca_{ex}$  and  $Mg_{ex}$  with their solution concentrations, in terms of activity. Therefore comparison of soils on the basis of the Gapon selectivity coefficients ( $K_G$ ) should provide good comprehensive and indicative information of potassium replenishment capacity of the soils (Diatta *et al.*, 2006) the  $K_G$  as reported by Beckett (1964) may be arranged and calculated as follows:

$$\frac{K_{ex}}{(Ca + Mg)_{ex}} = K_G \cdot \frac{\gamma K_{equ}}{\sqrt{(\gamma Ca + \gamma Mg)_{equ}}}$$

By rearrangement this equation to the quantity-intensity form, the following is obtained.

$$K_G = \frac{K_{ex}}{(Ca + Mg)_{ex}} \cdot \frac{\sqrt{(\gamma Ca + \gamma Mg)_{equ}}}{\gamma K_{equ}}$$

Assuming  $Ca_{ex} + Mg_{ex} = CEC$  on exchange material, therefore;

$$K_G = \frac{K_{ex}}{CEC} \cdot AR_{equ}^k \rightarrow EPP = 100 \cdot K_G \cdot AR_{equ}^k$$

That EPP is exchangeable sodium percentage.

## RESULTS AND DISCUSSION

**Soil properties:** Selected properties of the studied soils presented in Table 1a, b, show that these properties differed notably, while they were almost from the same region.

Soil particles, especially clay, organic carbon varied significantly even in soils of the region. Variations are 10-51 and 0.5-1.6%, respectively.

The soil pH in water ( $pH_{H_2O}$ ) was mostly slightly alkaline and the difference  $pH_{KCl} - pH_{H_2O}$  is negative for all soils, suggesting the predominance of negative charges (Diatta *et al.*, 2006). Cation Exchange Capacity (CEC) values of soils were in the range from 8.7 to 26  $cmol_{(+)}$   $kg^{-1}$ . Amounts of soil solution K ( $K$ ) and exchangeable K ( $K_{ex}$ ) fluctuated from 0.14 to 3.16 ( $meq L^{-1}$ ) and 0.24 to 0.85 ( $meq kg^{-1}$ ), respectively.

The soils contained a significant percentage of K saturation (%K), varied from 1.19 to 4.51% (Table 1b). In some countries, the k saturation is used for assessment of soil k- status (Mustcher, 1995).

**Potassium quantity-intensity (Q/I) parameters:** Q/I relationships for the studied soils are shown in Fig. 2. And amounts of quantity-intensity isotherms are presented in Table 2.

According to Q/I plots, was inferred that potassium Q/I releasing curves as compared with potassium Q/I adsorption curves had a lower slope in all soils due to K fixation in soil. The main cause of that is K fixation in soil. Difference in slope is increased whenever K fixation was more in soil. Adsorption curves are normal with conventional shape of Q/I curves. Increasing in amount of K to soil,  $\Delta K$  was increased severely and due to  $\Delta K$  slope variation versus potassium activity ratio ( $AR_{equ}^k$ ) was high. While in releasing curves, amount of k fixed are proportionate to amount of K added and increasing K activity ratio that is deduced of  $\Delta K$  amount. As a result of exchangeable potassium slope variation versus potassium.

Activity ratio variation was less than adsorption Q/I curves. But these differences in slope were not similar in different soils. Soils with more K fixation had more slope difference.

Just as plots demonstrate relations that relations are linear in small amount of  $AR_{equ}^k$  and in high portions are colinear. But there was extra differences in amount of  $AR_0^k$ ,  $PBC_0^k$ ,  $K_{lab}$ ,  $K_x$  that exhibited differences status in potassium of soils.

Correlation between potassium activity ratio in adsorption plots were indeed intensity parameter and quantity index parameters, like labile K ( $K_{lab}$ ) was nonsignificant or weak.

**Table 1a: Some physical and chemical properties and classification of soil selected**

Soil No.	CEC	K <sub>ex</sub> <sup>o</sup>	K <sub>s</sub> <sup>•</sup>	K <sub>p</sub> <sup>•</sup>	Fe-BCD <sup>▼</sup>	Fe-OX	Mn-BCD	Mn-OX
1	12.90	0.25	0.28	1.94	2536.9	1211.0	136.4	37.9
2	8.70	0.40	0.35	4.51	3180.7	651.0	339.7	80.0
3	22.00	0.43	0.14	3.47	2269.9	1900.0	94.2	16.0
4	21.00	0.25	3.16	1.19	1580.5	987.0	74.5	35.9
5	22.70	0.85	0.55	3.75	2102.2	850.0	33.4	27.0
6	26.00	0.70	0.20	3.04	2731.5	1332.0	67.0	19.6
7	8.90	0.24	0.50	2.71	3083.4	1432.0	502.0	180.0
8	11.00	0.27	0.41	2.84	3286.2	2200.0	578.4	170.1
9	9.00	0.25	0.51	2.89	3070.9	1400.0	496.8	108.3

CEC: meq 100 g<sup>-1</sup>, <sup>o</sup>K<sub>ex</sub>, <sup>•</sup>K<sub>s</sub>: meq L<sup>-1</sup>, <sup>•</sup>K<sub>p</sub>: %, <sup>▼</sup>Fe-BCD, Fe-OX, Mn-BCD, Mn-OX: mg kg<sup>-1</sup>

**Table 1b: Some chemical properties of soil selected**

Soil No.	Soil classification	Depth (cm)	C <sub>org</sub> (%)	Particle size (%)			pH		
				Clay	Silt	Sand	pH <sub>p0</sub>	pH <sub>Kcl</sub>	ΔpH
1	Typic calcixererts	0-25	0.66	27.00	40.00	33	7.73	7.59	-0.14
2	Typic xerorthents	0-30	0.59	21.00	45.00	34	7.72	7.36	-0.36
3	Calcic haploxeralfs	0-30	1.50	40.00	36.00	24	7.52	7.11	-0.41
4	Gypsic haploxererts	0-15	0.62	10.00	53.00	37	7.85	7.30	-0.55
5	Typic haploxererts	0-25	1.13	51.00	40.00	9	7.67	7.28	-0.39
6	Calcic haploxeralfs	0-25	1.60	49.00	39.00	12	7.55	7.05	-0.50
7	Typic xerorthents	0-30	0.44	20.00	46.00	34	7.70	7.57	-0.13
8	Typic haploxererts	0-25	0.60	42.00	40.00	18	7.41	7.10	-0.31
9	Typic xerorthents	0-30	0.50	24.00	43.00	33	7.47	7.31	-0.16

**Table 2: Quantity-Intensity (Q/I) parameters of the soil investigated**

Soil No.	AR <sup>■</sup>	K <sub>lab</sub> <sup>o</sup>	PBC <sub>0</sub> <sup>K</sup>	-ΔG <sub>equ</sub> <sup>KO</sup>	K <sub>G</sub>	(C <sub>0</sub> K <sub>0</sub> ) <sup>•</sup>	E <sub>min</sub> <sup>•</sup>
1	7.65	-4.29	52.90	-2.12	3.94	0.61	2.00
2	15.06	-4.99	31.14	-1.82	3.34	1.39	2.37
3	1.74	-1.28	73.21	-2.76	0.50	0.19	2.22
4	15.47	-8.68	56.14	-1.81	12.99	1.57	2.30
5	3.03	-2.69	88.83	-2.52	0.81	0.67	3.36
6	2.36	-2.37	100.64	-2.63	0.78	0.22	2.23
7	19.90	-9.10	41.81	-1.70	7.34	1.51	0.93
8	11.93	-9.76	76.90	-1.92	4.20	0.84	0.23
9	12.66	-7.64	49.60	-1.90	4.38	0.86	0.20

<sup>■</sup>(mmol dm<sup>-3</sup>)<sup>0.5</sup>, <sup>o</sup>meq 100 g<sup>-1</sup> soil, <sup>•</sup>meq 100 g<sup>-1</sup> (mmol dm<sup>-3</sup>)<sup>0.5</sup>, <sup>o</sup>Kcal mol<sup>-1</sup>, <sup>•</sup>meq L<sup>-1</sup>, <sup>•</sup>meq 100 g

**Table 3: Linear coefficients of correlation between selected properties of soil and potassium quantity-intensity parameters (n = 10)**

	CEC	C <sub>org</sub>	Clay	Silt	pH	K <sub>ex</sub>	K <sub>s</sub>	K <sub>p</sub>	Fe-BCD	Fe-OX	Mn-BCD	Mn-OX
AR <sup>o</sup>	-0.74*	-0.89**	-0.80**	0.80**	0.33	-0.71*	0.38	-0.25	0.33	-0.14	0.67*	0.73*
K <sub>lab</sub>	-0.63	0.84**	0.56	0.71*	0.21	0.71*	-0.44	0.45	-0.31	-0.20	-0.74*	-0.8**
PBC <sub>0</sub> <sup>K</sup>	0.79*	0.79*	0.86**	-0.53	-0.41	0.72*	-0.16	0.04	-0.28	0.31	-0.47	-0.41
-ΔG <sub>equ</sub> <sup>K</sup>	-0.79*	-0.96**	-0.78*	0.79*	0.31	-0.73*	0.38	-0.30	0.35	-0.16	0.68*	0.71*
K <sub>G</sub>	-0.23	-0.64	-0.81**	0.94**	0.56	-0.63	-0.86**	-0.73*	-0.30	-0.17	0.17	0.28
(C <sub>0</sub> K <sub>0</sub> )	-0.54	-0.81**	-0.80**	0.91**	0.58	-0.50	0.58	-0.22	0.05	-0.40	0.40	0.50
E <sub>min</sub>	0.67***	0.54	0.22	-0.12	0.57	0.68***	0.15	0.11	-0.67***	-0.63	-0.88***	-0.80***

\*Significant at p<0.05, \*\*p<0.01, at least

But this correlation with intensity parameters like soil equilibrium concentration of soluble potassium (C, K<sub>0</sub>) was significant Table 3.

**Labile potassium (k<sub>lab</sub>):** The amount of ΔK at Ar<sup>k</sup><sub>equ</sub> = 0, represents labile potassium in adsorption curves. This parameter showed the amount of K which is readily available and is capable of ion exchange during period of equilibrium between soil colloids and soil solution.

The labile k values were fluctuated from -1.28 to -9.78 meq 100 g<sup>-1</sup>soil (Table 2). This implies that soils are characterized by high capacity for k supplying to plants. K<sub>lab</sub> values were higher than the exchange exchangeable

K (K<sub>ex</sub>) indicating there by that potassium of these soils should be released basically via solubility or diffusion processes than exchange. This implies that any addition of K (from fertilization. practices) in these soils could result a significant partition of K to the soil exchangeable portion. As compared to other studied soils, whose values of labile k were less negative, demonstrating that these soils had a strong ability to adsorb K (Nash, 1971) K<sub>lab</sub> was significantly and positively correlated with. C<sub>org</sub> (r = 0.84\*\*), K<sub>ex</sub> (r = 0.71\*), silt (r = 0.71\*) And negatively with Mn-BCD (r = -0.74\*) and Mn-OX (r = -0.8\*). In such cases potassium dynamics of soils should be basically controlled by mineral soil constituents (Scott, 1968).

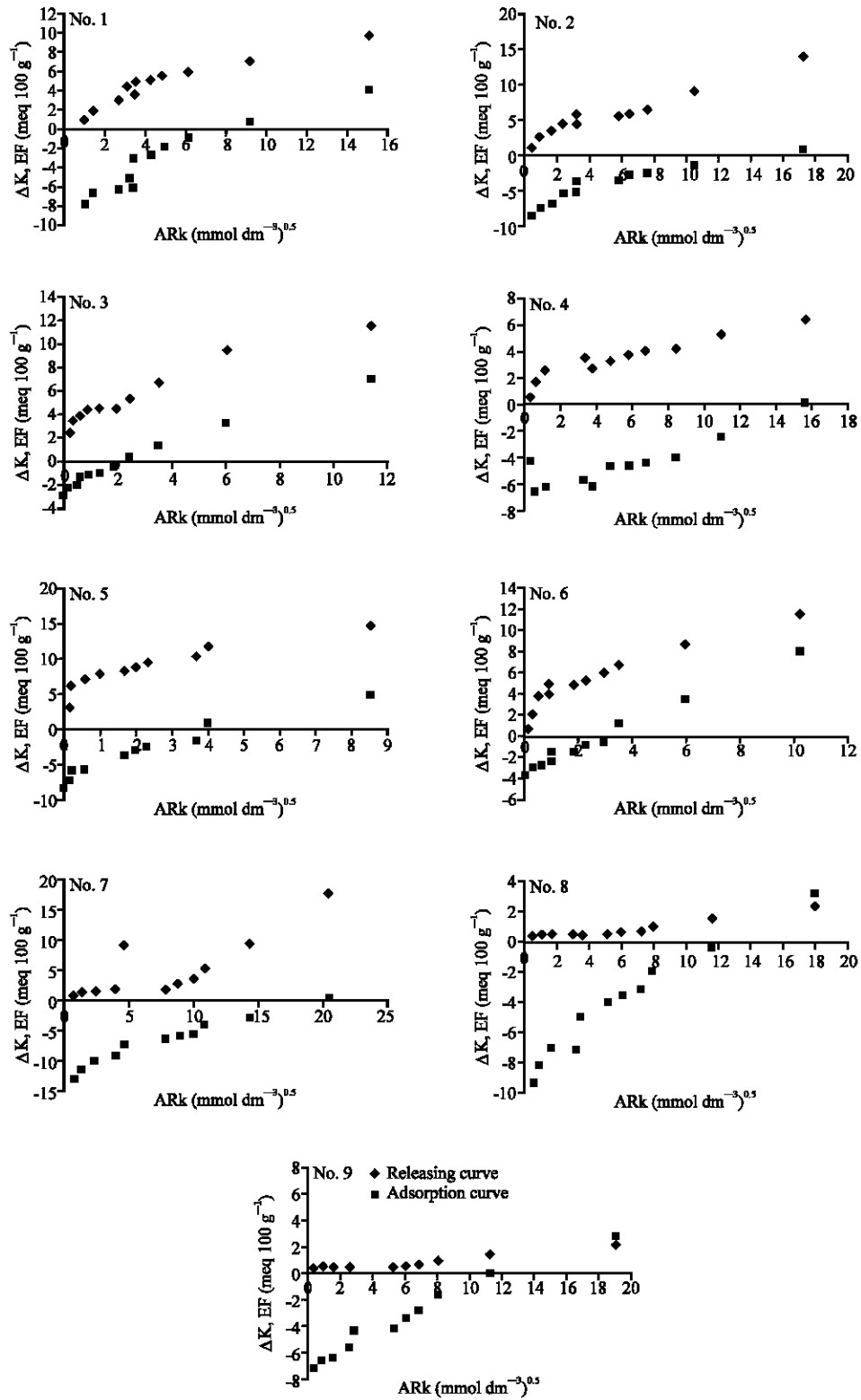


Fig. 2: Quantity-Intensity plots for the soil selected

Table 4: Linear coefficients of correlation between potassium quantity-intensity parameters

	AR <sup>0</sup>	K <sub>lab</sub>	PBC <sub>eq</sub> <sup>k</sup>	-ΔG <sub>equ</sub> <sup>k</sup>	K <sub>G</sub>	E <sup>0</sup>	(C,K <sub>0</sub> )	E <sub>min</sub>
AR <sup>0</sup>	1.00	-0.86**	-0.79*	0.96**	0.75*	-0.51	0.93**	-0.50
K <sub>lab</sub>	-0.86**	1.00	0.47	0.88**	-0.75*	0.71*	-0.74*	0.71*
PBC <sub>eq</sub> <sup>k</sup>	-0.79*	0.47	1.00	-0.78*	-0.49	0.30	-0.73*	0.28
-ΔG <sub>equ</sub> <sup>k</sup>	0.96**	-0.88**	-0.78*	1.00	0.74*	-0.54	0.89**	-0.53
K <sub>G</sub>	0.75*	-0.75*	-0.49	0.74*	1.00	-0.24	0.88**	-0.22
E <sup>0</sup>	-0.51	0.71*	0.30	-0.54	-0.24	1.00	-0.17	0.99**
(C,K <sub>0</sub> )	0.93**	-0.74*	-0.73*	0.89**	0.80**	-0.17	1.00	-0.17
E <sub>min</sub>	-0.50	0.71*	0.28	0.54	-0.22	0.99**	-0.17	1.00

\*Significant at p<0.05, \*\*p<0.01, at least

**Equilibrium potassium activity ratio (AR<sub>0</sub><sup>k</sup>):** The intercept of the curve with the activity ratio axis (ΔK = 0) gives the value of the activity ratio of potassium in soils. The values of the equilibrium activity ratio (AR<sub>0</sub><sup>k</sup>) ranged between 1.74 to 19.90 (mmol dm<sup>-3</sup>)<sup>0.5</sup>

In the present study, potassium dynamics in soil solution should be related both of Ca<sub>ex</sub> and Mg<sub>ex</sub>, which directly influenced the overall potassium activity ratios of the soils. The significantly high share of both Ca<sub>ex</sub> and Mg<sub>ex</sub> (more than 89% CEC) was probably responsible for the relatively low AR<sub>0</sub><sup>k</sup> values obtained in this study. AR<sub>0</sub><sup>k</sup> could be attributable to a greater number of specific k sites, which could fix k. According to Schneider (1997), the release of K increases and the fixation of K decrease when Ca concentrations of the surrounding solution increase. The intensive cropping decreased the equilibrium activity ratio. The exhaustion level however was high level however was high (11.93-19.90) for soils No. 2, 4, 7, 8 and No. 9 and low (1.47-7.65), for other soils.

Nafady and Lamm (1971) reported the reduced equilibrium ratio due to cropping. They explained that it was due to the reduction of the labile K but also to the increase in the adsorption capacities of the soils for potassium. AR<sub>0</sub><sup>k</sup> is significantly and positively correlated with silt (r = 0.80\*\*) Mn-BCD (r = 0.67\*), Mn-OX (r = 0.73\*) and negatively with CEC (r = -0.74\*), clay (r = -0.80\*), C<sub>org</sub> (r = -0.89\*\*) and K<sub>ex</sub> (r = -0.71\*) (Table 4).

**Equilibrium potential buffering capacity (PBC<sub>equ</sub><sup>k</sup>):** This parameter is the slope of the linear part of the Q/I plots, being a measure of soil ability to supply k activity (intensity factor) in soil solution.

PBC<sub>equ</sub><sup>k</sup> fluctuated from 31.14 to 100.64 meq 100 g<sup>-1</sup> (mmol dm<sup>-3</sup>)<sup>0.5</sup>. soils with highest PBC<sub>equ</sub><sup>k</sup> values were characterized by the lowest percent K saturation, indicative of higher potential to replenish K concentration in soil solution (Arnold, 1978). High PBC<sub>equ</sub><sup>k</sup> values are a measure of constant availability of K in the soil solution over a long period. Whereas low PBC<sub>equ</sub><sup>k</sup> would suggest the need for frequent K supply throughout fertilization practices. Removal of adsorbed K from non specific planner surface sites by cropping increased the buffer

capacities, indicating that higher energy sites became involved as the number of cropping increased.

The lower PBC<sub>eq</sub><sup>k</sup> of soils No. 1, 3, 4, 7 and No. 9, compared to the other soils may be attributed to its higher content of mica (illite) and higher K saturation (Maclean, 1963; Munn and Mclean, 1975). PBC<sub>eq</sub><sup>k</sup> is significantly and positively correlated with CEC (r = 0.79\*) clay (r = 0.86\*\*), C<sub>org</sub> (r = 0.79\*), K<sub>ex</sub> (r = 0.72\*). Correlations showed that whenever exchangeable sites are more in soils, intendency and capability of them for K adsorption is more. As a result, potential buffering capacity of soil will increase.

**Free energy of potassium replenishment at equilibrium**

**(- ΔG<sub>equ</sub><sup>k</sup>):** Potassium potential of the soils expressed as free energy of k replenishment ranged from -1.7 to -2.76 kcal mol<sup>-1</sup>. According to standard for -ΔG<sub>equ</sub><sup>k</sup> reported by Woodruff (1955). The K supply for all soils is relatively high (i.e., -ΔG<sub>equ</sub><sup>k</sup> less than -3.0 kcal mol<sup>-1</sup>, basically).

-ΔG<sub>equ</sub><sup>k</sup> was significantly and positively correlated with silt (r = 0.79\*), Mn-BCD (r = 0.68\*) Mn-OX (r = 0.71\*) and negatively with CEC (r = -0.79\*), C<sub>org</sub> (r = -0.96\*\*) and clay (r = -0.78\*). Positive correlation of silt with -ΔG<sub>equ</sub><sup>k</sup> shows that silt portion of soils have an important effect on K supply for soils due to belonging feldspars and microclines (Scott, 1968).

**Gapon selectivity coefficient (K<sub>G</sub>):** The Gapon selectivity coefficient for potassium expresses the relative affinity soils may develop towards K in the presence of Ca and both soil solid phase and soil solution under equilibrium conditions (Diatla *et al.*, 2006).

Of all the soils studied, No. 4, 7, 8 and No. 9 deserve more attention since their K<sub>G</sub> were higher and amounted 4.2 to 12.99. K<sub>G</sub> is positively correlated with silt (r = 0.94\*\*) and negatively with clay (r = -0.81\*\*), K<sub>s</sub> (r = 0.86\*\*), K<sub>p</sub> (r = -0.73\*).

**Initial concentration or equilibrium solution potassium**

**(C, K<sub>0</sub>):** In reality, it shows concentration of soil solution potassium when don't take place releasing and adsorption

from a plot of  $\Delta K$  versus soil soluble potassium, the  $(C, K_0)$  parameter was obtained for each soil the intercept of the curve where  $(\Delta k = 0)$ , was initial concentration or equilibrium solution potassium.  $(C, K_0)$  amounts were fluctuated from 0.19 to 1.57 meq  $L^{-1}$ . Soils that had higher potential buffering capacity (73.21-100.64 meq  $100 g^{-1}$  ( $mmol dm^{-3}$ )<sup>0.5</sup>), had lower soil equilibrium concentration of soluble potassium  $(C, K_0)$  (0.19-0.84 meq  $L^{-1}$ ). While soils with lower  $PBC_{equ}^k$  had more  $(C, K_0)$  amounts. These results showed in spite of that the soils with high potential buffering capacity could make steady soil soluble potassium level in a long time and they usually were in equilibrium with lower soluble potassium levels.  $(C, K_0)$  was significantly and positively correlated with silt ( $r = 0.91^{**}$ ) and negatively with  $C_{org}$  ( $r = -0.81^{**}$ ) clay ( $r = -0.80^{**}$ ).

**Least soil exchangeable potassium ( $E_{min}$ ):**  $E_{min}$  gained by averaging three points of EF amounts that had most potassium releasing (points had most negative  $\Delta k$  amounts).  $E_{min}$  amounts fluctuate from 0.2 to 2.37 meq  $100 g^{-1}$  soil.  $E_{min}$  was significantly and positively correlated with CEC ( $r = 0.67^*$ ) and  $K_{ex}$  ( $r = 0.68^*$ ) and negatively with Mn-BCD ( $r = -0.88^{**}$ ) Mn-OX ( $r = -0.80^{**}$ ).

## CONCLUSIONS

Exchangeable potassium ( $K_{ex}$ ) determined by  $NH_4OAc$  may not be a reliable indicator of the soil potassium ( $K^+$ ) available to crops in soils containing micaceous minerals. Potassium quantity-intensity relationships (Q/I) can be used to predict  $K^+$  availability to plants.

The application of quantity- intensity (Q/I) approach for evaluating potassium dynamics of selected Fars agricultural soils have investigated with parameters labile K ( $K_{lab}$ ), equilibrium activity ratio for k ( $AR_0^k$ ), equilibrium potential buffering capacity for k ( $PBC_0^k$ ), free energy of the k replenishment ( $-\Delta G_{equ}^k$ ), Gapon selectivity coefficient ( $K_G$ ), which held assessing the degree of potassium lability, Initial concentration or equilibrium solution potassium  $(C, K_0)$ , Least soil Exchangeable Potassium ( $E_{min}$ ).

The quantity- intensity (Q/I) parameters were differently controlled by soil properties Potassium activity ratio ( $AR_0^k$ ), was positively correlated with silt ( $r = 0.80^{**}$ ) Mn-BCD ( $r = 0.67^*$ ), Mn-OX ( $r = 0.73^*$ ). Labile k ( $k_{lab}$ ) was controlled more by  $C_{org}$  ( $r = 0.84^{**}$ ),  $K_{ex}$  ( $r = 0.71^*$ ), silt ( $r = 0.71^*$ ).

Labile potassium in Q/I adsorption curves was more than releasing curves. Because these differences in K

labile amount in adsorption and releasing according to different fixation capacity weren't similar. Exchangeable potassium correlation with labile potassium in adsorption curves will be less than releasing curves.

It was found that Fe and Mn oxides also positively fluctuated intensity parameters and negatively quantity parameters, this implies that studies on potassium dynamics of soils should additionally consider the levels of Fe and Mn, as well.

The letter one along with the pool of labile k ( $k_{lab}$ ) indicate that soils will sufficiently support plant cropping without any of k shortage as stated by the  $-\Delta G_{equ}^k$  values

Low productivity power of Iran in soils is not concerned with amount of carbonates. Limited factors are dryness and droughty, salinity, lack of awareness and research in the region. Suitable and proper management supplying of water and sufficient fertilizer, will have a yield equal to best soils of world. In summery, it is said that problems, management and production costs for acidic soils are more than calcareous soils by far. And the Q/I parameters provide useful information for understanding K availability in calcareous soils and can be used for K fertilizer recommendation.

In Iran, arid regions constituent the most part of the country; so, amount of potassium is sufficient with the exception of some sandy or clayey soils with extensive culture that have lost their K, but have reported a need for K fertilizer recommendation. According to high expenses of fertilizers, lack of information about the effect of potassium in calcareous and arid soils and also fundamental role of K in plants, evaluation of potassium status and relations is inevitable.

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