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

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Abstract: Potassium exchange-equilibrium were obtained from quantity-intensity (Q/I) isotherms, i.e., K equilibrium activity ratio (AR\textsubscript{k}), K labile (K\textsubscript{lab}), equilibrium potential buffering capacity for k (PBC\textsubscript{eq}), free energy of k replenishment (-ΔG\textsubscript{eq}), the Gapon selectively coefficient (k\textsubscript{G}), least soil exchangeable potassium (Emin) and initial equilibrium concentration solution potassium (C, k\textsubscript{i}). 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\textsubscript{k}) ranged between 1.74 to 19.90 (mmol dm\textsuperscript{-3})\textsuperscript{0.5}, labile K values fluctuated within the range 1.28 to -9.78 meq 100 g\textsuperscript{-1} soil. And equilibrium potential buffering capacity (PBC\textsubscript{eq}) fluctuated from 31.14 to 100.64 meq 100 g\textsuperscript{-1} (mmol dm\textsuperscript{-3})\textsuperscript{0.5}. Potassium was significantly controlled by soil properties. Potassium activity was controlled more by silt (r = 0.80\textsuperscript{**}), Mn-BCD (r = 0.67\textsuperscript{*}), Mn-OCX (r = 0.73\textsuperscript{*}) and the -ΔG\textsubscript{eq} values had significantly correlated with silt (r = 0.79\textsuperscript{*}), Mn-BCD (r = 0.68\textsuperscript{*}) Mn-OCX (r = 0.71\textsuperscript{*}). 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\textsuperscript{'} availability in calcareous soils and can be used for K\textsuperscript{'} 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 include 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 \(γK\textsubscript{eq} \sqrt{(γCa + γMg)\textsubscript{eq}}\) or AR\textsubscript{eq} is a measure of the intensity of labile K in a solution equilibrium with a soil provides a satisfactory measurement of their availability or the potential of potassium. AR\textsubscript{eq} is a measure of the intensity of labile K in the soil. Different soils exhibiting the same value of AR\textsubscript{eq} may not possess the same capacity for maintaining AR\textsubscript{eq} 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\textsubscript{4}OAc (1 N) is used extremely as a way for evaluation of soil adsorbable k status (K\textsubscript{lab}) and determination of plant requirement to k fertilizers.

Soils of rich mica minerals, maintained much of it's K with high energy because of specific barrier of k adsorption. A portion of k is released during extraction with NH\textsubscript{4}OAc (Hoseinpour and Kalbasi, 2000). Likely that's way, is weak correlation between extracted K with NH\textsubscript{4}OAc 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\textsuperscript{'} with Ca\textsuperscript{2+} + Mg\textsuperscript{2+} (Al-Karnani 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.

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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; Alaffifi, 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\textsubscript{K}) value is indicative of a good K availability while a low PBC\textsubscript{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\textsubscript{Ca}/Mg\textsubscript{K} against \gamma K\textsubscript{Ca}/\gamma CA\textsubscript{M} + \gamma Mg\textsubscript{K}. However, in most field soils K\textsubscript{Mg} << Ca\textsubscript{M} + Mg\textsubscript{Mg}. If so, small changes in K\textsubscript{K} may be accompanied by only insignificant changes in Ca\textsubscript{M} + Mg\textsubscript{Mg} and the isotherm may be represented as a graph of K\textsubscript{K} versus \gamma K\textsubscript{Ca}/\gamma CA\textsubscript{M} + \gamma Mg\textsubscript{Mg}. 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 comprehensive 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, Inceptisols, Aridisols, Vertisols, Alfisols) from agricultural lands of the Baltekan 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\textsubscript{4}OAC (pH = 7) method. Exchangeable K (K\textsubscript{ex}) was measured by the method of NH\textsubscript{4}OAC (1 M) buffered at pH = 7 (Page et al., 1992) K saturation (K%) can be estimated from the following equation (Mustech, 1995).

\[
K\% = \frac{K_{ex}(mol\cdot kg^{-1})}{CEC(mol\cdot kg^{-1})}
\]

Soil pH was potentiometrically measured in water and 1 M KCl extracts at soil to solution ratio of 1: 25 and \Delta PH (= pH\textsubscript{ex}-pH\textsubscript{K}) 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\textsubscript{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\textsubscript{2} (0.002 M) without KCI. The prepared soil suspensions were shaken for 1 h at 298\(^\circ\)K, allowed to
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<sub>6.0</sub>) was mostly slightly alkaline and the difference pH<sub>6.0</sub>-pH<sub>9.0</sub> 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 emol/100 kg<sup>−1</sup>. Amounts of soil solution K (K<sub>s</sub>) and exchangeable K (K<sub>e</sub>) fluctuated from 0.14 to 3.16 (meq L<sup>−1</sup>) and 0.24 to 0.85 (meq kg<sup>−1</sup>), 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, ΔK was increased severely and due to ΔK slope variation versus potassium actively ratio (AR<sub>e</sub>) was high. While in releasing curves, amount of K fixed are proportionate to amount of K added and increasing K actively ratio that is deduced of ΔK 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<sub>e</sub> and in high portions are collinear. But there was extra differences in amount of AR<sub>e</sub>, PBC<sub>cl</sub>, K<sub>K</sub>, K<sub>e</sub> 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<sub>L</sub>) was nonsignificant or weak.
Table 1a: Some physical and chemical properties and classification of soil selected

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>CEC</th>
<th>K⁺</th>
<th>K⁺⁺</th>
<th>Fe-BCD⁺⁺</th>
<th>Fe-OX</th>
<th>Mn-BCD</th>
<th>Mn-OX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.90</td>
<td>0.25</td>
<td>0.28</td>
<td>1.94</td>
<td>2536.9</td>
<td>1211.0</td>
<td>136.4</td>
</tr>
<tr>
<td>2</td>
<td>8.70</td>
<td>0.40</td>
<td>0.35</td>
<td>4.51</td>
<td>3180.7</td>
<td>651.0</td>
<td>339.7</td>
</tr>
<tr>
<td>3</td>
<td>22.00</td>
<td>0.43</td>
<td>0.14</td>
<td>3.47</td>
<td>2269.9</td>
<td>1900.0</td>
<td>94.2</td>
</tr>
<tr>
<td>4</td>
<td>21.00</td>
<td>0.25</td>
<td>3.16</td>
<td>1.19</td>
<td>1580.5</td>
<td>987.0</td>
<td>74.5</td>
</tr>
<tr>
<td>5</td>
<td>22.70</td>
<td>0.85</td>
<td>0.55</td>
<td>3.75</td>
<td>2102.2</td>
<td>850.0</td>
<td>33.4</td>
</tr>
<tr>
<td>6</td>
<td>24.00</td>
<td>0.20</td>
<td>3.04</td>
<td>2731.5</td>
<td>1332.0</td>
<td>67.0</td>
<td>19.6</td>
</tr>
<tr>
<td>7</td>
<td>8.90</td>
<td>0.24</td>
<td>0.50</td>
<td>2.71</td>
<td>3083.4</td>
<td>1432.0</td>
<td>502.0</td>
</tr>
<tr>
<td>8</td>
<td>11.00</td>
<td>0.27</td>
<td>0.41</td>
<td>2.84</td>
<td>3882.6</td>
<td>2260.0</td>
<td>578.4</td>
</tr>
<tr>
<td>9</td>
<td>9.00</td>
<td>0.25</td>
<td>0.51</td>
<td>2.89</td>
<td>2870.9</td>
<td>1400.0</td>
<td>496.8</td>
</tr>
</tbody>
</table>

CEC: mmol 100 g⁻¹, K⁺: eq 100 g⁻¹, K⁺⁺: eq 100 g⁻¹, Fe-BCD⁺⁺: Fe-BCD⁻⁻, Fe-OX, Mn-BCD, Mn-OX: mmol kg⁻¹

Table 1b: Some chemical properties of soil selected

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil classification</th>
<th>Depth (cm)</th>
<th>Cₑₑₑ (%)</th>
<th>Particle size (%)</th>
<th>pH</th>
<th>pH₂_{H₂O}</th>
<th>pH₂_{H₂O}</th>
<th>ΔpH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Typic calcicretes</td>
<td>0-25</td>
<td>0.66</td>
<td>Sand</td>
<td>7.73</td>
<td>5.95</td>
<td>–0.14</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Typic xerorthents</td>
<td>0-30</td>
<td>0.59</td>
<td>Clay</td>
<td>7.72</td>
<td>7.36</td>
<td>–0.36</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Calcic haploxerents</td>
<td>0-30</td>
<td>1.50</td>
<td>Silt</td>
<td>7.76</td>
<td>7.38</td>
<td>–0.38</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Typic haploxerents</td>
<td>0-15</td>
<td>1.92</td>
<td>Clay</td>
<td>7.75</td>
<td>7.36</td>
<td>–0.39</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Typic xerorthents</td>
<td>0-25</td>
<td>1.13</td>
<td>Silt</td>
<td>7.79</td>
<td>7.37</td>
<td>–0.42</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Calcic haploxerents</td>
<td>0-25</td>
<td>1.60</td>
<td>Sand</td>
<td>7.81</td>
<td>7.38</td>
<td>–0.43</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Typic xerorthents</td>
<td>0-30</td>
<td>0.44</td>
<td>Clay</td>
<td>7.85</td>
<td>7.41</td>
<td>–0.44</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Typic xerorthents</td>
<td>0-30</td>
<td>0.60</td>
<td>Silt</td>
<td>7.85</td>
<td>7.41</td>
<td>–0.44</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Typic xerorthents</td>
<td>0-30</td>
<td>0.50</td>
<td>Sand</td>
<td>7.86</td>
<td>7.41</td>
<td>–0.45</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Quantity-Intensity (QI) parameters of the soil investigated

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>AR²</th>
<th>Kₑₑₑ</th>
<th>PB₃</th>
<th>-AGₑₑₑ</th>
<th>Kₑₑₑ</th>
<th>Cₑₑₑ</th>
<th>Eₑₑₑ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.65</td>
<td>4.27</td>
<td>52.90</td>
<td>-1.12</td>
<td>3.94</td>
<td>0.61</td>
<td>2.09</td>
</tr>
<tr>
<td>2</td>
<td>15.06</td>
<td>-4.99</td>
<td>31.14</td>
<td>-2.86</td>
<td>0.50</td>
<td>0.19</td>
<td>2.22</td>
</tr>
<tr>
<td>3</td>
<td>1.71</td>
<td>-1.28</td>
<td>73.21</td>
<td>-1.98</td>
<td>12.99</td>
<td>1.57</td>
<td>2.30</td>
</tr>
<tr>
<td>4</td>
<td>15.47</td>
<td>-8.08</td>
<td>58.64</td>
<td>-2.52</td>
<td>0.61</td>
<td>0.67</td>
<td>3.36</td>
</tr>
<tr>
<td>5</td>
<td>5.03</td>
<td>-2.69</td>
<td>88.83</td>
<td>-1.70</td>
<td>1.34</td>
<td>5.11</td>
<td>0.93</td>
</tr>
<tr>
<td>6</td>
<td>2.96</td>
<td>-2.37</td>
<td>100.64</td>
<td>-1.40</td>
<td>1.34</td>
<td>5.11</td>
<td>0.93</td>
</tr>
<tr>
<td>7</td>
<td>1.90</td>
<td>-9.10</td>
<td>41.81</td>
<td>-1.00</td>
<td>4.38</td>
<td>0.86</td>
<td>0.20</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>AR²</th>
<th>Kₑₑₑ</th>
<th>PB₃</th>
<th>-AGₑₑₑ</th>
<th>Kₑₑₑ</th>
<th>Cₑₑₑ</th>
<th>Eₑₑₑ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.74</td>
<td>0.89</td>
<td>0.80</td>
<td>0.33</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>-0.63</td>
<td>0.84</td>
<td>0.56</td>
<td>0.71</td>
<td>-0.44</td>
<td>0.45</td>
<td>-0.31</td>
</tr>
<tr>
<td>0.79</td>
<td>0.79</td>
<td>0.56</td>
<td>-0.53</td>
<td>0.41</td>
<td>0.21</td>
<td>-0.44</td>
</tr>
<tr>
<td>-0.79</td>
<td>-0.56</td>
<td>-0.78</td>
<td>0.79</td>
<td>0.31</td>
<td>-0.73</td>
<td>0.38</td>
</tr>
<tr>
<td>-0.35</td>
<td>0.94</td>
<td>0.56</td>
<td>-0.63</td>
<td>-0.86</td>
<td>-0.73</td>
<td>-0.30</td>
</tr>
<tr>
<td>-0.54</td>
<td>-0.81</td>
<td>-0.80</td>
<td>0.91</td>
<td>-0.50</td>
<td>-0.58</td>
<td>-0.22</td>
</tr>
<tr>
<td>0.67</td>
<td>0.54</td>
<td>0.22</td>
<td>-0.12</td>
<td>0.57</td>
<td>0.68</td>
<td>0.15</td>
</tr>
</tbody>
</table>

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

But this correlation with intensity parameters like soil equilibrium concentration of soluble potassium (Cₑₑₑ, Kₑₑₑ) was significant Table 3.

Labile potassium (Kₑₑₑ): The amount of ΔK at ARᵣₑₑₑ = 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⁻¹ soil (Table 2). This implies that soils are characterized by high capacity for k supplying to plants. Kₑₑₑ values were higher than the exchangeable K (Kₑₑₑ) 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 absorb K (Nash, 1971) Kₑₑₑ was significantly and positively correlated with Cₑₑₑ (r = 0.84**, Kₑₑₑ (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

<table>
<thead>
<tr>
<th>AR&lt;sup&gt;5&lt;/sup&gt;</th>
<th>K&lt;sub&gt;b&lt;/sub&gt;</th>
<th>PBC&lt;sub&gt;E&lt;/sub&gt;</th>
<th>-ΔG&lt;sub&gt;E&lt;/sub&gt;&lt;sup&gt;5&lt;/sup&gt;</th>
<th>K&lt;sub&gt;e&lt;/sub&gt;</th>
<th>E&lt;sup&gt;5&lt;/sup&gt;</th>
<th>(C,K&lt;sub&gt;e&lt;/sub&gt;)</th>
<th>E&lt;sub&gt;ext&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>-0.86**</td>
<td>-0.79*</td>
<td>0.96**</td>
<td>0.75*</td>
<td>-0.51</td>
<td>0.93**</td>
<td>-0.50</td>
</tr>
<tr>
<td>K&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1.00</td>
<td>0.47</td>
<td>0.88**</td>
<td>-0.75*</td>
<td>0.71*</td>
<td>-0.74*</td>
<td>0.71*</td>
</tr>
<tr>
<td>PBC&lt;sub&gt;E&lt;/sub&gt;</td>
<td>0.47</td>
<td>1.00</td>
<td>-0.78*</td>
<td>0.30</td>
<td>-0.73*</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>-ΔG&lt;sub&gt;E&lt;/sub&gt;&lt;sup&gt;5&lt;/sup&gt;</td>
<td>-0.88**</td>
<td>-0.78*</td>
<td>1.00</td>
<td>0.74*</td>
<td>-0.54</td>
<td>0.89**</td>
<td>-0.53</td>
</tr>
<tr>
<td>K&lt;sub&gt;e&lt;/sub&gt;</td>
<td>0.75*</td>
<td>-0.75*</td>
<td>0.74*</td>
<td>1.00</td>
<td>-0.24</td>
<td>0.88**</td>
<td>-0.22</td>
</tr>
<tr>
<td>E&lt;sup&gt;5&lt;/sup&gt;</td>
<td>0.51</td>
<td>0.30</td>
<td>-0.54</td>
<td>-0.24</td>
<td>1.00</td>
<td>-0.17</td>
<td>0.69**</td>
</tr>
<tr>
<td>(C,K&lt;sub&gt;e&lt;/sub&gt;)</td>
<td>0.93**</td>
<td>-0.74*</td>
<td>-0.73*</td>
<td>0.89**</td>
<td>0.80**</td>
<td>-0.17</td>
<td>1.00</td>
</tr>
<tr>
<td>E&lt;sub&gt;ext&lt;/sub&gt;</td>
<td>-0.50</td>
<td>0.28</td>
<td>0.54</td>
<td>-0.22</td>
<td>0.99**</td>
<td>-0.17</td>
<td>1.00</td>
</tr>
</tbody>
</table>

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

Equilibrium potassium activity ratio (AR<sub>b</sub>): 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>e</sub>) ranged between 1.74 to 19.90 (mmol dm<sup>-3</sup>)<sup>1/2</sup>

In the present study, potassium dynamics in soil solution should be related both of Ca<sub>e</sub> and Mg<sub>e</sub> which directly influenced the overall potassium activity ratios of the soils. The significantly high share of both Ca<sub>e</sub> and Mg<sub>e</sub> (more than 89% CEC) was probably responsible for the relatively low AR<sub>e</sub> values obtained in this study. AR<sub>e</sub> 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>e</sub> 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 = -0.89**), C<sub>e</sub> (r = -0.89**) and K<sub>e</sub> (r = -0.71*) (Table 4).

Equilibrium potential buffering capacity (PBC<sub>E</sub>): 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>E</sub> fluctuated from 31.14 to 100.64 meq 100 g<sup>-1</sup> (mmol dm<sup>-3</sup>)<sup>1/2</sup>. soils with highest PBC<sub>E</sub> 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>E</sub> values are a measure of constant availability of K in the soil solution over a long period. Whereas low PBC<sub>E</sub> 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>E</sub> 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>E</sub> is significantly and positively correlated with CEC (r = 0.79*) clay (r = 0.86**), C<sub>e</sub> (r = 0.79*), K<sub>e</sub> (r = 0.72*). Correlations showed that whenever exchangeable sites are more in soils, industriality 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>eq</sub>): 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>eq</sub> reported by Woodruff (1955). The K supply for all soils is relatively high (i.e., -ΔG<sub>eq</sub> less than -3.0 kcal mol<sup>-1</sup>, basically).

-ΔG<sub>eq</sub> 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>e</sub> (r = -0.96**) and clay (r = -0.78*). Positive correlation of silt with -ΔG<sub>eq</sub> 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>c</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 (Diatta et al., 2006).

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

Initial concentration or equilibrium solution potassium (C, K<sub>e</sub>): In reality, it shows concentration of soil solution potassium when don’t take place releasing and adsorption.
from a plot of ΔK versus soil soluble potassium, the 
(C, K₀) parameter was obtained, for each soil the intercept 
of the curve where (Δk - 0), was initial concentration or 
equilibrium solution potassium (C, K₀) 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)⁵), had lower soil equilibrium concentration 
of soluble potassium (C, K₀) (0.19-0.84 meq L⁻¹). While 
soils with lower PBC, had more (C, K₀) 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, K₀) was significantly and positively correlated with 
silt (r = 0.91**) and negatively with Corg (r = -0.81**) clay 
(r = -0.80**).

**Least soil exchangeable potassium (Eₘ): Eₘmin gained by 
averaging three points of EF amounts that had most 
potassium releasing (points had most negative ΔK 
amounts). Eₘmin amounts fluctuate from 0.2 to 2.37 
meq 100 g⁻¹ soil. Eₘmin was significantly and positively 
correlated with CEC (r = 0.67*) and Kₘ (r = 0.68*) 
and negatively with Mn-BCD (r = -0.88**) Mn-OX 
(r = -0.80**).

**CONCLUSIONS**

Exchangeable potassium (Kₑ) determined by 
NH₄OAc may not be a reliable indicator of the soil 
potassium (K') available to crops in soils containing 
miscellaneous 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 
aricultural soils have investigated with parameters labile 
K (Kₑ), equilibrium activity ratio for k (ARₑ), equilibrium 
potential buffering capacity for k (PBCₑ), free energy of 
the k replenishment (ΔGₑ), Gapon selectivity coefficient 
(Kₑ), which held assessing the degree of potassium 
libility, Initial concentration or equilibrium solution 
potassium (C, K₀), Least soil Exchangeable Potassium 
(Eₘ).

The quantity-intensity (Q/I) parameters were 
differently controlled by soil properties Potassium activity 
ratio (ARₑ), was positively correlated with silt (r = 0.80**) 
Mn-BCD (r = 0.67*), Mn-OX (r = 0.73*). Labile k (kₑ) was 
controlled more by Corg (r = 0.84**), Kₑ (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 (kₑ) 
indicate that soils will sufficiently support plant cropping 
without any of k shortage as stated by the -ΔGₑ values 
Low productivity power of Iran in soils is not 
concerned with amount of carbonates. Limited factors are 
dryness and drought, 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 
aacidic 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 constitute 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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