



## Potassium reserves in soils with arid and semi-arid climate in southern Iran: a perspective based on potassium fixation

S.S. Hashemi<sup>1\*</sup>, H. Abbaslou<sup>2</sup>

<sup>1</sup>Department of Soil science, College of Agriculture, Malayer university, Malayer, I. R. Iran

<sup>2</sup>Department of Civil, College of Civil Engineering, Sirjan University of Technology, Sirjan, I. R. Iran

\*Corresponding Author: Hashemy558@gmail.com

### ARTICLE INFO

#### Article history:

Received 14 March 2016

Accepted 13 September 2016

Available online 3 October 2016

#### Keywords:

Illite

Mineralogy

Potassium forms

**ABSTRACT-** The present research was conducted to study K forms and fixation in soils of southern Iran (Hormozgan Province) with aridic and aridic-ustic regimes and to address the relations between soil mineralogy and potassium forms. Thirteen surface soil samples (0-25 cm) were collected from different regions and analyzed in laboratory. Illite and feldspar and mica are the major clay and soil minerals for K reservoir, respectively. Mean of non-exchangeable, exchangeable and total content of K were equal to 31.3, 283.9 and 1080.6 mg kg<sup>-1</sup> soils, respectively. These forms of K were abundant in plateau and piedmont plain physiographical units while the greatest amount of soluble potassium was observed in flood and alluvial plain units. Despite the aridity of the region with low clay fraction and unlike the previous studies in calcareous arid soils of Iran, the amount of potassium fixation in soils was high, probably due to the predominance of micaceous minerals. In an adsorption experiment, the average K adsorption in soils was 71 percent after adding 1000 mg K kg<sup>-1</sup>. In general, the most active component in the K fixation was the silt fraction, dominated mica and illite. Potassium fixation boosted after increasing the wetting and drying cycles in relation to the samples that did not suffer these cycles.

### INTRODUCTION

Determining the readily available potassium concentration in agricultural soils is a main concern in crop production. The quantification of K fertilizations needs is a key factor in the optimization of crop yield (RanadeMalvi, 2011).

The primary aluminosilicates (K-Feldspars and micas) are the main sources of K in mineral soils. The soil silicate clay minerals (2:1) have a notable influence on soil potassium availability, and the presence of 2:1 clay minerals, even in subsidiary quantities, increases the effective K availability in soils (Poss et al., 1991).

The proportion of interlayer K in clay minerals was often evaluated to be in subsidiary quantities to plant nutrition. It is now expected that it might contribute to an indicative pool, in spite of the majority of the K supplies in many soils (Øgaard and Krogstad, 2005; Andrist-Rangel et al., 2006). The rate and degree of K fixation depend on the type of silicate clay mineral and its charge density, the degree of interlayering, the K<sup>+</sup> ions concentration as well as the competing cations concentration, the moisture content, and the pH of the solution in contact with the soil clay (Sparks and Huang, 1985). Montmorillonite, vermiculite, and weathered micas are the most responsible clay minerals for K fixation (Sparks and Huang, 1985).

The rate of K fixation or release on wetting or drying cycles depends on the type of colloid and the

amount of K<sup>+</sup> ions in the soil solution. The kind of adsorbed cations or anions is likely to influence the potassium fixation by 2:1 silicate clay minerals.

The distribution of K forms in a semiarid region of west-northern Iran (Urmia) showed that Plateau and Piedmont plains which occurred on a more stable landform position had a higher content of all forms of K along with clay (Rezapour et al., 2010). The statistically significant relationships between mineral K and HNO<sub>3</sub> extractable K, as well as those between non-exchangeable K and soil illite content suggest that those forms of K are greatly influenced by the presence of illite (Rezapour et al., 2010).

Alamdari et al. (2016) revealed that physiographic units, because of variation in the degree of weathering, geomorphological and topographical conditions, exhibited different amounts of clay minerals and so different amounts of K forms. In fact, the diversity of physiographic units, being reflected mainly in K-bearing minerals and clay content, caused a noticeable difference in the content, forms and distribution of K. They found a highly significant positive relationship between non exchangeable K and illite content.

In general, mica, chlorite, palygorskite, quartz, feldspars, gypsum, and calcite are common minerals in southern Iran with predominantly sedimentary parent materials (Abbaslou et al., 2013). Limited information is available regarding the availability and distribution

of potassium in arid soils with high amount of mica and feldspars (Sarah, 2004; NajafiGhiri et al., 2011; NajafiGhiri and Abtahi, 2013) about potassium forms in arid soils of southern Iran (Persian Gulf and Oman Sea banks). Therefore, the objectives of the present research were to: (1) study and quantify K forms in arid and aridic-ustic soil moisture regimes, (2) evaluate potassium fixation processes, and (3) assess the relationship between K forms, K fixation and soil mineralogy.

## MATERIALS AND METHODS

### Site Description

The research site is situated in an area of around 70,000 km<sup>2</sup> in Horomzgan province, southern Iran (Fig 1.). The major portion of the province has a mountainous terrain (36%). The study area, a part of the Zagros mountain range, has been the site of more or less continuous sediments from Triassic to Pleistocene. Most of the study area is located in a desert, with semi-desert climate with 25°C mean annual temperature and 185 mm as annual average precipitation, but humidity along the coastal regions is on a high percentage (Choopani et al., 2006). The common soil moisture regime of the study area is aridic and soil temperature regime is hyperthermic.

### Physical and Chemical Properties

Based on a previous soil survey and report (Abbaslou et al., 2013), 50 pedons were investigated. Thirteen representative pedons of Aridisols, Entisols and Inceptisols were selected for mineralogical study, which were mostly located in flood plains, piedmont, alluvial fans and plateaux. Pedons were described and classified according to the Soil Survey Manual (Soil

Survey Staff, 2012) and Keys to Soil Taxonomy (Soil Survey Staff, 2014), respectively.

Soil samples were taken from surface horizons. Particle size analyses (Gee and Bauder, 1986), organic carbon (Nelson and Summers, 1996) and calcium carbonate equivalent (CCE) (Loppert & Suarez, 1996) were determined for all the samples. Soil pH was measured with a glass electrode in a saturated paste (mixture of water and soil) (Thomas, 1996). Electrical conductivity (EC) was determined by the method of Rhoades (1996). Cation exchange capacity (CEC) was measured in the sodium acetate at a pH of 8.2 (Sumner and Miller, 1996). Gypsum was quantified with the revised acetone method (Loppert and Suarez, 1996) and corrected for hydration water.

### Different Forms of Potassium

Water soluble K was assessed through the extraction of 5 g soil sample in distilled water (25 mL) for overnight, followed by centrifugation and filtration. NH<sub>4</sub>-exchangeable K was analyzed using 10 g of soil sample in 25 mL ammonium acetate 1M (buffered at pH 7). The NH<sub>4</sub>-Ac- extractable K consists of exchangeable K and water soluble K. Nitric acid-extractable K was determined by boiling 2.5 g of soil in 25 mL of 1M HNO<sub>3</sub> for 10 minutes followed by washing with deionizer water. The difference between K extracted by HNO<sub>3</sub> and NH<sub>4</sub>-exchangeable extractable K was taken as non-exchangeable K. Total K was analyzed by acid digestion (48% HF+6M HCl). Structural K was calculated by subtracting total K from HNO<sub>3</sub> extractable K (Helmeke and Sparks, 1996). Analyses were carried out in three replicates and all extracted samples were measured for K by flame photometry (Jenway PFP7). Calculations were made by SPSS software.

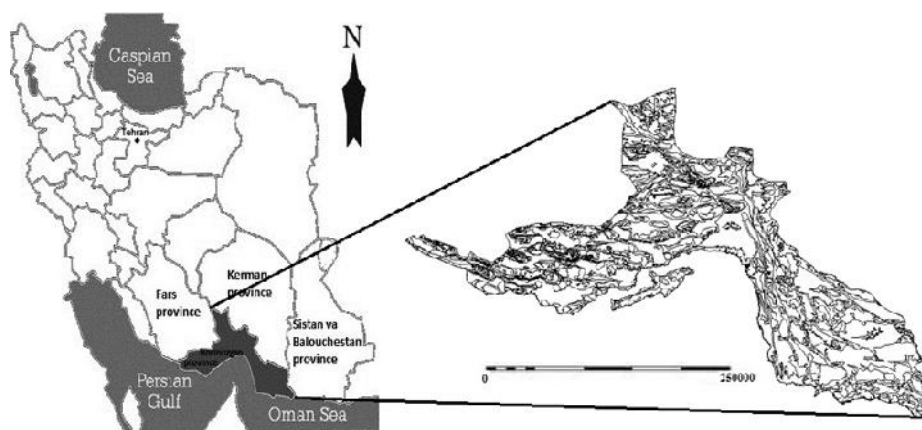


Fig. 1. The location of study area

## Mineralogical Analysis

Mineralogical study was made with the < 2 mm soil fraction. After oven-drying soil samples at 100°C for overnight, gypsum was removed by repeated washing with distilled water; calcium carbonate, organic matter, and Fe oxides were also removed using 1N sodium acetate (pH 4.8-5), 35% H<sub>2</sub>O<sub>2</sub>, and citrate-bicarbonate-dithionate, respectively (Jackson, 1979). Soil clay fractions were separated by centrifugation for 5 min with the speed of 750 rpm (Jackson, 1979), and the < 2 µm fraction was treated with Mg-K saturation; then, oriented slides were arranged for the following treatments: heating to 550°C; solvation with Glycerol; solvation with Dimethyl Sulfoxide (Moore and Reynolds, 1997). The prepared samples were analyzed using an X-ray diffractometer (Philips PW-1710 Cu K radiation). Interpretation of diffractograms was done by the software Xpowder ver.2004.04 (Azaroff and Buerger, 1958).

## Potassium Fixation Experiments

For K fixation experiments, 5 g of each soil sample was weighed in a plastic bottle and was shaken for 24 h at room temperature (20°C) after the addition of 25 mL KCl solution with different concentrations: 0, 150, 300, 500, 600 and 1000 mg kg<sup>-1</sup> (equal to 0, 30, 60, 100, 120 and 200 mg L<sup>-1</sup>, respectively). Control set was similarly shaken for 24 h after the addition of 25 mL distilled water. Ammonium acetate was used for extracting potassium three times. The extractants were collected in a 100 mL volumetric flask, diluted to volume, and measured for K by flame photometry (Jenway PFP7). The K fixation capacity was calculated using the following equation:

$$\text{Fixed K} = (\text{added K} + \text{NH}_4\text{OAc-extractable K of control sample}) - (\text{NH}_4\text{OAc-extractable K})$$

In order to assess the effect of drying and wetting on K fixation, 25 mL of KCl solution with concentrations of 0 and 1000 mg kg<sup>-1</sup> (equal to 0 and 200 mg l<sup>-1</sup>, respectively) were added to 5 gr of soil sample with three replicates at 80°C temperature. After drying, 25 mL of deionized water was added to the soil samples and placed in the oven for 3 and 6 days. This step was repeated three times for each sample. Then, K contents were extracted three times with 1M NH<sub>4</sub>OAc and measured for K by flame photometry (Jenway PFP7).

## RESULTS AND DISCUSSION

### Physico-Chemical Properties

Soils, in general, are moderately developed and contain high quantities of weatherable minerals including calcium carbonate and gypsum. The presence of gypsum in some pedons induced the texture toward coarse sizes (e.g. sand, sandy loam and silty loam) (Table 1). Calcium carbonate and gypsum content are high in all surface soils (average 48.1% and 6.6%, respectively). The cation exchange capacity values were between 3.95 and 11 Cmol.kg<sup>-1</sup> indicating that soils have low negative charges. EC values changed between 0.02 and 18.5 dS m<sup>-1</sup> due to the presence of gypsum and soluble salts in variable amount, with the

maximum amount observed in pedons 7 and 12 which were related to parent material and saline water (Table 1).

Semi-quantitative measurement of different amounts of minerals in the clay fraction of the samples are given in Table 2. As observed, Palygorskite, Illite, and chlorite are the main minerals in the clay fraction (<2 mm) in almost all the profiles. Smectite was more frequent in soils developed in the Zagros zone, declining from west to east. The results of clay mineralogy analyses indicated that inheritance is likely to be the main and particular source of chlorite, illite and kaolinite, whereas in situ neof ormation during the Tertiary of shallow saline and alkaline condition could be the principal agent of palygorskite presence in the sedimentary rocks and both inheritance and transformation from mica (illite) are concluded to be the main mechanisms for the occurrence of smectite in the studied pedons. (Abbaslou et al., 2013). Feldspars (plagioclase) and mica have the dominant primary minerals in the soils studied. Mineralogy of soils is mainly controlled by parent materials in arid and semiarid regions.

### Potassium Forms:

Values of water-soluble, exchangeable, non-exchangeable, and total K are presented in Table 3. The ranges of K forms are: total (739.3-1326.8mg kg<sup>-1</sup>), exchangeable (105.5- 432 mg kg<sup>-1</sup>), and non-exchangeable (3.3-69.4 mg kg<sup>-1</sup>). The amount of water-soluble K form ranged from 1.25 mg kg<sup>-1</sup> to 27.5 mg kg<sup>-1</sup> (Table 3). Darunsontaya et al. (2012) stated that water-soluble K has a negative relationship with sand content, but it has a positive relationship with clay and CEC. Our results indicated that exchangeable, mineral and total K values were the highest in soil 9, 10, 11 and 12 which were formed on plateau and piedmont plain physiographical units. As previously noted, some soils contain high amount of gypsum or calcite with low clay contents. This shows that the clay content may not be the factor for exchangeable and non-exchangeable K values. Since the moisture regime is similar in all regions (aridic or aridic-ustic), leaching rate, parent material, and type of physiographical units may have a substantial impact on the distribution of different potassium forms.

Alamdari et al. (2016) showed that the diversity of physiographic units, reflected mainly in K-bearing minerals and clay content, caused a noticeable difference in content, forms and distribution of K. Rezapour et al. (2010) concluded that units plateau and piedmont plain which occurred on a more stable landform position contained a higher content of all forms of K along with clay and illite.

Exchangeable K is held by the negative surface charges on organic matter and clay minerals. It is easily exchanged with other cations and is quite readily available to plants (Havlin et al., 2005). The highest levels of exchangeable K were observed in soil samples 9, 10, 11, 12 and 13 with the highest smectite and illite-smectite clay mineral contents (Table 3). As it was mentioned earlier, the amount of clay is very low in the soil samples studied; so, it can be interpreted that the amount of exchangeable K may not be notable.

Darunsontaya et al. (2012) concluded that Oxisols contain higher amounts of exchangeable K due to their higher clay contents. There is a positive relationship between NH<sub>4</sub>OAc-K and clay content ( $r=0.60$ ). But their results indicated that NH<sub>4</sub>OAc-K in Ultisols may not be sufficient to maintain crop production because of their minerals type.

The amount of non-exchangeable K in all samples was not high and ranged from 3.3 to 69.4 mg kg<sup>-1</sup>. In this research, no significant correlation was found among cation exchange capacity, non-exchangeable K and also other K forms. However, as the structural potassium increases, the non-exchangeable potassium will increase subsequently and a significant correlation was also observed between mica and non-exchangeable K.

**Table 1.** Physico-chemical properties of studied soils.

Soil No.	USDA Classification (2014)	Physiography unite	Depth (cm)	Clay	Silt	Sand	EC (dSm <sup>-1</sup> )	pH	CEC (Cmol.kg <sup>-1</sup> )	OM	Gypsum	CCE
					%							
1	Ustic Torriorthents	Old Alluvial fan	0-20	4	18	78	0.17	7.8	4.3	0.9	0.5	42.5
2	Ustic Haplocambids	piedmont	0-25	2	8	78.5	0.45	8.0	5.43	0.6	0.2	37
3	Ustic Haplocalcids	Piedmont	0-20	5	8.5	76.5	2.5	7.6	4.7	1.1	0.17	30.2
4	Typic Haplocambids	Floodplain	0-20	3	32.5	64.5	0.54	7.8	8.92	0.8	0.1	61.5
5	Fluventic Haplocambids	Piedmont plain	0-25	4	34	62	0.02	7.8	4.67	1.8	6	61.5
6	Typic Haplocambids	Alluvial plain	0-25	4	40	56	5.85	7.6	6.3	1.1	21.5	68.4
7	Typic Haplocambids	Flood plain	0-20	7.7	60	32.5	18	7.4	11	1	5	56.5
8	Torreric Calcicustepts	Piedmont plain	0-20	14	23	63	3.7	7.7	4.54	0.2	29.03	42.5
9	Torreric Calcicustepts	Piedmont plain	0-25	5	52	43	3.1	7.6	5	0.4	9	40.6
10	Ustic Calcigypsid	piedmont plain	0-25	2	55	43	3.3	7.8	3.95	1.1	10.32	77.4
11	Torreric Calcicustepts	plateau	0-25	2	39	59	6.4	7.7	10	1	2.15	39.2
12	Typic Haplocambids	plateau	0-20	3	28	69	18.5	7.6	6	0.8	1.8	39.6
13	Typic Haplocambids	Alluvial plain	0-25	2	42	56	2.35	7.9	9.1	0.8	0.1	29.1

**Table 2.** Mineralogy analysis of the studied soils.

Soil No.	USDA Classification (2014)	Clay minerals** (Semi Quantitative value %)	Soil Minerals* (Semi Quantitative value %)
1	Ustic Torriorthents	Chl, Paly, Ill, Ill-sme (40, 25, 28, 7)	Qua, Plag-Alk-Fel, Calc, Mic (29,35,26,10)
2	Ustic Haplocambids	Chl, Paly, Ill, Chl-sme (40, 30, 25,5)	Qua, Plag-Alk-Fel, Calc, Mic, (19,17,40,25)
3	Ustic Haplocalcids	Chl, Paly, Ill, Sme (35, 35, 25, 5)	Qua, Plag-Alk-Fel, Calc, Mic, (20, 24, 38, 18)
4	Typic Haplocambids	Chl, Paly, Ill, Chl-sme, Ill-sme (20, 30, 30, 10, 10)	Qua, Alk-Fel, Calc, Mic,Dol (13,35,34,5,13)
5	Fluventic Haplocambids	Chl, Paly, Ill (40, 20, 40)	Qua, Alk-Fel, Calc, Mic, (16, 28, 26, 10,20)
6	Typic Haplocambids	Chl, Paly, Ill (35, 20, 45)	Qua, Alk-Fel, Calc, Mic,Dol (13, 19,39,13, 16)
7	Typic Haplocambids	Chl, Paly (60, 40)	Qua, Alk-Fel, Calc, Mic,Dol (20,34, 29, 21, 13)
8	Torreric Calcicustepts	Chl, Paly, Ill (30, 50, 20)	Qua, Alk-Fel, Calc, Mic, Gyp (14, 34, 17, 10, 8, 17)
9	Torreric Calcicustepts	Chl, Paly (40, 60)	Qua, Alk-Fel, Calc, Mic,Dol, Gyp (19, 25, 22, 8, 14, 12)
10	Ustic Calcigypsid	Chl, Paly, Ill (20, 45, 35)	Qua, Alk-Fel, Calc, Mic,Dol, Gyp (17, 17, 13, 24, 14, 15)
11	Torreric Calcicustepts	Chl, Paly, Ill, Chl-sme, Sme (25, 30, 30, 10,5)	Qua, plag- Alk-Fel, Calc, Mic,Dol (12, 29, 18, 31, 10)
12	Typic Haplocambids	Chl, Paly, Ill, Chl-sme, Ill-sme (20, 15, 40, 15,10)	Qua, Plag-Alk-Fel, Calc, Mic,Dol (9, 28, 19, 20, 7)
13	Typic Haplocambids	Chl, Paly, Ill, Chl-sme, Ill-sme (30, 20, 30, 5, 15)	Qua, Plag-Alk-Fel, Calc, Mic,Dol (15, 31, 20,20, 8)

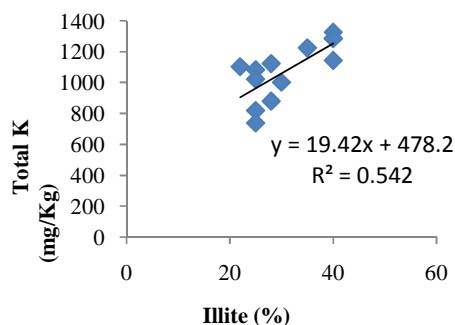
\* Relative distribution of soil minerals in Ap horizon (Qua: Quartz, Cal: Calcite, Pla: Plagioclase, Alk-Fel: Alkali feldspars, Dol: Dolomite, Gyp: Gypsum, Mic: Mica) \*\* Ill-sme: illite-smectite, Chl-sme: Chlorite-smectite, Sme: Smectite, Chl: Chlorite, Pal: palygorskite, Ill: illite.

**Table 3.** The amount of potassium forms in the studied soils.

Soil No.	K solution (mg kg <sup>-1</sup> )	Exchangeable K (mg kg <sup>-1</sup> )	Non exchangeable K (mg kg <sup>-1</sup> )	Total K (mg kg <sup>-1</sup> )
1	1.56	105.5	69.4	1124.2
2	1.25	248	36.3	1083.7
3	5.5	279.2	13.1	820.3
4	7.7	230	10.2	1002.7
5	4.6	135	27.5	1286.3
6	27.3	233	67.4	881.1
7	13	177.3	16.9	1022.9
8	5.8	245	45.8	1104.0
9	12.1	391.2	33.6	1144.5
10	8.7	420	3.3	1225.5
11	8.6	430.5	11.0	1326.8
12	1.8	432	10.7	1286.3
13	1.8	365	61.4	739.3
Average	7.7	283.9	31.27	1080.6

In Thailand, Darunontaya et al. (2012) studied Oxisols and Ultisols and found that soils contain the highest amounts of non-exchangeable K (>70 mg kg<sup>-1</sup>) because they have relatively high contents of illite in the clay fraction. These soils also contain silt-size K-rich feldspar which is a potential source of non-exchangeable K. The non-exchangeable K accounts for 4.9% of total K for Oxisols and 10.6% for Ultisols. Non-exchangeable K has a very weak positive relationship with sand content ( $r=0.32$ ).

Illite is abundant in studied soils; so, the presence of these clays is indicative of high values of total K (Fig. 2). Mica is common in soils number 5, 7, 10, 11, 12 and 13.

**Fig. 2.** Relationship between total potassium and illite percentage in the studied soils

The presence of primary minerals in these soils indicated that the total K content is the most. The soils with greater mica and chlorite contents have higher extractable K with HNO<sub>3</sub> where muscovite and mica are more frequent in the soil, subsequently the total potassium increases as well (e.g. Pedons 5, 7, 10, 11, and 12).

Darunontaya et al. (2012) showed that total K contents relate to the persistence of primary minerals. For all soils, the illite/kaolinite peak intensity ratio in XRD patterns of the clay fraction is systematically related to the total K ( $r=0.59$ ).

## Potassium Fixation

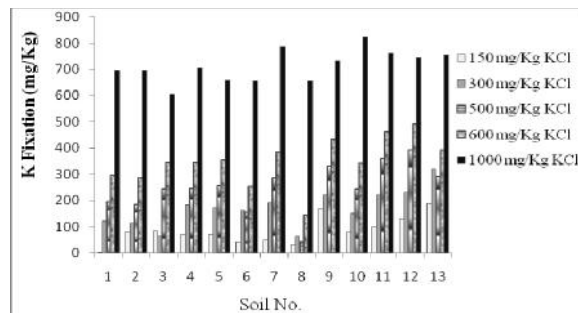
The K fixation increased with increasing KCl concentration. At the lowest concentration of KCl added (150 mg kg<sup>-1</sup>), average K fixation was equal to 85 mg kg<sup>-1</sup>, while in the highest content of KCl added (1000 mg kg<sup>-1</sup>), average K fixation was equal to 712 mg kg<sup>-1</sup> (71%) (Table 4). Potassium fixation was much higher in the soils with more illite and chlorite content; hence, clay mineralogy is proved to be a key factor in K fixation.

**Table 4.** A comparison of K fixation average between wetting and drying and no wetting and drying

Soil No.	K Fixation (1000 mg kg <sup>-1</sup> KCl)	K Fixation Average (1000 mg kg <sup>-1</sup> KCl) after 3 days (wet and drying)	K Fixation Average (1000 mg kg <sup>-1</sup> KCl) after 6 days (wet and drying)
1	696.1	277.8	290.7
2	694.8	6.5	117.9
3	604.4	10.0	149.0
4	705.6	163.5	180.7
5	656.5	155.5	161.5
6	655.2	218.7	116.0
7	785.6	121.4	99.5
8	654.4	117.4	164.9
9	731.9	363.1	350.8
10	822.4	323	452.7
11	761.9	493.5	226.7
12	741.9	87.3	135.8
13	752.4	302.9	167.3
Average	712.5	203.1	201

With respect to the soil clay content and cationic exchange capacity of pedon 7, the amount of potassium fixation was high. Mineralogical analyses of the soil show the presence of high amount of chlorite (approximately 60 %).

As shown in Fig.3, soil numbers 10, 11 12 and 13 have the highest fixation at the maximum concentration K added (1000 mg kg<sup>-1</sup> KCl). The mentioned soils have a very low clay content and also low CEC (3.95-9 Cmol<sub>c</sub>kg<sup>-1</sup>). According to texture (Table 1) and K fixation (Table 4) results, the soils with high rate of potassium fixation were 7, 10, 11, 12, and 13 which had high silt fractions as well.

**Fig. 3.** Potassium fixation values by adding different concentrations of KCl solutions in different soil samples

The silt fractions seem to be responsible for nearly a half of the soil K fixation capacities. Thus, it can be concluded that the fixation increases due to the high

amount of silt fraction dominated with mica and also high amounts of illite, which is line with the findings of Murashkina et al. (2007).

Najafi and Abtahi (2013) showed that a positive and significant relationship was obtained between K fixation capacity and smectite content for the clay fractions. However, no such relationship was obtained for silt and sand fractions.

Therefore, illite and chlorite minerals in all size fractions may be responsible for high K fixation. Therefore, the most added K may be fixed by the silt fractions, governed by mica and phyllosilicate minerals (illite). It can be concluded that the type of clay minerals has a substantial effect on K fixation. The great values of CCE in all samples (average equal to 48.2%) can affect the declining of K fixation. Clay content decreased with increasing carbonate content in the soil. Therefore, the contribution of clay as a main factor to K fixation will be diminished in such soils. The results show that the major sediments are calcareous and gypsiferous and also soils are not highly weathered; so, this fact has led to the majority of soils to be coarse textured (sandy to loamy sand) and consequently, the impact of clay as a main factor on K fixation is not valid. Although the region is arid and clay size fractions are few, the amount of K fixation has been much higher than previous K fixation studied in the arid soils of Iran. For instance, K fixation has been 60 to 82 % by adding 1000 mg K kg<sup>-1</sup>. So, it can be concluded that clay and CEC are not the only possible factors for K fixation; there are other factors such as mineral type in clay or silt fractions, pH, and calcium carbonate content. The results show that K fixation after adding K to the soil will be increased, but the percentage of fixation is reduced in the soil. However, both the amount and percentage of fixation were increased at maximum concentration added (1000 mg kg<sup>-1</sup>) (Fig. 4).

Bostani and Savaghebi (2011) obtained a negative and significant correlation between the amount of Potassium fixation and clay, pH, CEC, OM, exchangeable and available Potassium.

#### Effect of Wetting and Drying on Potassium Fixation

Results show that soils with the highest content of exchangeable K have the highest K fixation values under wetting and drying cycles. Also, potassium fixation increased with increasing incubation period, but in some soils (6, 7, 11, and 13), this trend was reverse. The average potassium fixation after 3 and 6 days was equal to 203.1 and 201 mg kg<sup>-1</sup>, respectively (Fig. 5). So, the amount of fixation has increased with increasing wetting and drying from 3 to 6 days. Soil number 10 has displayed the highest percentage of fixation in terms of no wetting and drying. Wetting and drying soils makes the releasing of K from non-exchange sites possible, and the release of K occurs from interlayer sites because of declining the soluble K in most of the soils. Hence, the amount of K fixation in cycles without wetting has been less than that of those in cycles with wetting, which matches the findings of Steenkamp et al. (1989) and Jafari and Baghernejad (2007).

Wetting and drying cycles have an important impact on K fixation in a short period of time with K addition to soils. In addition, the K ions are adsorbed at the edge of surfaces and are prevented from entering to the inner parts of clay structure. So, the more equilibrium time could work in favor of fixation and adsorption of potassium between layers.

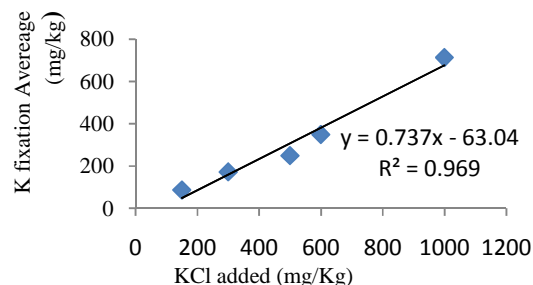


Fig. 4. Potassium Fixation trend with increasing KCl solutions

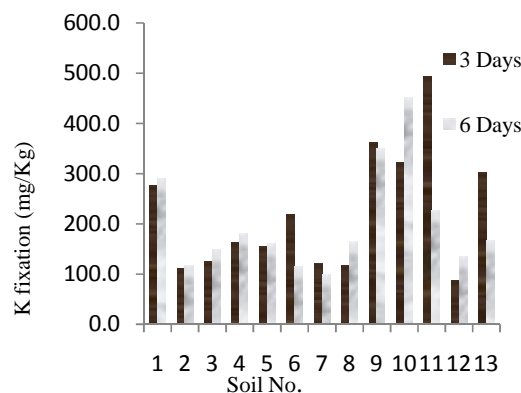


Fig. 5. The effect of drying and wetting cycles on K fixation

#### CONCLUSIONS

The results of this piece of research indicate that the amounts of exchangeable, mineral and total potassium in soils located on plateau and piedmont physiographic units were more than those of the other soils. The highest levels of soluble potassium were found in flood and alluvial plains. Generally, the main reason for higher K reservoir in plateau units could be the stable conditions for the evolution of minerals with much K reservoirs (including illite and illite-smectite) and higher soluble K amounts in flood and alluvial plain units may be due to the presence of water. A significant correlation was observed between non-exchangeable potassium and illite mineral. Illite and chlorite are the common minerals in the clay fraction and also mica and phyllosilicate minerals are dominant in the silt size fractions of the soils studied. The presence of these minerals can be the reason for high levels of total K. Since the moisture regime of the area is aridic and aridic-ustic, the main factors of potassium forms are geomorphology and the condition of soil genesis

including the transformation of primary minerals to secondary and clay minerals.

By increasing the time of wetting and drying cycles, the releasing and accessibility of potassium were increased. The amount of K fixation was low which was

due to less stability time in comparison to the conditions without wetting and drying process. In general, the rate of K values was low in wetting and drying processes, whose reason may be the condition of K equilibrium during performing such cycles.

## REFERENCES

- Abbaslou, H., Abtahi, A., Martin Peinado, F.J., Owliaie, H., & Khormali, F. (2013). Mineralogy and characteristics of soils developed on Persian Gulf and Oman sea basin, southern Iran: implications for soil evolution in relation to sedimentary parent material. *Soil Science*, 178 (10), 568-584.
- Alamdari, P., Kamrani, V., & Mohammadi M. H. (2016). Clay mineralogy relationships with Potassium forms in different physiographic units. *Journal of Water and Soil*, 29(6), 1578-1589. (In Persian)
- AndristRangel, Y., Simonsson, M., Andersson, S., Oborn, I., & Hillier, S. (2006). Mineralogical budgeting of K in soil: a basis for understanding standard measures of reserve K. *Journal of Plant Nutrition Soil Science*, 169, 605–615.
- Azaroff, L.V., & Buerger, M.J. (1958). *The Powder Method in X-Ray Crystallography*. New York, NY, McGraw-Hill Book Co. (www.xpowder.com).
- Bostani, A., & Savaghebi, G. (2011). Study of potassium fixation capacity in some under-cultivation Sugarcane soils in Khuzestan. *Journal of Water and Soil*, 25 (5), 982-993. (In Persian)
- Choopani, S., Khosroshahi, M.M., Gholampoor, M., & Mirakhorlo, K. (2006). Determination of desert areas of Hormozgan Province from geological aspect [Abstract in English]. *Iranian Journal Range Desert Research*, 1(22), 17–26.
- Darunsontaya, T., Suddhiprakarn, A., Kheouenromne, I., Prakongkep, N., & Gilkes, R. J. (2012). The forms and availability to plants of soil potassium as related to mineralogy for upland Oxisols and Ultisols from Thailand. *Geoderma*, 170, 11-24.
- Gee, G.W., & Bauder, J.W. (1986). Particle size analysis, hydrometer method. p. 404-408. In A. Klute et al. (ed.) *Methods of Soil Analysis*, Part I, 3<sup>rd</sup> Ed. America Society Agronomy., Madison, WI.
- Havlin, J.L., Beaton, J.D., Tisdale, S.L., & Nelson, W.L. (2005). Potassium, 7<sup>th</sup> ed. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management*, New Jersey, Upper Saddle River.
- Helmke, P.A., & Sparks, D.L. (1996). Lithium, sodium, potassium, rubidium, and cesium. p. 551-574. In D. L. Sparks et al. (ed.) *Method of soil analysis*. Part III. 3<sup>rd</sup> Ed. Am. Soc. Agron., Madison, WI.
- Jackson, M.L. (1975). *Soil chemical analysis: Advanced course*. University of Wisconsin, College of Agriculture, Department of Soil Science, USA, Wisconsin, Madison.
- Jafari, S., & Baghernejad, M. (2007). The effect of wetting and drying and cultivation systems on potassium fixation in some soils and clays of Khuzestan. *Journal of Water and Soil Science*, 41, 75-89.
- Loppert, R.H., & Suarez, D.L. (1996). Carbonate and gypsum. In D. L. Sparks et al. (ed.) *Method of soil analysis*. Part III. 3<sup>rd</sup> Ed. Am. Soc. Agron., Madison, WI.
- Moore, D.M., & Reynolds, R.C. (1997). *X-Ray Diffraction and the identification of clay minerals*. 2<sup>nd</sup> Edition. USA, Oxford University
- Murashinka, M.A., Southard, R.J., & Pettygrove, G.S. (2007). Silt and fine sand fractions dominate K fixation in soils derived from granitic alluvium of the San Joaquin Valley, California. *Geoderma*, 141, 283-293.
- NajafiGhiri, M., Abtahi, A., Owliaie, H., Hashemi, S.S., & Koohkan, H. (2011). Factors affecting potassium pools distribution in calcareous soils of southern Iran. *Arid land Research and Management*, 25 (4), 313-327.
- NajafiGhiri, M., & Abtahi, A. (2013). Potassium Fixation in Soil Size Fractions of Arid Soils. *Soil and Water Research*, 2, 49-55.
- Nelson, D.W., & Sommers, L.E. (1996). Total carbon, organic carbon and organic matter. P. 961-1010. In D. L. Sparks et al. (ed.) *Methods of Soil Analysis*, Part III, 3<sup>rd</sup> Ed., Am. Soc. Agron., Madison, WI.
- Øgaard, A.F., & Krogstad, T. (2005). Release of interlayer K in Norwegian grassland soils. *Journal of Plant Nutrition Soil Science*, 168, 80–88.
- Poss, R., Fardeau, J.C., Saragoni, H., & Quantin, P. (1991). Potassium release and fixation in ferralsols (oxisols) from southern Togo. *Journal of Soil Science*, 42, 649–660.
- RanadeMalvi, U. (2011). Interaction of micronutrients with major nutrients with special reference to potassium. *Karnataka Journal Agricultural Science*, 24(1), 106-109.
- Rezapor, S., Samadi, A., Jafarzadeh, A.A., & Oustan, S. (2010). Impact of clay mineralogy and landscape on potassium forms in calcareous soils, Urmia region. *Journal of Agricultural Science and Technology*, 12, 495-507.
- Rhoades, J.D. (1996). Salinity: Electrical conductivity and total dissolved solids. In D. L. Sparks et al. (ed.) *Methods of Soil Analysis*, Part III, 3<sup>rd</sup> Ed., Am. Soc. Agron., Madison, WI.
- Sarah, P. (2004). Soil sodium and potassium adsorption ratio along a Mediterranean–arid transect. *Journal of Arid Environments*, 59 (4), 731-741.
- Soil Survey Staff. (2012). *Soil Survey Manual*. USDA. Handbook No. 18. Washington, D.C.
- Soil Survey Staff. (2014). *Keys to Soil Taxonomy*. USDA.NRCS. Washington, D.C.
- Sparks, D.L., & Huang, M. (1985). *Physical Chemistry of Soil Potassium*. In: R.D.Munson.(ed). Potassium in Agriculture. ASA. CSSA. SSSA. Madison, WI, USA.
- Steenkamp, C.J., Theron, A.A., & De Bruyn, J.A. (1989). Potassium fixation in an Arcadia soil. II. Fixation by the clay fraction. *South African Journal of Plant and Soil*, 6 (2), 86-91.
- Sumner, M.E., & Miller, W.P. (1996). Cation exchange capacity and exchange coefficients. P. 1201-1229. In D. L. Sparks et al. (ed.) *Methods of Soil Analysis*, Part III, 3<sup>rd</sup> Ed., Am. Soc. Agron., Madison, WI.
- Thomas, G.W. (1996). Soil pH and soil acidity. In D. L. Sparks et al. (ed.) *Methods of Soil Analysis*, Part III, 3<sup>rd</sup> Ed., Am. Soc. Agron., Madison, WI.



## نگهداری پتاسیم در خاک های با اقلیم خشک و نیمه خشک جنوب ایران: با تاکید بر تثبیت پتاسیم

سهیلا سادات هاشمی<sup>۱\*</sup>، حکیمه عباسلو<sup>۲</sup>

گروه علوم خاک، دانشکده کشاورزی، دانشگاه ملایر، ملایر، ج. ا. ایران.

گروه عمران، دانشکده مهندسی عمران، دانشگاه سیرجان، سیرجان، ج. ا. ایران

\*نویسنده مسئول

### اطلاعات مقاله

#### تاریخچه مقاله:

تاریخ دریافت: ۱۳۹۴/۱۲/۲۴

تاریخ پذیرش: ۱۳۹۵/۶/۲۳

تاریخ دسترسی: ۱۳۹۵/۷/۱۲

#### واژه‌های کلیدی:

ایلات

شکل های پتاسیم

کانی شناسی

**چکیده-** تحقیق حاضر برای مطالعه شکل های پتاسیم و تثبیت آن در خاکهای جنوب ایران، با رژیم رطوبتی اریدیک و اریدیک - یوستیک، با توجه به ارتباط بین کانی شناسی خاک و شکل های مختلف پتاسیم صورت گرفته است. ۱۳ نمونه خاک سطحی (۲۵-۰ سانتیمتری) از نواحی مختلف جمع آوری و در آزمایشگاه تجزیه شدند. ایلات از کانیهای اصلی رس و فلدسپار و میکا کانی های خاک برای نگهداشت پتاسیم هستند. میانگین پتاسیم غیرتبادلی، تبادلی و کل به ترتیب برابر با ۲۸۳/۹ و ۱۰۸۰/۵ میلی گرم بر کیلوگرم بدست آمد. این شکل های پتاسیم در واحدهای فیزیوگرافی فلات و دشت دامنه ای بیشترین فراوانی را داشته، در حالیکه بیشترین مقدار پتاسیم محلول در واحدهای دشت رسوبی و سیلابی مشاهده شد. علی رغم خشک بودن ناحیه با ذرات رس کم و مطالعات قبلی غیرمشابه در خاکهای آهکی نواحی خشک ایران، مقدار تثبیت پتاسیم در خاکها بسیار بالا بود، که احتمالاً به دلیل غالب بودن کانی میکائی منطقه است. در آزمایش جذب میانگین جذب پتاسیم در خاکها ۷۱ درصد پس از اضافه نمودن ۱۰۰۰ میلی گرم در کیلوگرم پتاسیم بدست آمد. به طور معمول فعالترین جزء در تثبیت پتاسیم بخش سیلت با غالبیت میکا و ایلات آن است. تثبیت پتاسیم پس از افزایش دوره های تری و خشکی نسبت به نمونه های که بدون چرخه تری و خشکی بودند، دارای روند کاهشی می باشد.