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POTASSIUM FORMS FOR MAIN SOIL ORDERS IN THE NORTH OF IRAQ

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ABSTRACT

Fifteen soil samples were collected from five locations in the North of Iraq from three surface genetic horizons for the five locations [Semeel (Vertisols), Imerik (Aridisols), Gerderash (Inceptisols), Perdi (Aridisols) and Wermawa (Mollisols)] to study the forms of potassium and its distribution with the depth. All studied soils are calcareous and non-saline soils contain low organic matter.

The studied forms of K in the surface horizons of the studied soils (soluble, exchangeable, available, non-exchangeable, mineral and total potassium) were ranged between (12 – 40, 82 – 229, 97 – 246, 656 – 3800, 462 – 2933 and 1200 – 5400) mg kg^{-1} respectively, while in the intermediate (A and A1) soil horizons were (5 –26, 67 – 214 , 72 – 216 , 676 – 3040 , 709 – 2048 and 1700 – 5200) mg kg^{-1} respectively and in the third horizon of studied soils were (4 – 14 , 68 – 191, 70 – 186 , 345 – 3232 , 419 – 4516 and 1700 – 5800) mg kg^{-1} respectively, this illustrates the amount of soluble, exchangeable, available (soluble + exchangeable), non-exchangeable decreases with the depth. The constituted percent of the soluble, exchangeable; available; nonexchangeable and mineral potassium from total-K in all pedons equal to 0.469; 4.185 ; (4.538); 52.141 and 43.318 respectively.

Correlation study illustrates positively and significantly correlated between total potassium with exchangeable, available, non-exchangeable, mineral, while positively and significant relation demonstrate between exchangeable, available, non-exchangeable with silt content in the soils, but positively relation found between soluble potassium with pH and negatively to EC. The high amount of soluble K found in Perdi pedon (Aridisols) but higher amount of the exchangeable, non- exchangeable, available and total-K demonstrate in Imerik pedon (Aridisols) while large amount of mineral-K shown in Gerderash pedon (Inceptisols)

***KEYWORD*:** Potassium forms**,** Soil orders, North of Iraq, Calcareous soil.

INTRODUCTION

Potassium (K) is a soft, silvery-white metal, in pure form its light that reacts very high with water, it is referred named potash (K2O) (Mikkelsen and Bruulsema, 2005). Potassium is followed by nitrogen and phosphorus as fertilizer use, K includes only one-seventh of the total nutrients (Hasan, 2002; Murashkina et al., 2007, Gurav, et al., 2018). For all plants, potassium is an important nutrient element (White, 2003 and Stanley, 2005) and its availability in soils is affected by soil moisture, clay minerals, rate of fertilization and soil texture (Samadi, 2006, Simonsson, et al., 2007).

The amount of potassium in the soil varies depending on the physicochemical properties of the soil, most of the soils contain high amounts of total-K but relatively small quantity of available-K (Lalitha and Dhakshinamoorthy, 2014). McAfee (2008) referred that mica and feldspar extending between (90 - 98 %) potassium of the most prevalent components of soil. The potassium quantity in soils is usually high, ranging between 3000 to 100,000 kg K hectar^{-1} in the 20 cm of surface soil (Sparks, 2001).

The agricultural activities, temperature regimes, leaching, and some soil properties such as soil orders, depth, cation exchange capacity (CEC), soil moisture, particle size distribution (PSD), carbonate minerals and soil salinity could also affect K equilibrium in Vertisols and Alfisols soils had the uppermost contents of dissimilar K forms, (Ghiri et al., 2010).

The role of potassium is very important in plant development like activation of several enzymes, involved in protein creation, membrane permeability, photosynthesis, daylight dry, salinity and disease (Lakudzala, 2013; Hasanuzzaman *et al*., 2018). Potassium plays an important role in plant governing development including plant-water relation, osmoregulation, and internal cation/anion balance (Marschner, 2010).

Soil potassium separated into soluble, non-exchangeable, exchangeable and structural (mineral) forms. Soil K soluble and exchangeable potassium accounts for only 0.1–2% of total potassium; meanwhile, non-exchangeable potassium (2–10%) but high percentage of soil potassium is structural (mineral) ranged from 90 to 98% (Sparks and Huang 1985). Soil K present in four forms according to increasing order of plant availability: solution (1-10 ppm), exchangeable (40-600 ppm), nonexchangeable (50-750 ppm) and mineral (5000-25000 ppm) (Havlin *et al.*, 1999).

The portion of potassium that can be directly taken from the soil solution by plants is known as water-soluble K (Rashid, et al., 2017). In Maharashtra's Sawangi watershed, different Vertisols, Gajbhiye *et al.* (1993) demonstrated that water-soluble K made up 10% of total K Although exchangeable K is used as a measure of potassium availability in soils, it does not show consistent trends across various mineralogical suites (Raheb and Heidari, 2012). The non-exchangeable K (fixed) form is held between neighboring tetrahedral layers of dioctahedral and trioctahedral sheets of mineral micas, vermiculites, and intergrade clay minerals such chloridized vermiculite (Sparks and Huang, 1985; Sparks, 1987). Mineral K contains a significant quantity of total K in most soils (Metson 1980). Muhr, et al., 1965) reported that Exchangeable K (mg kg^{-1}): low (0–50), medium (50– 110) and high (>110). But Srinivasarao, et al., (2007 and 2010) demonstrate that non-exchangeable K (mg kg^{-1}): low (0 –300), medium (300 – 600) and high (> 600).

In the North of Iraq, from Nineveh province soils AL-Badrani and Radhwan (2019) indicated that that water soluble, exchangeable, available, non-exchangeable, mineral and total forms for surface soil were ranged between (0.006 - 0.146, 0.691 - 1.124, 0.708 - 1.167, 1.150 - 3.261, 35.480 - 52.810, 38.780 - 58.650) cmol kg^{-1} respectively, while for sub-surface soil (0.003-0.105, 0.554 - 0.914, 0.559 - 0.997, 0.997 - 2.801, 30.040 - 56.770, 32.550 - 60.880) cmol kg^{-1} respectively. These forms constituted only 0.075; 1.65; 1.73; 3.95 and 92.03 percent of the total-K respectively. Soluble K ranged from 0.026 to 0.947 cmol kg^{-1}, exchangeable K ranged from 142 to 793 mg kg^{-1}, nonexchangeable K ranged from 247 to1446 mg kg^{-1}, structure (mineral) K ranged from 3792 to13110 mg kg^{-1}, and total K ranged from 4352 to 15109 mg kg^{-1} (Azadi, et al., 2015). Al-Obaidi1, et al. (2015) found the soluble, exchangeable and non-exchangeable potassium in some soils of Duhok ranged between 0.003 - 0.011, 0.31 – 0.93, 0.28 – 3.46 cmol kg^{-1}.

Positively and significantly correlations found between the different forms of K and negatively with $CaCO_3$ contented of the soils. In Lebanese soils, Al-Zubaidi, et al., (2010) found soluble-K, exchangeable-K, non-exchangeable-K, mineral-K, and total-K average values were: 0.0122, 0.2324, 1.1791, 12.478 and 13.9471 cmol kg^{-1} soil. In the soils of Southern Iran, the diverse forms of K, such as water-soluble, exchangeable, non-exchangeable, and mineral K, are likewise relatively high (5.8, 241, 736 and 6000 mg kg^{-1} respectively (Najafi-Ghiri et al., 2010).

The goals of this study is to determine forms of potassium in the three surface horizons of four soil orders classifying according to the USDA system in the North of Iraq, compare it between the orders of potassium forms, and relation these forms with some physico-chemical properties of soil orders.

MATERIALS AND METHODS

Fifteen soil samples were collected from four orders in the North of Iraq or three samples from three surface genetic horizons for each order after classifying soil according to the USDA system, included Semeel (Vertisols), Imerik (Aridisols), Gerderash (Inceptisols), Perdi (Aridisols) and Wermawa (Mollisols). Soil samples were air-dried, crushed, and then passed through a 2 mm sieve.

Physico-chemical properties of soil were determined such as particle size distribution (PZD) by hydrometer method (Klute, 1986), EC and soil pH according to Rowell (1996), organic matter as stated by the procedure of Walkely and Black (1965), Total carbonate by calcimeter apparatus (Loeppert and Saurez, 1996). Active carbonate using the method mentioned by Kozhekov and Yakovleva (1977). Cation exchange capacity (CEC) determined by (1N) ammonium acetate, at pH (8.2) by using flame photometer model, JENWAY, LDT, FELSTED, DUNMOW, ESSEX, CM63LB, and MODE: FFP7. (Polemio and Roads, 1977).

Water soluble-K was estimated by shaking 10g of soil with a 1:1, soil water ratio, next shaking 30 minutes mechanical shaking and late filtered to obtain clear extract due to Pratt, 1982; Rowell, 1996).

Exchangeable-K was determined by shaking a 10 g sample of soil in (1M) solution of NH_4OAC (buffered at pH 7) after that filtration as describe by (Pratt, 1982; Knudsen, et al., 1996). Non-exchangeable-K was measured by boiling 5g of soil sample in 50 ml of (1M) HNO_3 solution. The difference between K extracted through HNO_3 and exchangeable-K equal non-exchangeable-K (Jackson, 1968; Page et al., 1982). Total K was determined by digesting 2g of soil samples with a 20 mL acid mixture of $HClO_4$-HNO_3 and leached with HCl due to (Jackson, 1958). Mineral-K was measured by subtracting total-K from HNO_3 extractable (Martin and Sparks, 1983). All K forms extract were analyzed by the flame photometer. Available potassium was measured by treated 5 g of soil with 25 ml of neutral solution 1 N NH_4OAC. The suspension was filtered after being shaken for five minutes on a mechanical shaker. A flame photometer was used to calculate the amount of potassium in the filtrate (Dhawan *et al.*, 1968).

RESULTS AND DISCUSSION

The texture of studied soil ranged from clayey to loamy soils (Table, 1) the high clay found in A_2 horizon of Mollisols order (629.8) g kg^{-1} and low amount in Ap horizon of Inceptisols which was (184.8) g kg^{-1} and all soils are non-saline calcareous EC ranged between (0.08 – 0.60) dS m^{-1}, Total carbonate ranged from (84.0 to 309) g kg^{-1} soil the high value found at Gerderash soil (Inceptisols) while low value observed at Semeel soil (Vertisols), active carbonate (34 to 200) g kg^{-1} carbonate, pH (7.8 to 8.8), CEC (10.3 to 26.0) $cmol_c$ kg^{-1}, organic matter (2.6 to 23.1) g kg^{-1} soil (Table, 2).

Table (1): Particles size distribution and the texture of studied soils.

Governorates	Location	Pedon No.	Depth cm	Horizon	PSD g kg^{-1}			Texture
					Sand	**Silt**	**Clay**	
Duhok	**Semeel**	**1**	0 – 12	Ap	97.7	405.0	497.3	Silty Clay
			12 – 30	A	117.7	357.5	524.8	Clay
			30 – 55	Bt1	110.2	297.5	592.3	Clay
Mousel	**Imerik**	**2**	0 – 6.5	Ap	127.7	532.5	339.8	Silty Clay Loam
			6.5-18.5	A1	115.2	470.0	414.8	Silty Clay
			18.5-65.5	A2	65.2	470.0	464.8	Silty Clay
Erbil	**Gerderash**	**3**	0 – 7	Ap	475.2	340.0	184.8	Loam
			7 – 16	A1	440.2	362.5	197.3	Loam
			16 – 57	A2	467.7	325.0	234.8	Loam
Kirkuk	**Perdi**	**4**	0 – 8.5	Ap	175.5	465.0	359.8	Clay Loam
			8.5- 20	A	225.2	407.5	367.3	Clay Loam
			20 – 54	Btk	272.7	327.5	399.8	Clay Loam
Sulaimani	**Wermawa**	**5**	0 – 20	Ap	70.2	400.0	529.8	Silty Clay
			20 - 45	A1	45.2	400.0	554.8	Silty Clay
			45 – 61	A2	45.2	325.0	629.8	Clay

Soluble potassium

Soluble K is the type of potassium that microorganisms and plants can readily absorb. Unless a recent application of K-fertilizer has been applied, soil solution K levels are normally low. In studied soil soluble potassium ranged between (4 - 40) mg kg^{-1} (Table 3), the low amount found in A_2 horizon of Inceptisols at Gerderash location but the high amount was observed in Ap horizon of Perdi soil (Aridisols). This difference might be due to the high percentage of total and active calcium carbonate, pH and low EC in Gerderash soil and high CEC and EC in Perdi soil and some effect attributable to the quantity and quality of clay minerals, organic matter content in soil and depletion of an element by the plant. Havlin *et al.*, 2005 denoted for optimum plant growth K^+

concentration differs, dependent on the crop and yield level which was ranged from 1 to 10 mg kg^{-1} soil. The equilibrium and kinetic processes that occur between the forms of soil K, divalent cation concentration in solution, soil moisture content, and the exchanger phase affect solution K levels (Sparks, 2000). The degree of replenishment of K in solution from non-exchangeable sites affects potassium content in soil solution (Srinivasarao, and Srinivas, 2017). The quantity of soil solution K in Iraqi soils ranges between (0.39 - 3.90), (0.39 - 23.4) and (1.17 -56.94) mg kg^{-1} soil by (Rahi *et al*., 1978; Al- Obaidi, 1996; AL-Badrani and Radhwan, 2019)**.** Gurav, et al., (2019) found the soluble potassium in some vertical soil in India soils and ranged between (1 – 98) mg kg^{-1}.

Table (2): Some physicochemical properties of studied soil samples.

Locations	Pedon No.	Depth cm	Horizon	Total Carbonate g kg^{-1}	Active Carbonate g kg^{-1}	CEC $Cmol_c$ kg-1	pH	EC dS m^{-1}	O.M gkg^{-1}
Semeel	1	0 – 12	Ap	195.0	95	24.00	7.8	0.60	23.1
		12 – 30	A	155.0	67	25.60	8.2	0.10	16.9
		30 – 55	Bt1	84.0	34	25.70	8.6	0.12	12.0
Imerik	2	0 – 6.5	Ap	181.4	47	16.10	7.9	0.40	21.5
		6.5– 18.5	A1	180.7	66	16.04	8.4	0.13	15.1
		18.5–65.5	A2	180.0	40	15.30	8.5	0.10	8.6
Gerderash	3	0 – 7	Ap	287.0	100	10.30	8.6	0.34	10.1
		7 – 16	A1	300.0	195	12.20	8.8	0.08	9.0
		16 – 57	A2	309.0	200	11.08	8.8	0.09	18.2
Perdi	4	0 – 8.5	Ap	216.8	165	20.00	7.8	0.60	11.7
		8.5 – 20	A	220.0	126	18.50	8.0	0.40	4.1
		20 – 54	Btk	260.0	140	18.90	8.0	0.40	3.4
Wermawa	5	0 – 20	Ap	192.0	120	19.00	7.8	0.40	10.8
		20 – 45	A1	190.0	110	26.00	8.2	0.30	13.3
		45 – 61	A2	162.0	100	24.00	8.3	0.10	2.6

Table (3): Forms of potassium (mg kg^{-1}) in studied soils

Locations	Pedon No.	Depth cm	Horizon	Soluble-K	Exch-K	Available-K	Non Exch-**K**	Mineral-K	Total-K
Semeel	**1**	0 – 12	Ap	16	82	97	656	462	1200
		12 – 30	A	6	67	72	764	869	1700
		30 – 55	Bt1	5	68	70	345	1287	1700
Imerik	**2**	0 – 6.5	Ap	20	229	246	3762	709	4700
		6.5– 18.5	A1	11	214	216	2691	1695	4600
		18.5–65.5	A2	12	191	186	3232	1277	4700
Gerderash	**3**	0 – 7	Ap	24	153	188	1614	2933	4700
		7 – 16	A1	6	102	106	676	1822	2600
		16 – 57	A2	4	80	97	644	1676	2400
Perdi	**4**	0 – 8.5	Ap	40	150	197	2180	470	2800
		8.5 – 20	A	26	127	168	1346	709	2200
		20 – 54	Btk	14	130	134	1154	4516	5800
Wermawa	**5**	0 – 20	Ap	12	150	170	3800	1450	5400
		20 – 45	A1	5	112	123	3040	2048	5200
		45 – 61	A2	4.	101	112	2680	419	3200

The pattern distribution of water soluble potassium in studied soil indicated to decrease in soluble K with increase in soil depth, which ranged from (12 – 40), (5 – 26) and (4 – 14) mg kg^{-1} (Table, 3) this decrease of soluble K agrees with the decrease of organic matter and EC while disagrees with pH and clay percent (Table, 2). Similar results were found by (Raskar and Pharande, 1997; AL-Badrani and Radhwan 2019). The soluble potassium in Semeel, Imerik, Gerderash, Perdi and Wermawa represent 0.656, 0.306, 0.302, 0.950 and 0.147 of the total potassium respectively. Amount of water-soluble K in some soils of Sulaimani governorate ranged from 0.003 to 0.013 cmol kg^{-1} soil with a mean value of 0.006 cmol kg^{-1}soil, which consisted 0.095% of total-K and reported the soluble K has a significant positive relationship with organic matter, EC, exchangeable and non- exchangeable K and it has negative correlation with active $CaCO_3$ (Mam Rasul, 2008). Wang *et al*. (2011) indicated that the kind of clay minerals and the concentration of Ca^{2+} and Na^{+} ions in the soil solution were shown to be connected to the critical level of soluble K which was released of non-exchangeable K form.

Available K and soluble K had a significant and positive correlation with EC with the correlation coefficient values of (0.60* and 0.72**) respectively and negatively significant correlated with pH (-0.53*) and correlated but non-significant with silt (0.48). AL-Badrani and Radhwan (2019) found similar results with EC (r = 0.707**), available K (r =0.684**) and silt (r=0.477*). These results agreed with (Samadi *et al*., 2010) which found a positive correlation.

Table (4): Coefficients of correlation (r) amongst altered forms of potassium with itself and some soil properties

K-Forms and properties	Soluble-K	Exch-K	Avail-K	Non Exch-K	Mineral-K	Total-K
Soluble-K						
Exchangeable -K	0.12					
Available-K	0.62*	0.96**				
Non-Exchang-K	0.14	0.75**	0.71**			
Mineral-K	-0.13	0.06	-0.01	-0.15		
Total-K	0.04	0.67*	0.59*	0.71**	0.59*	
Sand	0.11	-0.15	-0.07	-0.52	0.46	-0.09
Silt	0.48	0.80**	0.80*	0.66*	-0.37	0.28
Clay	-0.36	-0.24	-0.33	0.23	-0.32	-0.05
Total $CaCO_3$	0.18	0.02	0.10	-0.22	0.47	0.16
Active $CaCO_3$	0.12	-0.31	-0.19	-0.31	0.22	-0.10
CEC	-0.20	-0.44	-0.46	-0.04	-0.33	-0.28
pH	-0.53*	-0.22	-0.32	-0.37	0.24	-0.13
EC	0.75**	0.18	0.35	0.14	-0.05	0.08
O.M	-0.04	0.03	0.01	-0.05	0.34	-0.27

2- Exchangeable potassium

This is held on an exchange site by the negative charges of organic matter and clay and is accessible to plants. The exchangeable potassium in studied soil ranged between (67 – 229) mg kg^{-1} (Table 3), the low quantity showed in A horizon of Semeel pedon (Vertisols) it may be due to the low value of EC, high clay content and type of minerals; however, the great quantity presented in Ap horizon of Imerik pedon (Aridisols), this higher attributes to the higher value of EC and organic matter and low activity of calcium carbonate which facilitates exchange site to contact with soil solution and increases potassium to exchange. Higher exchangeable potassium was recorded at surface as compared to two horizons of sub-surface depths. The amount of exchangeable K according to the horizons ranged between (82 – 229), (67 – 214) and (68 – 191) mg kg^{-1} (Table 3) from the surface to subsurface horizons respectively, The higher concentration of exchangeable-K in surface horizon could be due to high organic matter content, use of K fertilizers, decomposing of crop residue, and a high degree of weathering process in the surface horizon compared to the lower horizons, the release of soluble K from crop residue. These results were parallel with those observed by (Saini and Grewal., 2014; AL-Badrani and Radhwan (2019).The exchangeable potassium for Semeel, Imerik, Gerderash, Perdi and Wermawa pedons represent 4.92, 4.529, 3.503, 4.456 and 2.695 of the total potassium respectively.

The exchangeable K of Kurdistan soil is high (0.64 – 1.99) cmol kg^{-1} especially in the cultivated layer (Al-Zubaidi, 2003). Al-Obaidi (1996) observed that, exchangeable K in some Iraqi soils ranged between (0.10 – 1.60) cmol kg^{-1} soil, and also Mehmedany (1999) found that the exchangeable K ranged between (0.46 - 1.76) cmol kg^{-1} soil in some soils of Iraqi Kurdistan Region. Gurav, et al., (2019) noted that the exchangeable potassium in some vertical soil in India soils varied from (21 – 455) mg kg^{-1}. According to Muhr, et al., (1965) all horizons in the Semeel and sub-surface horizons of Gerderash and the last horizon of Wermawa contain a medium quantity of exchangeable K and other horizons contain a high quantity or more than 110 mg kg^{-1}.

In the table (4) shown that exchangeable K had highly significant correlation with available K, non-exchangeable-K and silt content with the correlation coefficient values or r = 0.96**, r= 0.75**, and r= 0.80** respectively and significant positive correlated with total-K (0.067*) and negatively correlated but non-significant with CEC (-0.44). Without CEC, these results are agreeing with the results found by AL-Badrani and Radhwan (2019). The exchangeable potassium is more related to the type and amount of clay and its net negative charge (Parfitt, 1992).

3- Available potassium

The available-K content were ranged between 70 – 246 mg kg^{-1} (Table 3), the lower value observed in Bt1 horizon in Semeel pedon (Vertisols) it may be due to the type of clay minerals, while the higher value detected in Ap horizon in Imerik pedon (Aridisols) the cause of high values of available-K is similar to exchangeable potassium due to EC, O.M and low activity of $CaCO_3$.

The distribution of available-K according to the horizons ranged from (97 – 246), (72 – 216) and (70 – 186) mg kg^{-1} (Table 3) from the surface horizon to middle and third horizons respectively, This increase of available-K in surface and decrease in sub surface horizon is similar to the distribution of exchangeable potassium and similar causes effect on it. Similar finding were also described by (Siddiqua *et al*., 2018; AL-Badrani and Radhwan, 2019). The available potassium for Semeel, Imerik, Gerderash, Perdi and Wermawa pedons represent 5.476, 4.628, 4.039, 5.660 and 3.000 of the total potassium respectively.

Table (4) illustrates a significant and positive relationship between available potassium with non-exchangeable-K (r=0.71**), total-K (r=0.67*) silt (r=0.80**) while negative non-significant correlation observed to CEC (-0.46). These results are similar to those noted by (Saini and Grewal, 2014; AL-Badrani and Radhwan, 2019). The positive correlations between forms of potassium with other forms point out that the available-K is governed by the other forms of potassium in the soil.

4- Non exchangeable K

Bhonsle *et al.* (1992) found that non-exchangeable forms of potassium have been considered as a main source of potassium to plants which is low available for plants uptake and gradually transition from non-exchangeable K to more readily available (soluble and exchangeable K) forms (Najafi - Ghiri *et al*., 2010).

The non-exchangeable potassium in studied soils ranged between (345 – 3800) mg kg^{-1} (Table 3), the low amount showed in the Bt1 horizon of Semeel soil (Vertisols) is similar to available-K causes; however, the larger amount found in Ap horizon of Wermawa pedon (Aridisols), this greater may attribute to the type of clay mineralogy. The quantity of non-exchangeable-K in the surface layer is more than another sub surface layer or it decreases with the depth of pedon, the ranged between (656 – 3800), (676 – 3040) and (345 – 3232) mg kg^{-1} (Table 3) from the surface horizon to subsurface horizons respectively. Non-exchangeable-K levels have been found to decrease as soil depth increases (Ngwe *et al*., 2012). Non-exchangeable K is different from mineral K for the reason that it is bound within the crystal structures of soil mineral particles. It's held together by micas (dioctahedral and trioctahedral), vermiculites, and intergrade clay minerals like chloridized vermiculite in tetrahedral layers (Sparks and Huang, 1985; Sparks, 1987). Mehmedany (1999) illustrates that the non-exchangeable K ranged between (89.7 - 713.7) mg kg^{-1} soil in some soils of the Iraqi Kurdistan Region.

Non-exchangeable potassium for Semeel, Imerik, Gerderash, Perdi and Wermawa pedons represent 39.857, 69.100, 29.057, 52.777 and 70.860 of the total potassium respectively, when the concentration of K in the soil solution exceeds 1 mmol l^{-1}, the release of K from non-exchangeable to exchangeable form may be limited (Martin and Sparks (1983). According to Subba Rao, et al., (1993); Srinivasarao, et al., (2007 and 2010), all studied soils contain high concentration of non-exchangeable potassium except Bt1 horizon for Semeel contain medium concentration of non-exchangeable potassium.

Non-exchangeable-K has positive significant relation with total-K (r=0.71**) and silt (r=0.66*), while negatively relation but non-significant found to sand (-0.52). Zareian et al., (2018) showed that non-exchangeable K concentration and K desorption rate are influenced by soil order, soil depth, and clay type. Non-exchangeable K emission has a significant impact on soil K fertility.

5- Mineral-K

Mineral K desorption to the form exchangeable and soluble K, and adsorption on the site of exchange depend on the balance between various forms of K which influence by some factors like root absorption, applied fertilizer K, soil wetness, soil pH, and soil temperature (Zhang *et al*, 2011; Britzke *et al.*, 2012).

Mineral-K in the studied pedons ranged between (462 - 4516) mg kg^{-1}, low values found in the Ap horizon of Semeel pedon and high value recorded in Btk horizon of Perdi pedon, and the distribution of mineral-K in Gerderash and Wermawa pedons decrease with the depth but for another pedon increase with the depth, from the range between (462 – 2933), (709 – 2048) and (419 – 4516) mg kg^{-1} from the surface to sub surface pedons respectively. The mineral-K form is difficultly available to the plants. However, with time, these minerals finally break down, and minor amounts of potassium are out to the soil solution. It is found in the feldspars, mica and clay minerals which are part of the soil. Mineral-K depends on soil type, types and amounts of clay minerals, types of primary, secondary minerals, removal of K from weathering degree on the particle-size distribution, and ecological conditions (Sharpley, 1987; Das *et al*., 1993; Dhakad *et al*., 2017).

A positive and significant relationship was also noted among mineral-K and total-K (r =0.59*). These results are in contract with the results of (Mandal *et al*., 2011; AL-Badrani and Radhwan (2019). While the mineral-K in studied pedons was positively correlated but non-significant with total $CaCO_3$ (r= 0.47) and sand (0.46). Mineral-K consisted of total-K percent in studied soil varied from 55.007, 26.367, 67.337, 42.291, 26.442 and 43.318 from Semeel, Imerik, Gerderash, Perdi and Wermawa respectively.

6- Total potassium

Total-K made up a considerable high amount of the total potassium in soil and was unavailable to plants as a structural constituent of soil minerals. (Lalitha and Dhakshinamoorthy, 2014). Total potassium content is dependent on the kind of parent material, primary and secondary minerals, and soil parts.

The total potassium content of the calcareous pedon studied differ from 1200 to 5800 mg. kg^{-1} the junior value noted Ap horizon of Semeel pedon (Vertisols); however, the greater value was revealed in Btk in Perdi pedon (Aridisols). The distribution of total potassium content in the horizons of studied soils was various from (1200 to 5400), (1700 to 5200) and (1700 to 5800) mg kg^{-1} from surface horizons to sub surface respectively, and have no uniform pattern about the distribution with the soil depth, similar uniform distribution reported by AL-Badrani and Radhwan (2019). The higher content in higher altitudes may be attributed due to the presence of illite, mica and feldspars as primary potassium-bearing minerals which are capable of releasing a large amount of potassium. Sparks (1987) found the content of total K in soils usually ranged from 750 to 25000 mg kg^{-1} in the surface 20 cm of the soil profile. Mica weathering to biotite, vermiculite, or smectite and feldspar structural disintegration over a longer period may occur if potassium is not applied (Shaikh *et al*., 2007).

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جورێن پوتاسیومی د ئوردەرێن سەرە کی یێن ئاخێن باکورێ عیراقێ

پوختە

پازدە نمونێن ئاخێ هاتنە وەرگرتن ژ پێنج جهان ل باکورێ عیراقێ و ژ سێ تەخێن بوماوەیی یێن پێنج جهان ئەو ژی ئەڤەنە سێمێل (VERTISOLS)، عمێریك(ARIDISOLS) ، گردەرەش (INCEPTISOLS)، پردێ (ARIDISOLS) و وارماوا (MOLLISOLS) بو خواندنا جورێن پوتاسیومی و بەلاڤبوونا وی دگەل کویراتیێ. و ئەنجام دیاربوون کو هەمی ئاخ د کلسی نە و نە د سویرن و مادێ ئەندامی تێدا کێمە.

ل تەخێن سەرڤە یێن ئاخێت ڤەکولینێ ئەنجامێن پوتاسیومێ حەلیایی و یێ پێکگهور و یێ بەرهەڤ و یێ پێکنەگهور و یێ کانزایی و یێ سەرجەم د ناڤبەرا (١٢ - ٤٠)، (229-82) ، (246-97) ، (3800 - 656) ، (2933 - 462) و (5400 - 1200) ملگم کگم-١ ل دویڤ ئێک و ل تەخێن ناڤێ A) و1 (Aدناڤبەرا (5 –26) ، (214 - 67) ، (216 - 72) ، (676) - (3040) ، (709 - 2048) و (5200-1700) ملگم کگم-١ لدویڤ ئێك. و ل تەخێن سیێ ژمارێن وان (14-4) ، (191-68) (186-70) ، (3232-345) ، (4516 - 419) و (5800 - 1700) ملگم کگم-١ لدویڤ ئێک. و چەنداتیا پوتاسیومێ حەلیای و پێکگهور و بەرهەڤ و پێکنەگهور کێم دبیت دگەل کویراتیا ئاخێ. و رێژا پوتاسیومێ حەلیای و یێ پێکگهور و یێ بەرهەڤ و یێ پێکنەگهور و یێ کانزایی ژ پوتاسیومێ سەرجەم دبیتە (0.469 , 4.185 , 4.538 , 52.141 و 43.318) لدویڤ ئێك.

ئەنجاما ديارکر کو پەيوەنديەکا پوزەتيف يا ئەرێنى يا هەی د ناڤبەرا پوتاسيومێ سەرجەم دگەل پوتاسيومێ پێکگهور و يێ بەرهەڤ و يێ پێکنەگهور و يێ کانزايى د ئاخێ دا. هەروەسا پەيوەنديکا پوزەتيف يا ئەرێنى ديار بوو دناڤبەرا سلتێ دگەل پوتاسيومێ پێکگهور و يێ بەرهەڤ و يێ پێکنەگهور ، بەلێ پەيوەنديەکا پوزەتيف يا نەرێنى ديار بوو د ناڤبەرا پوتاسيومێ حەلياى دگەل پلا ترشاتى و تفتاتيێ (PH)و پەيوەنديەکا نێگەتيف دگەلEC. پوتاسيومێ حەلياى ب رێژەکا مەزن ديار بوو د ئاخا پردێ (ARIDISOLS)بەلێ رێژا مەزن يا پوتاسيومێ پێکگهور و بەرهەڤ و پێکنەگهور و سەرجەم ديار بوو ل ئاخا عميريکێ(ARIDISOLS) ، بەلێ پوتاسيومێ کانزايى ب رێژەکا مەزن ديار بوو ل ئاخا گردەرەش. (INCEPTISOLS)

صور البوتاسيوم في الرتب الرئيسية لترب شمال العراق

الخلاصة

تم جمع خمسة عشر عينة تربة من خمسة مواقع في شمال العراق ومن ثلاثة افاق وراثية في خمسة مواقع هي سميل (Vertisols) و عميريك (Aridisols), كرده رش (Inceptisols), بردي (التون كبري) (Aridisols) و وارماوا (Mollisols) لدراسة صور البوتاسيوم وتوزيعها مع العمق. جميع ترب الدراسة كانت كلسية غير ملحية وتحتوي على كميات قليلة من المادة العضوية.

قيم صور البوتاسيوم الذائب و المتبادل و الجاهز و غير المتبادل و المعدني والكلي للافاق السطحي في ترب الدراسة تراوحت بين [12-40 ، 82-229 ، 97-246 ، 656 – 3800 ، 462 - 2933 و 1200 - 5400] ملغم كغم-1 على التوالي ، بينما في الافاق الوسطى لترب الدراسة (A و A1)كانت [5 –26 ، 67 - 214 ، 72 - 216، 676 - 3040 ، 709 - 2048 و 1700-5200] ملغم كغم-1 على التوالي و كانت للأفق الثالث لترب الدراسة بين[4-14، 68-191،70-186، 345-3232، 419 – 4516 و 1700 – 5800] ملغم كغم-1 على التوالي. وهذا يوضح بان كمية البوتاسيم الذائب و المتبادل و الجاهز و غير المتبادل يقل مع العمق. و ان نسبة صور البوتاسيم الذائب و المتبادل و الجاهز و غير المتبادل و المعدني من البوتاسيوم الكلي في جميع بيدونات الدراسة هي 0.469 , 4.185 , 4.538 , 52.141 و 43.318 على التوالي.

دراسات الارتباط توضح علاقة ارتباط معنوية وموجبة بين البوتاسيوم الكلي مع البوتاسيوم المتبادل و الجاهز والغير المتبادل والمعدني، بينما وجدت علاقة موجبة ومعنوية بين محتوى الغرين مع البوتاسيوم المتبادل و الجاهز والغير المتبادل في التربة، ظهرت علاقة موجبة ولكن غير معنوية بين البوتاسيوم الذائب مع الرقم الهيدروجيني (pH) و سـالبة مع التوصيل الكهربائي (EC). كميات عاليـة من البوتاسـيوم الذائب ظهرت في تربـة بردي (Aridisols) ولكن ظهرت كميات كبيرة من البوتاسيوم المتبادل، والغير متبادل ، و الجاهز, و الكلي في تربة عميريك (Aridisols), بينما وجدت كميات كبيرة من البوتاسيوم المعدني في تربة كردهرش (Inceptisols).