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STUDY OF POTASSIUM RELEASE AND ITS RELATIONSHIP WITH CHEMICAL SOIL PROPERTIES AND ITS EFFECT IN ALFAALFA GROWTH IN SOME OF SOILS SALTY IN WASIT PROVINCE

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Abstract
This study was aimed to determine of the chemical and, physical soil properties by potassium release, ten different locations were chose in Waist Province, then chose three locations according to the contrast in its salty and clay contents. These locations are Al-swaira, Nuamaniya and Al-Hay. Potassium was extracted from the studies by different methods such as the chemical methods and the biological methods. These chemical extractions are water, the organic acid solution [(COOH)2, C6H8O7] and Ca-resin. Potassium is extracted by mentioned solutions above (0.5 molar conc) Potassium is extracted by missible displacement. Every technique is about ten periods. The duration of every one is twenty minutes. The total period is about (200) minutes except the resin which is used by Batch equilibrum technique. This technique is about ten periods. The duration of every one is about 7 days. The total period is about (70) days. In this experiment, Alfalfa plant (local classes) was in planted in plastic pots. The volume of every pot is about 3.5 kg ,then cut five often on different time period when reach the flowers percentage (10%) for total growth period (200) days. Potassium is determined in all the extractions and for all the used methods in this study by flame photometer system. The results of this study display that the best extract to release potassium in calcic Iraqi soils is Ca-resin by Batch equilibirum technique in field capacity compared with the organic extracts acidity.

Keyword: Potassium release, chemical soil properties, alfalfa plant.

Introduction

Potassium is one of the most important and common essential elements in the Earth's crust. Its natural percentage is 2.6%, and it is often present in the form of K2O. The potassium content of soils varies depending on the quantity and type of dominant minerals (Stanly, 2005; Sposito, 1989). The most important sources of potassium in soil are primary soil minerals such as feldspar and mica (Mengle and Kirkby, 2001). Potassium is present in four forms: permanent, exchangeable, non-exchangeable, mineralized, and total potassium (Ali et al., 2014). Its availability is influenced by soil chemical and physical properties, such as the degree of soil reactivity, soil texture, mineral composition, organic matter, soil temperature, cation exchange capacity, and the concentration of cations in the soil solution (Havlin et al., 2005; IPI, 2016). Potassium is an essential element that plays a vital role in plant growth and metabolism, significantly helping to sustain plants under various forms of biotic and abiotic stress (Wang et al., 2013).

Potassium also ranks third in plant requirements after nitrogen and phosphorus, and is considered an essential nutrient that forms the backbone of crop production and determines its quality (SQO, 2015). The use of acidic extracts, whether organic or inorganic (diluted or concentrated), helps extract and release potassium by supplying the solution with hydrogen ions, which are effective in releasing potassium from exchange sites. They also help dissolve and decompose primary and secondary minerals (Martin, 1985; Sparks and Richards et al., 1988; Sparks, 1992; Al-Ubaidi, 1996; Al-Rubaie, 1998). Examples of these acids include sulfuric, nitric, and hydrochloric acids. Organic acids include oxalic and citric acids, the latter of which are somewhat similar to the release of acids produced in the root zone by organisms and plant roots (Sparks and Huang, 1988; Sony and Huany, 1988).

The use of capsules containing either a positive H-resin or Ca-resin, NO3-resin, HPO4-resin, or a mixture called mixed-bedion-exchange resin can be placed or injected into natural soil samples, field-stirred samples, or directly into the soil. RAQs are expressed as: Resin adsorption quantities per unit surface area, mmol/cm².

Martin and Sparks (1985) and Yang and Skogley (1992) indicated that these methods are among the best chemical methods, especially after mixing them with soil at saturation (Yang et al., 1991). These are charged organic reservoirs that are saturated with hydrogen or saturated with a basic ion such as sodium, calcium, or any other ion. However, Talibudeen et al. (1978) preferred the use of calcium-saturated resin over hydrogen-saturated resin because the latter reacts with soil minerals and breaks down their mineral composition, resulting in an increase in the amount of potassium released. The released amount represents not only the release of non-returnable potassium, but also the release of a portion of mineral potassium (Goulding 1987).

The use of resins is a recent trend in nutrient extraction and a promising method for standard nutrient fertility tests, as this method allows for simulating the status of these elements and tracking them in different soil environments. Therefore, this study was conducted to determine the relationship between the chemical and physical properties of the soil and potassium release in the saline soils of Wasit Province using resins and some chemical extracts, and comparing them with biological growth indicators in alfalfa cultivation.

Materials and Methods

Site Selection

Ten different sites were selected from Wasit Province, with depths of (0-30 cm), some of whose chemical and physical properties are listed in Table (1). Three sites were then selected based on the variation in their clay and salt content: Al-Suwayrah, Al-Numaniyah, and Al-Hayy.

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Evaluation of Chemical and Physical Properties

The chemical and physical properties of the study soils were estimated according to what was described by Page et al. (1982).

Table (1) some chemical and physical properties of the study soil samples

No.	Location	Soil g/ kg^{-1}				pH	Ec dsm^{-1}	CaCo3 g/kg^{-1}	exchange capacity ces/mol	Organic matter g/kg^{-1}
1		sand	clay	silt	texture					
2	Al-Zubaidiyah	90	425	485	SiC	8.00	7.05	160	29.00	15.00
3	Al-Suwayrah	75	320	605	C	7.88	8.00	250	33.00	3.00
4	Al-Ahrar	98	470	432	CL	8.20	6.50	200	28.50	14.00
5	Al-Muwafaqiyah	275	220	505	C	7.50	7.45	195	34.00	8.00
6	Al-Aziziyah	112	570	318	SiCL	7.60	6.88	185	35.00	12.00
7	Al-Numaniyah	522	122	356	L	7.30	7.00	225	29.00	8.00
8	Badra	240	540	220	SiL	7.60	7.70	130	25.00	11.00
9	Al-Hafriya	310	580	110	SiL	7.60	8.00	115	45.00	12.00
10	Al-Hay	100	500	400	SiC	7.00	7.99	226	26.50	30.55
		300	505	195	SiL	7.50	7.88	125	26.70	2.00

Potassium formulas

Soluble potassium

Soluble potassium was determined in a (1:1) soil:water extract.

Exchangeable potassium

Exchangeable potassium by the ammonium chloride method. Exchangeable potassium was extracted using a 1 M ammonium chloride solution (pH 7) according to the method described in Pratt (1982).

Exchangeable potassium by the calcium chloride method

Exchangeable potassium was extracted using 1 M calcium chloride after subtracting the soluble potassium according to the method described in Pratt (1982).

Unchangeable potassium

Unchangeable potassium was extracted using a 1 M boiling nitric acid solution according to Pratt (1982). Unchanged potassium was calculated from the difference between the amount extracted with 1 M nitric acid and the amount extracted with 1 M ammonium chloride.

Total Potassium

Total potassium was estimated using a mixture (48% hydrofluoric acid + 97% sulfuric acid + 62% perchloric acid) using plastic lids, as described by Page et al. (1982).

Mineral Potassium

Mineral potassium was estimated mathematically according to the formula proposed by Martin and Sparks (1985) as follows: Mineral potassium = total potassium - [potassium extracted with calcium chloride + potassium extracted with boiling nitric acid] (Table 2).

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Table (2) Different potassium formulas (cen/mol. kg^{-1}) in the study soils

No.	Soluble potassium	Exchangeable potassium extract		Unconjugated potassium	Mineral potassium	Total potassium
		Calcium chloride	Ammonium chloride			
1	0.07	0.07	1.00	1.98	32.44	35.00
2	0.05	0.05	0.88	1.88	31.48	34.28
3	0.04	0.04	0.90	1.37	40.59	43.32
4	0.06	0.06	0.65	1.26	52.37	54.66
5	0.08	0.08	1.00	1.35	43.22	45.75
6	0.02	0.02	0.55	1.47	28.52	30.72
7	0.03	0.03	0.86	1.55	20.25	22.76
8	0.04	0.04	0.95	1.00	55.62	56.26
9	0.15	0.15	1.35	2.00	58.22	60.00
10	0.08	0.08	0.98	1.33	50.00	52.23

Potassium Release in Soil

A series of different experiments were conducted to study the ability of extracts to release potassium, as follows:

Acidic Solutions

Potassium was extracted using weak organic acids (0.5 M oxalic acid, 0.5 M citric acid), as these acids represent the conditions present in the root zone of plants, using the gentle miscibility displacement method. 20 cm long glass columns with a radius of 5 cm were used, with glass wool placed at the bottom of the column. A soil sample of 50 g of dry soil was then placed. The extraction solution (citric acid and oxalic acid) was then allowed to pass gently through the soil at a speed of 1 ml/minute, according to Martin and Sparks (1985). The filtrates were received from the bottom of the column over ten time periods, with each extraction time lasting one minute. Potassium was estimated in the equilibrium extraction solutions.

Potassium release using calcium-saturated resin (Ca-resin) using the stable batch equilibrium method.

Before the potassium release process, the Amberlite IR.120 resin was pretreated. The resin was placed in a glass column and a calcium-impregnated resin solution was added according to the following equation.

$$2H\text{-}Resin + Ca \longrightarrow Ca\text{-}resin + 2H^{+}$$

The resin was then washed several times to saturate with calcium. The resin was then washed with distilled water to remove chlorine, which was detected using silver nitrate. Martin and Sparks (1985) then dried for further use. To study potassium release, 5 grams of the saturated resin were placed in a piece of polyester. Sherif and Hedia (2001) mentioned that Polyester forms a permeable membrane, allowing the calcium in the resin to replace the soil potassium, according to the principles of cation exchange in the soil, as shown in the following equation.

$$Ca\text{-}Resin + 2K\text{-}soil \longrightarrow 2K\text{-}resin + Ca\text{-}soil$$

The polyester resin-containing piece was placed in a plastic container containing 50 grams of dry soil. The soil was then moistened to field capacity and incubated at a constant temperature of 298°K. The soil moisture was maintained at field capacity throughout the incubation period by weighing the containers daily. Resin capsules were separated from the soil ten times weekly for a total period of 70 days. The resin was washed with 50 ml of 2 M hydrochloric acid (drop by drop) using a burette, according to the method Sherif and Hedia (2001). Potassium was estimated in the resin extract.

Biological Release of Potassium

To determine the soil's ability to release potassium and supply it to the plant, alfalfa, a local variety known for its high capacity for biological potassium extraction, was planted in plastic pots with a capacity of 3.5 kg of soil, at a rate of 32 seeds per pot for ten surface soils. The soil was moistened to field capacity on August, 2023, and fertilized with phosphorus (100 g/pot) in the form of superphosphate.

The plants were left to grow. They were harvested when the flowering rate reached 10% of the total plants, resulting in five harvests of different growth periods (210) days. Plant samples were cleaned with distilled water after each harvest, dried, and wet-digested using a mixture of sulfuric and perchloric acid according to the method Havlin et al. (1985).

Potassium Estimation

Potassium was determined in the chemical and aqueous extracts using a flame photometer as described by Page et al. (1982).

Statistical Analysis

Statistical analysis was used to calculate the correlation coefficient (r) between the values of the aggregated concentration of released potassium and some soil properties using the logarithmic equation for the relationship between X and Y as follows: Y = a + bLt. Duncan's test was also used at a probability level of 0.05 to determine significant differences between the acidic and resinous treatments used.

Results and Discussion

Different forms of potassium in the study soils

Table (2) shows the values of soluble potassium, which ranged (0.02-0.15) mmol.kg^{-1}. The highest concentration of soluble potassium (0.15) mmol.kg^{-1} was recorded in soil (9) from the Al-Hay site, while the lowest concentration of soluble potassium (0.02) mmol.kg^{-1} was recorded in soil (6) from the Al-Numaniyah site. These values fall within the soluble potassium values found for Iraqi soils by several researchers, such as Al-Obaidi (1996). Those who obtained values for soluble potassium ranging between (0.007 - 0.03) mmol.kg^{-1} for twelve sites collected from different regions of Iraq. The results of the statistical analysis presented in Table (3) indicated a significant positive correlation between soluble potassium and each of the clay (r = 0.750*), clay + silt (r = 0.651*), electrical conductivity (r = 0.649*), and organic matter (r = 0.685*).

Exchangeable Potassium

Table (2) shows the values of exchangeable potassium extracted with calcium chloride after subtracting the dissolved potassium, which ranged between (0.55-1.35) mmol.kg^{-1}, with the highest value recorded at (1.35) mmol. kg^{-1} in soil (9) from the Al-Hay site, and the lowest value was (0.55) mmol.kg^{-1} in soil No. (6) from the Al-Numaniyah site. This table also shows the values of exchangeable potassium extracted with ammonium chloride, which ranged from (1.25-2.25) mmol.kg^{-1}. In general, the values of exchangeable potassium extracted with ammonium chloride were higher than those extracted with calcium chloride, indicating the presence of a significant amount of weathered mica clay minerals, such as vermiculite, in the studied soils.

Ammonium chloride has the ability to penetrate the hexagonal sites of these minerals and displace potassium from them according to the principle of cation exchange, leading to the extraction of a greater amount of potassium compared to calcium chloride. The results of the statistical analysis indicated a positive correlation between exchangeable potassium and organic matter (r = 719*), clay (0.747*), and clay + silt (0.650), while the relationship was negative with electrical conductivity (-0.498).

Non-exchangeable potassium

Table (2) shows the values of non-exchangeable potassium extracted by boiling nitric acid. These values ranged from 1.00 to 2.00 cmol.kg^{-1}. The highest value was recorded in the Al-Hay soil compared to the other soils studied. These values fall within the range found by Al-Ubaidi (5). The statistical analysis indicated a significant positive correlation between non-exchangeable potassium and clay (r = 799*) Table (3).

Mineral potassium

The results presented in Table (2) indicate a high content of mineral potassium in the studied soils compared to other potassium forms. These values ranged from 20.25 to 58.22 cmol.kg^{-1}. Mineral potassium constituted a high percentage of total potassium, confirming that the parent material of these soils is the primary source of potassium. The results of the statistical analysis indicated a negative correlation between mineral potassium and cation exchange capacity (r = -570) and electrical conductivity (r = -0.153), and a positive correlation with clay (r = 0.840*) Table (3).

Total Potassium

Table (2) shows a wide range of variations in the total potassium content of the studied soils, increased 58.4 to 23.6 cmole.kg^{-1}. The highest value was recorded in the Hay soil, and the lowest value was recorded in the Numaniyah soil. This variation is due to differences in texture and mineral composition.

Table (3) Correlation coefficient (r) values for potassium formulas and some soil properties

Potassium formulas	Soluble potassium	Exchangeable potassium	Unexchanged potassium	Mineral potassium
Cation exchange capacity	0.579	0.571	0.500	-0.570
Electrical conductivity	0.649*	-0.498	0.802*	-.0.153
Organic matter	0.685*	0.719*	0.601	0.605
Clay	0.750*	0.747*	0.799*	0.840*
Clay + silt	0.651*	0.650*	0.650*	0.780*

Potassium release by miscible displacement using acidic solutions and water

The results shown in Table (4) indicate the amount of potassium released. It is noted from these values that the amount of potassium released varied depending on the soil, with a range of (41.12-2.69) $mg.kg^{-1}$. The largest amount of potassium released was achieved in soil (9) from the Al-Hay site (41.12) $mg.kg^{-1}$ using oxalic acid. The smallest amount of potassium released was (2.69) $mg.kg^{-1}$ from soil (6) from the Al-Numaniyah site using distilled water. This difference is due to differences in the chemical and physical properties of the soil. The increased amount of silt 500 g/kg and the decreased amount of sand (100) g/kg^{-1} in soil number (9) were the reason for the higher amount of potassium released compared to soil number (6), which was characterized by a higher amount of sand 522 g/kg and a lower amount of clay 356 g/kg^{-1}.

Statistical analysis revealed positive correlations between the potassium released from soils treated with acidic solutions and some physical and chemical soil properties, including significant correlations between the released potassium and the cation exchange capacity (r=0.798*-0.990**), clay (r=0.898**-0.989**), and organic matter (r=0.895**-0.999**). Chemical extracts can be ranked according to their ability to extract potassium, regardless of soil type, as follows: oxalic acid < from citric acid < from distilled water. Oxalic acid was distinguished by the release of a greater amount of potassium than citric acid. This is due to the nature of the organic acid, its chemical composition, and the arrangement of atomic bonds (Sony and Huang 1985).

Table (4) Amount of potassium released when treated with organic acid solutions and water using the miscible displacement method

Sample No.	Released potassium concentration ($mmol\ kg^{-1}$) after 10 extractions		
	Organic acid treatments and water		
	H_2O	$C_6H_8O_7$	$(COOH)_2$
1	3.30	25.03	31.39
2	8.30	24.63	30.42
3	3.26	26.63	32.10
4	2.93	24.93	31.40
5	4.58	25.51	35.32
6	2.69	9.24	12.76
7	3.44	10.14	13.78
8	10.88	33.0	40.85
9	11.92	33.88	41.20
10	11.13	33.59	41.01
Mean	5.66	24.73	31.00

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Potassium release using calcium-saturated resin (Ca-Resin)

Table (5) shows the potassium values released by the cation exchange process (soil potassium with resin calcium). It is noted from the values mentioned above that the highest value appeared in the mixed clayey silt soil of Al-Hay (12.88) mg. kg^{-1} after a period of (70) days of extraction, while the lowest value appeared in the mixed soils of the Al-Numaniyah site (6.55) mg.kg^{-1} during the same time period. These values are relatively low compared to other chemical extracts, but these values are somewhat similar when compared. By biological extraction methods (alfalfa plant), therefore, the resins used in kinetic studies are among the best chemical methods, especially the calcium-saturated resin, which represents the plant's ability to absorb potassium in calcareous Iraqi soils. This leads us to conclude that the use of calcium-saturated resin using the stable equilibrium method at field capacity represents a reliable trace of potassium and simulates its presence in Iraqi soils.

Table (5) shows the amount of potassium released (mmol/kg) at different times (days) of chemical extraction

Sample no.	Chemical extraction duration (day)									
	7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**70**
1	0.10	0.38	0.66	1.20	2.73	3.66	4.78	7.85	8.95	9.60
2	0.09	0.34	0.72	1.18	1.75	2.69	3.79	5.12	6.74	8.61
3	0.18	0.30	0.76	1.53	3.00	4.12	5.24	7.21	8.79	9.71
4	0.15	0.25	0.45	0.81	1.65	3.20	5.20	6.34	7.00	7.66
5	0.22	0.46	0.80	1.60	3.23	6.54	7.53	8.41	9.5	10.12
6	0.08	0.28	0.53	0.84	1.30	2.00	2.89	4.12	5.64	6.55
7	0.09	0.18	1.60	2.85	3.28	4.56	5.33	6.77	7.10	7.56
8	0.44	0.88	1.66	3.33	6.21	8.33	9.41	11.00	11.89	12.13
9	0.55	1.28	2.05	2.94	4.00	5.38	7.05	9.02	11.3	12.88
10	0.48	0.98	1.80	3.60	6.81	7.60	8.52	9.67	10.71	11.50

Biological experiment on potassium depletion

Table (6) indicates that the total potassium uptake over (200) days of alfalfa growth (5 harvests) in soils (9, 6, and 2) reached (35.88, 14.55, and 22.00) mg.kg^{-1} dry matter, respectively. The results also indicated an increase in biological depletion in soil (6) from the Al-Numaniyah site, which has a mixed texture, compared to soil (9) from the Al-Hay site, which has a mixed clay silty texture. The same figure also indicates a significant change in the content of various potassium forms, both exchangeable and non-exchangeable, at different stages of alfalfa growth over a period of seven months. The results showed a significant decrease in the values of these forms after the end of the growing season, with the exchangeable potassium content decreasing from (8.33 to 3.20) mg.kg^{-1} in the Al-Suwayrah soil, and from 13.86 to 4.53 mg.kg^{-1} dry matter in the Al-Hay soil, and from 6.31 to 0.6 mg.kg^{-1} dry matter in the Al-Namaniyah soil.

The values released by the gypsum plant in the first harvest after a period of seventy days were 8.33, 6.31, and 13.86 mg.kg^{-1} dry matters for the Al-Suwayrah, Al-Namaniyah, and Al-Hay soils, respectively. These values are somewhat similar to the values released by the resin after a period of seventy days for the aforementioned soils, as shown in Table (5). This indicates that the continuous intensive cultivation conditions led to a substantial and significant change in the release of exchangeable potassium. This change was more pronounced in the Al-Hay soil than in the Al-Namaniyah soil. The figure also shows the behavior of the exchangeable potassium decline path after each of the five growth periods of the alfalfa plant.

The exchangeable potassium change rate was characterized by two distinct phases: the first, with a significant decrease, representing exchangeable potassium and the second, with limited change, representing non-exchangeable potassium. This decrease was greater in soil (9) compared to soil (6), and then reached a state of steady-state supply, particularly during the final growth periods, which expresses the steady rate of potassium release from the non-exchangeable phase to the exchangeable phase. This was confirmed by Havlin and Westfall, 1985.

Table (6) shows the total absorbed potassium (mg.kg^{-1}) by alfalfa in the studied soils

Sample no.	**Time (days)**				
	70	100	135	180	210
1	9.00	15.66	18.99	21.79	22.00
2	8.33	13.11	16.99	20.22	21.11
3	10.00	15.46	19.85	23.09	24.24
4	7.56	13.33	16.68	18.68	19.33
5	10.35	17.14	21.82	25.37	26.46
6	6.31	10.56	12.44	13.04	14.55
7	7.69	11.24	12.49	13.74	14.66
8	11.00	19.39	25.53	28.60	30.00
9	13.86	23.92	30.25	34.77	35.88
10	11.70	20.58	26.86	29.94	30.22

Conclusions

The study concludes that Potassium is determined in all the extractions and for all the used methods in this study by flame photometer system. The best extract to release potassium in calcic Iraqi soils is Ca-resin by Batch equilibirum technique in field capacity compared with the organic extracts acidity.

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