Study of the adsorption and release kinetics of potassium in some soils of Babylon province

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Abstract

The study included the adsorption, release To evaluated potassium availability, soil samples with different clay content (high, medium and low) were used in this study, which were selected from most of the soils of Babylon province. To aim this study, four experiments were required (three of which were laboratory) and the last one was biological. The first represents the mineral analysis experiment, and the second is to study the kinetics of potassium adsorption and release reactions. To calculate the potassium adsorption rate coefficient in the study soils, the best equation describing the potassium adsorption kinetics in the soils under study must be determined. By comparing the five equations, it was found that the Elovich equation is the best equation describing the potassium adsorption kinetics in soils with low, medium and high clay contents representing the study area when adding levels (5, 25, 50, 100, 150 and 200) mg K L-1. Therefore, it was adopted to calculate the potassium adsorption rate coefficient in all the study soils. Third, five kinetic equations were used, some of which were mathematical in nature and others were experimental statistical, to describe the release of potassium in soils with different clay content (sandy soil, loam soil, and clay soil). These are the zero-order equation, the first-order equation, the diffusion equation, the power function equation, and the Elovich equation. Two statistical criteria were adopted, namely the coefficient of determination R2 and the standard error SE, to compare the equations to choose the best one in describing the release of potassium from the study soils. The results show that the zero-order equation was superior in describing the release of potassium from the three soils, as the value of the coefficient of determination for the clay soil was 0.95 with a standard error of 0.3418, while the coefficient of determination for the first-order equation, diffusion, power function and Elovich were (0.85, 0.92, 0.91 and 0.84) respectively with a standard error of (22.793, 442, 42 and 201815, 33.762) in the same order.

key word : Elovich equation, potassium, release, kinetics

Introduction

Potassium ion is one of the essential elements and nutrients that determine agricultural production in terms of quantity and quality that plants need in large quantities. Iraqi soils in general have a relatively high store of potassium ion, as in most soils of dry and semi-dry regions, but its release rate is relatively slow and is not sufficient to meet the needs of the plant, especially plants with high requirements for this element, which necessitates the need to study the status and behavior of this element in the soil in order to increase its production. Those working in the field of chemistry are responsible for the task of reaching accurate means and methods to accurately express the readiness of this element, and to estimate the extent of the need for fertilization with fertilizers containing it. In light of this, some studies have paid attention to evaluating the readiness of potassium and its relationship to the mineral composition, as

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well as the mechanism of its release from the soils of dry and semi-dry regions, especially the applied minerals that represent the intermediate state of mica, due to the loss of potassium from its structural composition and its signs appeared in the soils of central and southern Iraq, but the release rate of potassium from it is relatively slow, as the release of potassium into the soil solution is affected by the availability of the minerals that carry it on the one hand, and the degree of weathering and transport on the other hand, and therefore it is not sufficient to meet the needs of many crops and intensive agriculture [2] Initial studies relied on traditional standards as an indicator of the strength of potassium preparation, but these studies did not take into account the behavior of potassium in terms of its release, adsorption, and association with mineral composition, as well as its release from exchange sites until reaching the soil solution by introducing the time factor as one of the factors. It was necessary to address the release and adsorption of this element to reveal the behavior of potassium in the soil [8 .[

Materials and Methods

Field Procedures

A field visit was conducted to the study area and the soil sites of the study area were identified according to the soil series for each site according to the soil texture and natural drainage. Two pedons were discovered:

.1-Selecting pedon 1, whose texture according to the morphological description was Loamy

.2-Selecting pedon 2, whose texture according to the morphological description was Clay

.3-Selecting site 3, whose texture was Sandy

The locations of the pedons and site 3 were identified and their coordinates were taken using a GPS device. Then the pedons were discovered and their horizons were described in a fundamental morphological manner according to the American Soil Survey Guide [13[

Location

The study sites are located in Babylon Governorate in central Iraq within the Middle Euphrates region south of Baghdad in Babylon Governorate, 30 km away from Najaf Governorate, located between longitudes 440 22' 36" east and latitudes 320 13' 27" north, as shown in Figure (1)

Geology of the study area The study area is part of the sedimentary plain, so its surface is generally flat and characterized by a slight gradual slope towards the east and south in particular, and its surface is free of variations in the shapes of the earth's surface, and if they exist, they are either the work of man or rivers or both together, and this flatness is due to the nature of the geological environment of the region and the sediments carried by the rivers, which led to the flatness of its surface, and it is part of the lands of the central regions of the sedimentary plain, and from a geological point of view, these areas are affected by sedimentation and erosion processes during the geological eras of recent formation, and it is located in the unstable platform area in relation to the tectonic division of Iraq, and its geological formation is linked in some way to the geological developments that occurred in Iraq and the region, as the age of the geological formations appearing on the surface of the region extends from the late Lower Eocene (Dammam) to the Upper Miocene Pliocene (Euphrates and Venus Formation) to the present time (modern sediments), and these sediments are the result of sediments Fluvial and aeolian deposits are characterized by stratification and succession and consist of layers of clay, silt, sand, calcium carbonate

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and a little calcium sulphate. These deposits are of fluvial origin.

Soil preparation

For the purpose of studying the behavior of adsorption, release and mineral composition in potassium readiness, soil samples with different clay content (high, medium and low) were obtained, which were selected from most of the soils of Babylon Governorate. Then, random soil samples were taken at a depth of 0-30 cm before planting, mixed and air dried, then ground with a 2 mm sieve and adopted as a composite sample representing the study soil and placed in plastic boxes for the purpose of conducting chemical and physical analyses. Table (1) shows some of the physical and chemical properties of the study soils.

Table 1: Some chemical and physical properties of the soils before planting

units	**soils**			**traits**	
	high	**medium**	**low**		
dSm^{-1}	3.44	3.14	2.85	Electrical conductivity Ece	
---	7.63	7.25	7.10	Reactivity pH	
$g.kg^{-1}$	8.85	5.67	3.41	Organic matter	
$Cmol^{+}kg^{-1}$	28.30	23.18	15.17	Ion exchange capacity	
$mmol.\ L^{-1}$	8.00	8.75	7.00	Calcium	Dissolved ions
	6.10	6.75	5.20	Magnesium	
	4.50	5.40	4.30	Sodium	
	1.85	1.75	1.20	Potassium	
	10.00	9.25	8.15	Sulfate	
	7.10	6.85	7.10	Chloride	
	7.20	5.90	4.75	Bicarbonate	
	Nill	Nill	Nill	Carbonate	
$mg.kg^{-1}$	30.31	26.50	20.53	Nitrogen	Available element
	16.51	14.15	9.55	Phosphorus	
	185.00	180.39	150.25	Potassium	
$Mg.m^{-1}$	1.33	1.36	1.39	Bulk density	
$g.kg^{-1}$	450.20	349.00	125.50	Clay	
	300.85	250.75	100.00	Silt	
	248.00	400.25	775.50	Sand	
	Clay loamy	loamy	sandy	Soil texture	

Laboratory analysis of the study soil

Analysis of soil particle sizes

The soil texture was determined by the hydrometer method described in (Richard, 1954.(

Soil reaction (PH(

It was estimated in the saturated paste extract by the electrical method using a pH meter according to [12.[

Electrical conductivity (Ece(

It was estimated in the saturated paste extract using an (Ec meter) according to [12.[

Organic matter (OM(

It was estimated by [14] method by oxidizing the organic carbon in the soil with potassium dichromate K2cr2o7 and then comparing it

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with ferrous ammoniacal sulfate Fe $(NH_4)_2(SO_4)_2.6H_2O$.

Gypsum

It was estimated by the acetone precipitation method according to [12.[

Carbonate minerals

Estimated by the NaOH titration method mentioned in [3[

available potassium

Estimated using a flame photometry device after extraction with ammonium acetate (NH_4CH_3CooH(

available phosphorus

Estimated ready phosphorus extracted with sodium bicarbonate solution (M0.5) according to Olsen's method and measured using a spectrophotometer at a wavelength of 882 nm according to [10.[

available nitrogen

Estimated nitrogen after extraction with a standard potassium chloride (2) solution using a microkjeldahl device according to the method explained by Bremner mentioned in [10.[

Dissolved positive ions

Calcium and magnesium

Determined in the saturated soil paste extract by titration with 0.01N EDTA in the presence of mercury indicator when estimating calcium and EBT indicator when estimating (Ca+Mg) (Richard, 1954.(

Sodium

Determined in the saturated soil paste extract using a flame spectrometer called (Flamphotometer) and described (Richards, 1954.(

Dissolved negative ions

Carbonates and bicarbonates

Carbonates were estimated in the saturated paste extract by titration with H_2SO_4 0.01N with phenolphthalein indicator, while bicarbonates were titrated in the presence of methyl orange indicator as mentioned in [10[

Sulfates

Were estimated in the saturated paste extract by the turbidity method by precipitation with barium chloride ($BaCl_2$) as mentioned in [6[

Chloride

Were estimated in the saturated soil paste extract by titration with silver nitrate ($AgNO_3$) in the presence of potassium chromate Richard (1954(

Methods of extracting and estimating potassium forms in soil

Soluble potassium

Soluble potassium was estimated according to the method proposed by Pratt (1965) and mentioned in [10.[

Exchangeable Potassium

Exchangeable potassium was extracted from soil samples by its 1 M ammonium acetate solution adjusted to pH 7 according to the method described in [10.[

Unexchangeable Potassium

Unexchangeable potassium was extracted by boiling with 1 M nitric acid at a ratio of 10:1 (soil:acid) according to the method described in [4,7 [

Mineral Potassium

Mineral potassium was calculated according to the method proposed by [9.[

mineral potassium = total potassium - (soluble + exchangeable + non-exchangeable.(

Total potassium

Total potassium was estimated in the digestion solution of soil samples treated with a mixture of nitric acid, sulfuric acid and concentrated perchloric acid in the ratios 2:4:4, respectively, using a 30 ml platinum beaker with diagnosis according to the method proposed by [5[

Laboratory experiments

Mineralogical Analysis experiment

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The mineral properties of the study soil clay are studied according to the following steps:

-1Pretreatment.

-2Sparation and fractionation.

-3Calculation of clay minerals.

-4tests of clay and soil samples by infrared spectroscopy.

Potassium adsorption experiment at dynamic equilibrium A quantity of air-dry soil from each sample was weighed and placed in plastic tubes with a capacity of (100) ml, then a potassium solution prepared from potassium sulfate was added to it at concentrations of 5, 25, 50, 75, 100, 125, 150, 200 mg-1, then the tubes were suspended and shaken for (24) hours using a shaker and in a quiet manner to ensure that the soil particles are not broken and at a constant temperature of (298) Kelvin. After the shaking period is over, a centrifugation process is carried out on it for (15) minutes, then filtration is carried out to obtain the equilibrium solution from the soil for the purpose of estimating the potassium concentration in it. The tubes containing the soil are kept for use in the subsequent experiment directly. After completing the adsorption experiment, the relationship between the adsorbed potassium mg K kg-1 soil and the potassium in the equilibrium solution (mg K L-1) is described using the Langmuir and Freundlich equations.

Langmuir equation

c/X/m = 1/kb+1/b.c

X/M = amount of adsorbed element (hg K g-1 soil.(

C = concentration of element at equilibrium (μg K ml-1.(

K = binding energy (ml-1 μg K.(

b = maximum adsorption (μg K g-1 soil) (Al-Anzi, 2022.(

2-2-5-3Freundlich equation

Log x/m= log K+ b log c

Since

X/m = amount of adsorbed element at equilibrium (μg K g-1 soil(

c = concentration of element at equilibrium (μg K ml-1(

K = binding energy (ml-1 μg K(

b = maximum adsorption (μg K g-1 soil) (Al-Anzi, 2022.(

Reverse adsorption (release) of potassium at dynamic equilibrium To study the reverse adsorption of potassium and to detect the ability of soils to retain potassium (for the studied soils, the soil samples on which the adsorption experiments were conducted) are washed inside the tubes first by adding (5) ml of pure ethanol with a concentration of 95% to each tube with shaking for 10 minutes, then the filtrate containing the dissolved potassium is separated using a centrifuge. This process is repeated three times and each time the filtrate is poured after that (5) ml of the extraction solution of calcium chloride (cad) with a concentration of (0.01) standard for the soil is added to the tubes, and shaken for (24) hours using a circular shaker and at a constant temperature (298 Kelvin), then the solution is separated using centrifugation and filtration, as the potassium in it is estimated, the reverse adsorption data are described by the single-surface Langmuir equation as its formulas mentioned above and the soils that have the ability to retain the adsorbed potassium. (IPI, 2016.(

Reverse adsorption (release) of potassium at dynamic equilibrium

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shaking for 10 minutes, then the filtrate containing the dissolved potassium is separated using a centrifuge. This process is repeated three times and each time the filtrate is poured after that (5) ml of the extraction solution for calcium chloride (cad) with a concentration of (0.01) standard for the soil is added to the tubes, and shaken for (24) hours using a circular shaker and at a constant temperature (298 Kelvin), then the solution is separated using centrifugation and filtration, where potassium is estimated in it. The reverse adsorption data are described by the single-surface Langmuir equation as its formulas were mentioned above and the soils that have the ability to retain potassium Adsorbent. (IPI, 2016). After conducting the adsorption experiment, a certain weight of soil is taken, and a reverse adsorption (release) experiment is conducted to study the release by successive extraction for the same times used in the adsorption experiment. Then the equations mentioned above are applied and the best equation is chosen to describe the release of potassium. After that, the release rate coefficient is calculated for each of the study soils [1[

Statistical analysis

The experiment was conducted according to the usual complete block design according to the arrangement of factorial experiments and with three replicates that included two factors, the first factor is the type of clay content and whether it is (high, medium or low) and the second factor is different levels of potassium fertilizer, which are 0 and a quarter of the fertilizer recommendation 75 kg K ha-1 and half of the fertilizer recommendation 150 kg K ha-1 and the full fertilizer recommendation for potassium, which is 300 kg K ha-1 in addition to the comparison treatment representing the absence of adding potassium fertilizer (without addition) and the data were analyzed according to the factorial design added to the factorial experiments [11] and the averages were compared according to the least significant difference (LSD) at the probability level of 0.05 and the results were analyzed using the Genstat program.

Results and discussion

The kinetic approach to potassium adsorption in the study soils

The adsorption of potassium in soils of different textures and different clay content was described by studying the adsorption kinetics in the soils according to the principles of kinetic chemistry, as the amount of adsorbed potassium was a function of time according to the mathematical equations (zero-order equation, first-order equation, diffusion equation) and the experimental equations (power function equation, Elovich equation), and the two statistical criteria, the coefficient of determination (R2), and the standard error (SE) for the five equations and for all soils, were used to choose the best equation to describe potassium adsorption in the study soils and calculate the adsorption rate coefficient. It is clear from Table (1) which represents the values of the coefficient of determination R2 and the standard error SE for the five kinetic equations in sandy soil, that the Elovich equation was the best equation in describing the kinetics of potassium adsorption in this soil, as it gave the highest rate of the coefficient of determination and the lowest standard error of 0.94 and 0.255 respectively, while the rate of the coefficient of determination R2 for the zero-order equation, the first-order equation, the diffusion equation and the power function equation were 0.81, 0.74, 0.87 and 0.86 respectively, and the values of the standard error rate for the four equations were 1.845, 1.473, 3.624 and

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2.72 respectively. Based on the results obtained, the Elovich equation was chosen to describe the relationship between the adsorbed amount of potassium and the natural logarithm of time and to calculate the adsorption rate coefficient from the slope of the straight line in the figure for sandy soil, as shown in Figure (1 .(

Table (1) Values of the coefficient of determination (R2) and the standard error (SE) for choosing the best equation to describe potassium adsorption in sandy soil

Equations										**Sandy soil**
Elovich		**Power Function**		**Diffusion**		**First order**		**zero order**		**Concentration (mg L^{-1})**
SE	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	
0.362	0.93	4.03	0.95	3.587	0.92	1.479	0.71	1.709	0.83	5
0.174	0.98	2.93	0.97	3.276	0.95	1.299	0.79	1.372	0.86	25
0.219	0.93	2.30	0.55	3.713	0.66	1.365	0.72	2.556	0.75	50
0.509	0.94	2.59	0.94	3.530	0.86	1.519	0.64	2.216	0.72	100
0.112	0.93	2.23	0.78	3.602	0.85	1.478	0.77	1.710	0.84	150
0.155	0.94	2.28	0.98	4.038	0.96	1.701	0.80	1.510	0.87	200
0.255	**0.94**	**2.726**	**0.86**	**3.624**	**0.87**	**1.4735**	**0.74**	**1.845**	**0.81**	**average**

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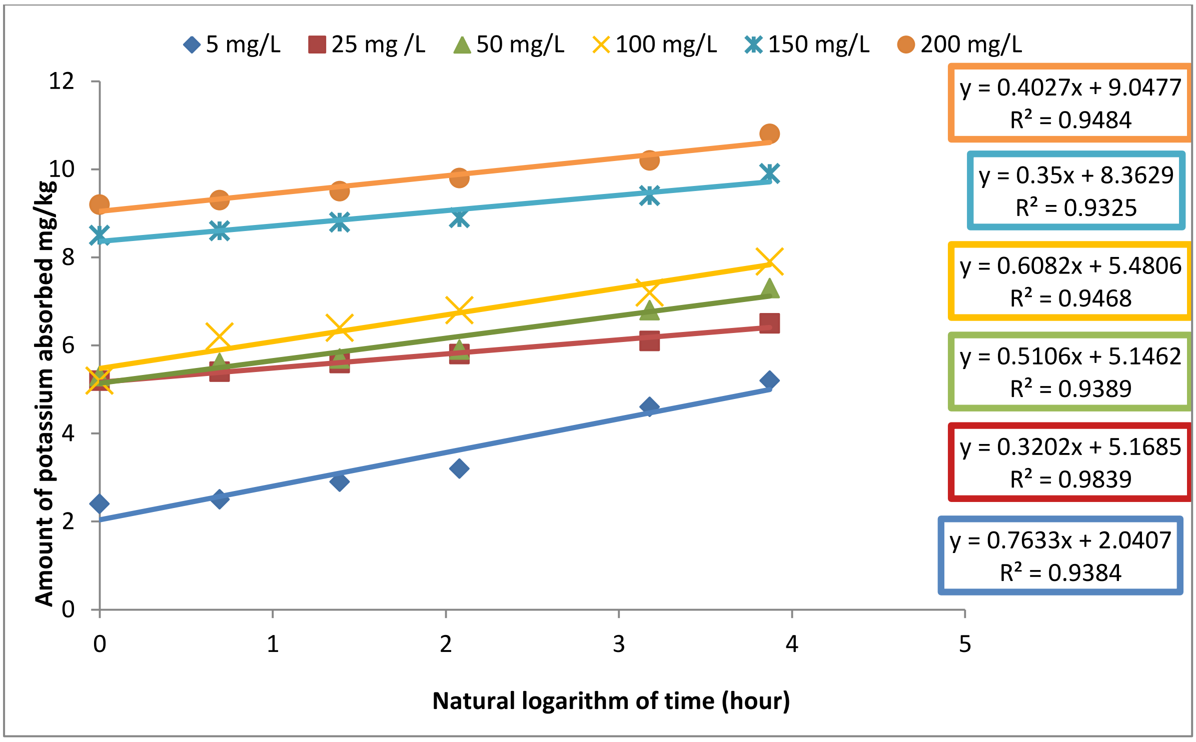

Figure (1) The absorbed amount of potassium with the natural logarithm of time in sandy soil according to the Elovich equation.

It is clear from the data in Table (2) that the Elovich equation was the best in describing potassium adsorption in loamy soil, as the average coefficient of determination (R2) for the Elovich equation and for all concentrations was 0.97, while the average standard error for adsorption for the Elovich equation and at all concentrations used was 0.570.

It is clear from Table (2) that the values of the coefficient of determination for the zero-order, first-order, diffusion and power function equations are 0.84, 0.75, 0.92 and 0.94 respectively with the standard error rate of 1.768, 1.377, 4.303 and 4.086 in the same order. Accordingly, the relationship between the amount of potassium adsorbed in the loamy soil with the natural logarithm of time was drawn and the adsorption rate coefficient for potassium in the loamy soil was calculated, as shown in Figure (2.(

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Equations										**Loamy soil**
Elovich		**Power Function**		**Diffusion**		**First order**		**zero order**		**Concentration (mg L^{-1})**
SE	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	
0.266	0.97	5.24	0.88	3.165	0.80	1.213	0.52	2.346	0.64	5
0.315	0.98	5.45	0.98	4.578	0.97	1.262	0.77	1.680	0.89	25
0.375	0.94	3.84	0.94	4.466	0.87	1.482	0.63	2.742	0.73	50
0.437	0.98	3.89	0.98	4.722	0.99	1.364	0.89	1.152	0.95	100
1.014	0.99	3.19	0.90	4.488	0.95	1.412	0.89	1.174	0.94	150
1.016	0.96	2.91	0.98	4.403	0.96	1.529	0.83	1.518	0.90	200
0.570	**0.97**	**4.086**	**0.94**	**4.303**	**0.92**	**1.377**	**0.75**	**1.768**	**0.84**	**average**

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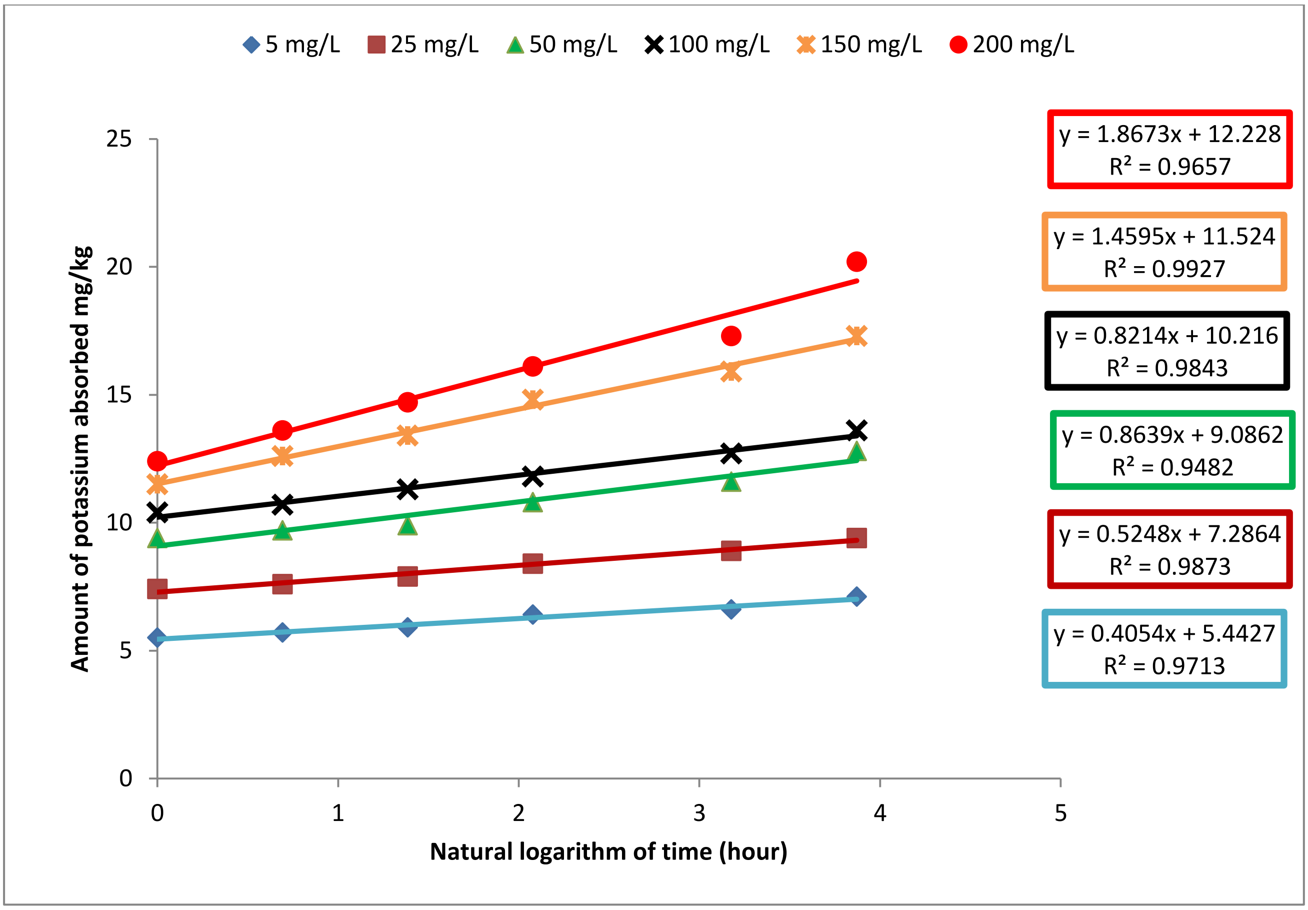

Figure (2) The amount of potassium absorbed with the natural logarithm of time in the loamy soil according to the Elovich equation.

Table (3) represents the values of the coefficient of determination (R2) and the standard error SE of the kinetic equations used in the study to describe the adsorption of potassium in clay soil at different concentrations of potassium. From the data in the table, it is clear that the Elovich equation was the best in describing the adsorption of potassium in clay soil, as it gave an average coefficient of determination (R2) of 0.95 with a standard error SE of 0.828. The values of the coefficient of determination (R2) for the zero-order equations were 0.82 with a standard error of 2.348, the first-order equation was 0.72 with a standard error of 1.435, and the diffusion equation was 0.92 with a standard error of 5.367. The power function equation gave a coefficient of determination of 0.95 and a standard error of 5.15. Based on the results of Table (3), the relationship between the adsorbed amount of potassium in clay soil and the natural logarithm of time was described using the Elovich equation to calculate the potassium adsorption rate coefficient in clay soil according to Figure (3 .(

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Table (3) Values of the coefficient of determination (R2) and the standard error (SE) for choosing the best equation to describe potassium adsorption in clay soil

Equations										**Clay soil**
Elovich		**Power Function**		**Diffusion**		**First order**		**zero order**		**Concentration (mg L^{-1})**
SE	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	
0.438	0.97	6.18	0.92	3.882	0.85	1.247	0.58	2.555	0.70	5
0.361	0.90	6.10	0.98	5.545	0.97	1.336	0.77	2.003	0.89	25
1.316	0.98	5.46	0.97	5.675	0.95	1.409	0.75	2.237	0.88	50
0.927	0.96	4.27	0.90	5.012	0.80	1.597	0.55	3.759	0.63	100
0.846	0.96	4.64	0.99	5.805	0.97	1.500	0.79	2.282	0.88	150
1.085	0.98	4.27	0.94	6.285	0.99	1.526	0.91	1.256	0.96	200
0.828	**0.95**	5.15	0.95	5.367	0.92	1.435	0.72	2.348	0.82	**average**

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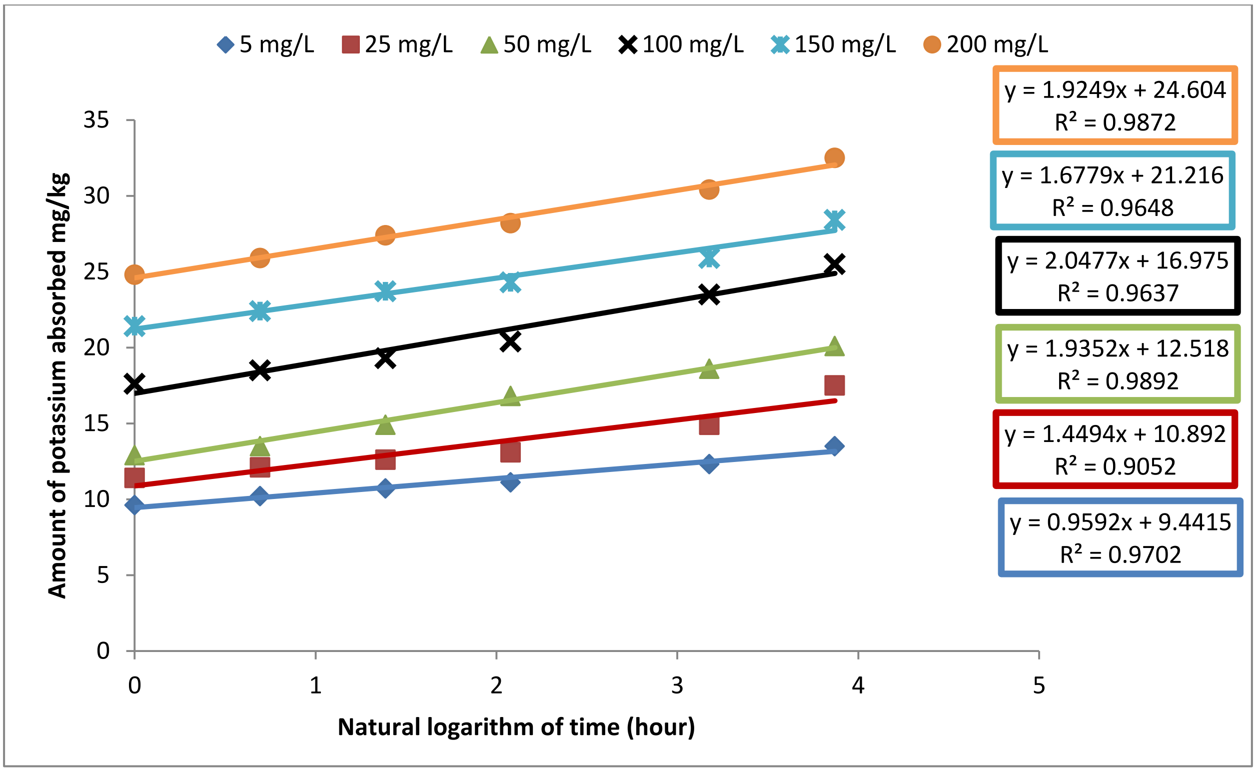

Figure (3) The absorbed amount of potassium with the natural logarithm of time in clay soil according to the Elovich equation

Potassium adsorption rate coefficient

To calculate the potassium adsorption rate coefficient in the study soils, the best equation describing the potassium adsorption kinetics in the soils under study must be determined. By comparing the five equations, it was found that the Elovich equation is the best equation describing the potassium adsorption kinetics in soils with low, medium and high clay contents representing the study area when adding levels of (5, 25, 50, 100, 150 and 200) mg K L-1. Therefore, it was adopted to calculate the potassium adsorption rate coefficient in all the study soils.

It is clear from Table (4) that the potassium adsorption rate coefficient in sandy soil ranged between 0.3202 and 0.7633 mg kg h-1 at concentrations of 150 and 5 mg L-1, respectively, at an average of 0.4925 mg kg h-1 for all concentrations, while the potassium adsorption rate coefficient values in loamy soil ranged between 0.4054 mg kg h-1 at a concentration of 5 mg L-1 and 1.8673 mg kg h-1 at a concentration of 200 mg L-1 for all concentrations used .

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Table (4) Values of the potassium adsorption rate coefficient in the study soils according to the Elovich equation

Adsorption rate coefficient of clay soil (mg kg ha^{-1})	**Adsorption rate coefficient of loamy soil (mg kg ha^{-1})**	**Adsorption rate coefficient of sandy soil (mg kg ha^{-1})**	**Concentration**)mg.L^{-1}(
0.9592	0.4054	0.7633	5
1.4494	0.5248	0.3202	25
1.9352	0.8639	0.5106	50
2.0477	0.8214	0.6082	100
1.6779	1.4595	0.350	150
1.9249	1.8673	0.4027	200
1.6657	**0.9903**	**0.4925**	**average**

It is noted from Table (4) that the values of the potassium adsorption rate coefficient in the clay soil ranged between 0.9592 and 2.0477 mg kg h-1 at concentrations of 5 and 100 mg L-1, respectively, and at a rate of 1.6657 mg kg h-1 for all concentrations. The above results show that the clay soil is superior in potassium adsorption rate coefficient over the rest of the study soils, followed by the loamy soil and finally the sandy soil. The reason for this arrangement may be due to the high clay content in the clay soil, which is reflected in the exchange capacity of positive ions, in addition to the mineral composition of the study clays, as it indicates the dominance of mica and smectite minerals inherited from mica according to the results of the mineral diagnosis of the current study soils. These minerals have a high ability to retain and fix potassium between their layers, which led to an increase in the potassium adsorption capacity on the one hand, and an increase in the potassium adsorption capacity in the clay soil on the other hand. We note from Table (4) that the values of the potassium adsorption rate coefficient in the clay soil were high at medium concentrations, specifically at concentrations of 50 and 100 mg L-1, and the latter was the highest compared to low and high concentrations. This may be due to the saturation of specialized and non-specialized sites for potassium adsorption at these concentrations, which was reflected in the adsorption rate. The success of the Elovich equation in describing the kinetics of potassium adsorption in the study soils means that the relationship between the amount of potassium adsorbed and time is a semi-logarithmic relationship, which indicates that the effect of increasing the added concentration on the reaction rate (adsorption)

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was low and that the role of other factors such as clay content, type of clay mineral, percentage of organic matter, as well as the exchange capacity of positive ions are influential in the rate of potassium adsorption in the study soils.

Kinetic approach to potassium release in the study soils:

Five kinetic equations were used, some of which are mathematical in nature and others are experimental statistics to describe potassium release in soils with different clay content (sandy soil, loamy soil, and clay soil), which are the zero-order equation, the first-order equation, the diffusion equation, the power function equation, and the Elovich equation. Two statistical criteria were adopted, which are the coefficient of determination R2 and the standard error SE, to compare between the equations to choose the best one in describing potassium release from the study soils.

Tables (1, 2 and 3) represent the values of the coefficient of determination R2 and the standard error SE for the five kinetic equations in describing the release of potassium from the study soils. These tables show the superiority of the zero-order equation in describing the release of potassium from the three soils, as the value of the average coefficient of determination for the clay soil was 0.95 with a standard error of 0.3418, while the average coefficient of determination for the first-order equation, diffusion, power function and Elovich were (0.85, 0.92, 0.91 and 0.84) respectively with a standard error of (22.793, 442, 42 and 201815, 33.762) in the same order .

Table (1) Values of the coefficient of determination (R2) and the standard error (SE) for choosing the best equation to describe the release of potassium in the clay soil

Equations										Sandy soil
Elovich		Power Function		Diffusion		First order		zero order		
SE	R^2	SE	R^2	SE	R^2	SE	R^2	SE	R^2	Concentration (mg L^{-1})
5.769	0.53	5.24	0.88	3.160	0.80	1.213	0.52	0.234	0.96	5
7.685	0.84	5.45	0.98	4.578	0.76	1.262	0.77	0.168	0.98	25
7.923	0.84	3.84	0.94	4.466	0.87	1.482	0.63	0.274	0.97	50
7.701	0.75	3.89	0.98	4.722	0.68	1.364	0.89	0.115	0.95	100
7.170	0.83	3.19	0.90	4.488	0.53	1.412	0.89	0.117	0.96	150
7.342	0.63	2.91	0.98	4.403	0.69	1.529	0.83	0.151	0.97	200
7.265	0.73	5.24	0.88	4.302	0.72	1.377	0.755	**0.1765**	**0.965**	**average**

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Table (3) Values of the coefficient of determination (R2) and standard error (SE) for choosing the best equation to describe potassium release in sandy soil

Equations										**Sandy soil**
Elovich		**Power Function**		**Diffusion**		**First order**		**zero order**		**Concentration (mg L^{-1})**
SE	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	**SE**	**R^2**	
19.752	0.81	15.534	0.82	12.842	0.85	1.850	0.86	0.168	0.96	5
59.531	0.82	13.289	0.86	38.605	0.66	5.202	0.85	0.272	0.96	25
48.449	0.82	5.810	0.84	96.119	0.68	14.255	0.81	0.204	0.98	50
23.430	0.81	12.778	0.89	20.599	0.57	32.979	0.82	0.194	0.96	100
82.998	0.81	52.766	0.88	44.891	0.59	72.227	0.84	0.112	0.96	150
49.787	0.80	70.870	0.91	55.596	0.65	90.419	0.85	0.260	0.94	200
47.324	**0.81**	**28.507**	**0.86**	**44.775**	**0.66**	**36.155**	**0.83**	**0.2016**	**0.96**	**average**

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The results of the tables show that the values of the average coefficient of determination R2 for the loamy soil and the zero-order equation were 0.96 with a standard error of 0.1765, while the first-order equation gave 0.75 and a standard error of 1.377, the diffusion equation 0.72 and a standard error of 4.302, and the power function equation 0.88 with a standard error of 5.24. Finally, the Elovich equation gave an average coefficient of determination of 0.73 and a standard error of 7.265, while the zero-order equation gave the highest values of the average coefficient of determination and the standard error for sandy soil compared to the rest of the equations, as they were 0.96 and 0.2016, respectively. Based on the results obtained above, the relationship between the amount of potassium released with time was drawn based on the zero-order equation, which was the best in describing the kinetics of potassium release from the study soils, and the The release rate coefficient according to the data of this equation is shown in Figures (1, 2 and 3 .(

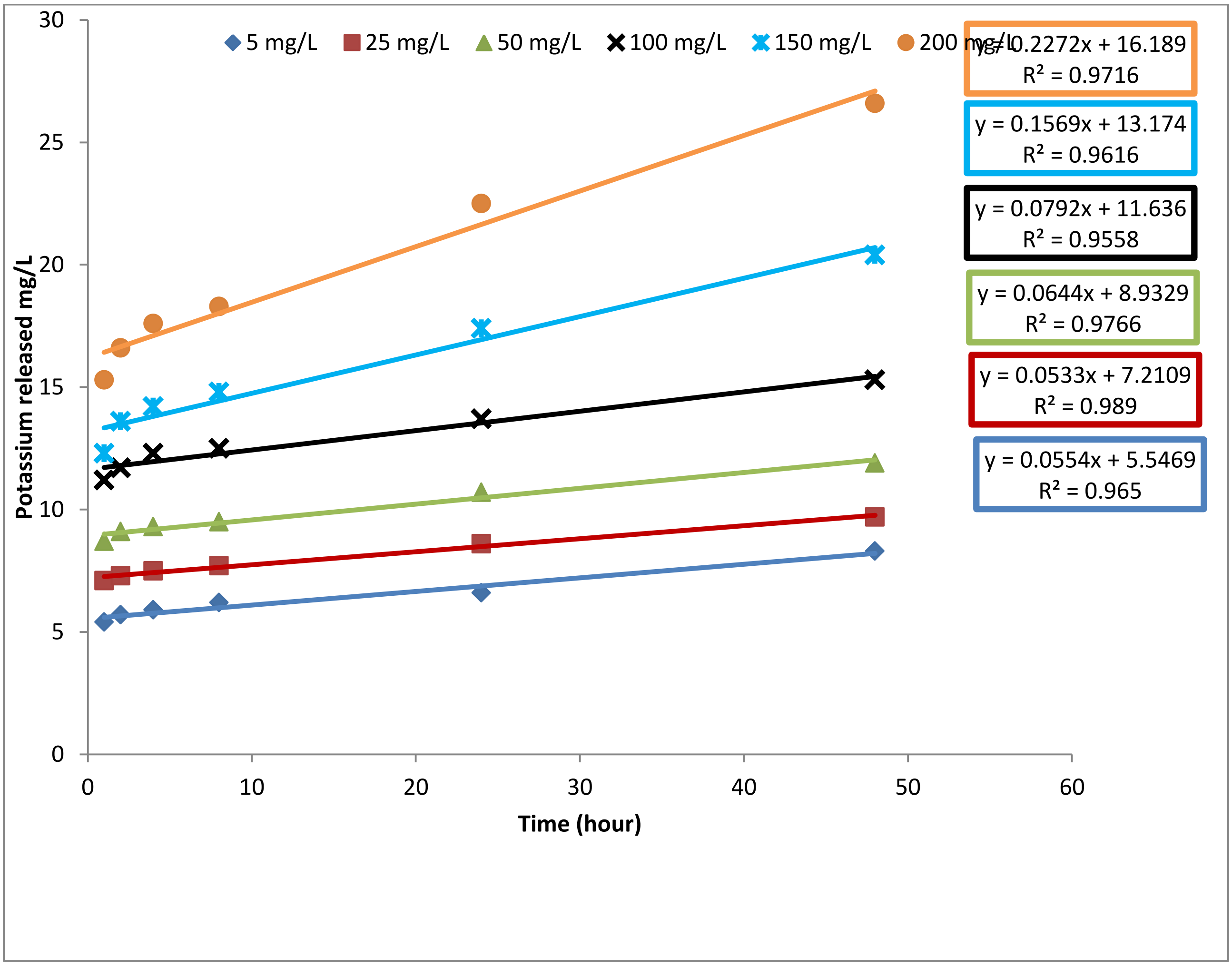

Figure (2) The amount of potassium released with time from the loamy soil according to the zero-order equation

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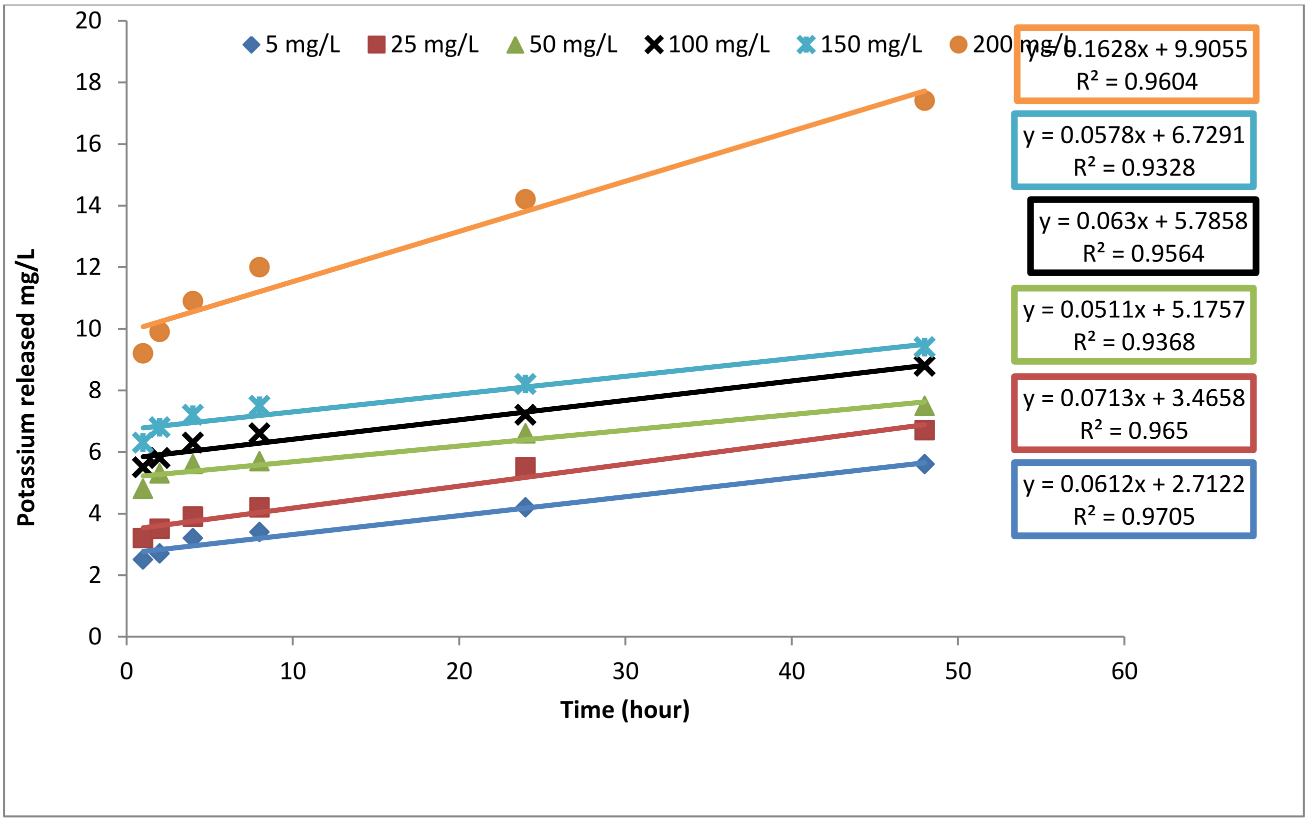

Figure (1) The amount of potassium released with time from the clay soil according to the zero-order equation

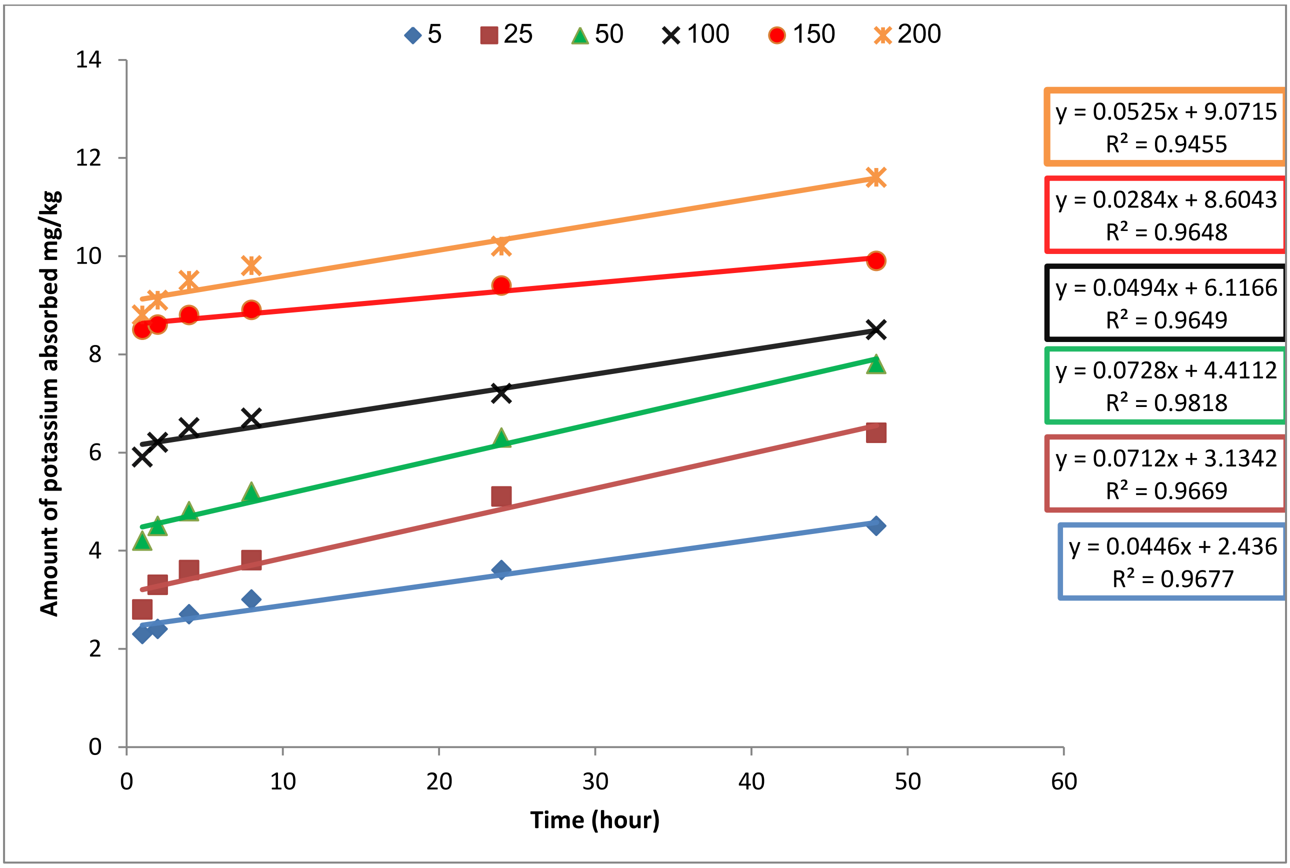

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Figure (3) The amount of potassium released with time from the sandy soil according to the zero-order equation

Potassium release rate coefficient from the study soil:

The zero-order equation was adopted to calculate the potassium release rate coefficient from the study soil, as it gave the highest values for the coefficient of determination R2 and the lowest values for the standard error compared to the rest of the kinetic equations. We note from the data in Table (4) that the loamy soil outperformed the rest of the study soils in the rate of potassium release rate coefficient, followed by the clay soil, and finally the sandy soil. The values of potassium release rate coefficient from the loamy soil ranged between 0.0533 and 0.2272 mg L-1 h-1 at concentrations of 25 and 200 mg L-1, respectively, at an average of 0.1060 mg L-1 h-1, while the values of potassium release rate coefficient from the clay soil ranged between 0.0511 and 0.1628 mg L-1 h-1 at an average of 0.0778 mg L-1 h-1 at concentrations of 50 and 200 mg L-1, respectively, and the values of potassium release rate coefficient from the sandy soil ranged between 0.0284 and 0.0728 mg L-1 h-1 at an average of 0.0531 mg L-1 h-1 at concentrations of 150 and 50 mg L-1, respectively.

Table (4) Values of potassium release rate coefficient for the study soils according to the zero-order equation

Release rate coefficient of clay soil ($mg.L/h^{-1}$)	Release rate coefficient of soil mix ($mg.L/h^{-1}$)	Release rate coefficient for sandy soil ($mg.L/h^{-1}$)	Concentration (mg L-1)
0.0612	0.0554	0.0446	5
0.0713	0.0533	0.0712	25
0.0511	0.0644	0.0728	50
0.0630	0.0792	0.0494	100
0.0578	0.1569	0.0284	150
0.1628	0.2272	0.0525	200
0.0778	**0.1060**	**0.0531**	**average**

We note from the previous results that the rate of potassium release was slow in all the study soils, especially the sandy soil. This may be due to the fact that the amount of potassium

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absorbed in the sandy soil was low due to its low clay content, which led to the retention of potassium within the mica mineral layers in the clay separator with a high binding energy that was reflected in the rate of its release. We also note from the results data that there was a relative superiority of the loamy soil in the rate of potassium release. This may be due to the saturation of specialized sites at low concentrations and the transfer of potassium adsorption to non-specialized sites with low binding energy, which led to the release of potassium more quickly compared to the rest of the study soils. The results also show that the rate of potassium release from the clay soil was relatively low, and this may be due to the nature of the mineral composition of the clay separator in this soil, as the dominance was for mica minerals in this soil according to the mineral diagnosis of the current study, and mica minerals retain potassium within the hexagonal openings in its crystal structure, which are suitable for the ionic diameter of potassium, which leads to the adsorption of potassium with a high binding energy that reduces the rate of its release into the soil solution, in addition to the clay soil containing smectite, which is inherited from the mica mineral, which is a mineral with a high ability to fix potassium. The success of the zero-order equation in describing the kinetics of potassium release from the soil of the current study means that increasing the added concentration of potassium does not affect the reaction rate (potassium release) according to the principles of kinetic chemistry, but rather the effect is due to other factors that affect potassium release from the soil, represented by the clay content and the nature of the clay mineral composition, in addition to the capacity of positive ions exchange.

Conclusions

.1The study soils, especially the clayey ones, were characterized by the dominance of mica minerals, which indicates the high capacity of these soils to fix potassium and a high binding energy and adsorption speed that increases with increasing clay content.

.2The speed of potassium release from the study soils was not affected by the increase in the added concentration, which means that soil factors represented by clay content and mineral composition had the greatest effect on the speed of potassium release.

.3The adsorption behavior of potassium was subject to the nature of the distribution of adsorption sites on the clay surfaces as well as the quality of these sites in terms of whether they are specialized or non-specialized.

.4The relationship of potassium release from the study soils was related to the adsorption capacity as well as the binding energy, as potassium held by weak energy is released from non-specialized sites (non-specific sites that are saturated at high concentrations of potassium.(

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