



EXTRACTION METHODS AND ADSORPTION KINETICS OF POTASSIUM IN CALCAREOUS SOILS OF MULTAN

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ABSTRACT

Understanding the dynamics of potassium (K) and its availability is fundamental in its efficient use as an important nutrient. The objectives of present study were to compare standard K extraction methods for extractable K and kinetics of K adsorption on five different textured soils. The soils were analyzed for physico-chemical properties, extractable K contents and kinetics of K adsorption. The soils had variable contents of soluble ($8-52\text{mg kg}^{-1}$), exchangeable ($13-215\text{mg kg}^{-1}$), fixed ($488-1836\text{mg kg}^{-1}$), structural ($2936-26362\text{mg kg}^{-1}$) and total K ($3438-28517\text{mg kg}^{-1}$). Except soluble K, the amount of K in different forms was significantly ($P\leq 0.05$) correlated with clay contents, electrical conductivity (EC), cation exchange capacity (CEC) and calcium carbonate in soils. Different methods varied the extracted K in different textured soils. Mehlich-III, ammonium acetate, AB-DTPA, and calcium chloride extracted K was maximum in sandy clay loam (298mg kg^{-1} , 267mg kg^{-1} , 226mg kg^{-1} , and 113mg kg^{-1}) and lowest was in loamy sand (33mg kg^{-1} , 24mg kg^{-1} , 30mg kg^{-1} , and 24mg kg^{-1}) respectively. Elovich and power function models best explained the K kinetics adsorption, as rate of adsorption constants were negatively correlated with sand contents in the soil type. Pearson correlation showed that the extractability of K by different methods and kinetics of K adsorption were dependent on soil texture EC, CEC and calcium carbonate contents. Hence, soil physico-chemical properties should be considered in recommending rate of K fertilization along with crop K demand and soil extractable K.

Keywords: adsorption kinetics, calcareous soils, extraction methods, fractions, potassium and soil texture

INTRODUCTION

Potassium (K) is the seventh abundantly found element in the earth crust; about 2.6% of total constituents (Mittlefelhd, 1999). Khalid *et al.* (2002) reported that only about 27% soils had optimum K levels ($\geq 150\text{mg kg}^{-1}$) in Pakistan. Optimum K should be maintained in soils for better crop production. However, the contribution of K in total NPK fertilizer usage in Pakistan is less than 1% (FAOSTAT, 2014). Therefore, K fertilization in Pakistan is insufficient to supplement the crop removal and the deficiency of K in soils is increasing, which has also been found in other countries (Römheld and Kirkby, 2010). About 30-35% of K deficiencies have been observed in Pakistani soils during the period of last two decades (Akhtar *et al.*, 2003).

Potassium is not static in soils and its availability for plants vary with space and time

(Raffic *et al.*, 2015; Tijjani and David, 2017). For example, contents in different K fractions correlate positively with clay and negatively with sand contents in soils (Kundu *et al.*, 2014; Babar *et al.*, 2015). The exchangeable K and soluble K significantly depend on the CEC, organic carbon and calcium carbonate (Elbaalawy *et al.*, 2016). The fractions content also depend upon the type of clay mineral in the soil (Ghiri and Abtahi, 2011). Similarly Raffic *et al.* (2015) reported the release of K showed positive significant relationship with soil properties such as pH, organic carbon, sand and clay. Contents of plant available K in soil depend on dynamic equilibrium among structural, fixed, exchangeable and soluble K reservoirs (Sparks, 1987).

Mostly the amount of K recommended for fertilization of crops is only based on exchangeable K and soluble K in soil and less attention is given to the other none changeable fraction of K (Jalali, 2006). A number of standard

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K extraction methods have been devised to estimate plant K availability (Woods *et al.*, 2005; Zebec *et al.*, 2017). Studies showed that different methods had their own effectiveness to extract K from soil (Hosseinpur and Zarenia, 2012; Prasad *et al.*, 2016) and the K availability to the plant cannot be described only by extractable K contents (Adesanwo *et al.*, 2013). In fact, limited information is available to compare the effectiveness of different K extraction method for different textured soils.

The availability of native and applied K to plants depends on buffering and adsorption capacities of K in soils. The kinetic adsorption of K in different soil minerals was reported by Sparks and Jardine (1984); they concluded that the first order equation well described the kinetic K adsorption phenomenon. Kinetic K release models had been compared in various studies (Xiao-Nan *et al.*, 2007; Zhou and Huang, 2007). However, no report has been published that describe the comparison of kinetic K adsorption models in calcareous soils of different textured and the relationship of these kinetic K adsorption models with soil texture.

There is a need of complete understanding of dynamic behavior of added K and the relationship of different fractions of K with properties of calcareous soils. The present study was aimed to provide the information about K forms, comparison of different extraction methods and kinetic adsorption models of K in calcareous soils of various textures. The relationships of forms, methods and models of K with soil properties were also studied.

MATERIALS AND METHODS

Soils

Five bulk soil samples, at the depth of 0 to 30cm, were collected with a stainless-steel soil auger from five locations of Multan (Pakistan). The samples were sandy clay loam (30.2828°N, 70.9482°E), loam (30.0996°N, 71.4263°E), sandy loam (30.2909°N, 71.3695°E), loamy sand (30.2907°N, 71.3698°E) and sand (30.3003°N, 71.3476°E). Sandy clay loam, loam, sandy loam and loamy sand were previously under cultivation of sugarcane, cotton, sugarcane and vegetables, respectively. The sand was a fallow land. The samples were thoroughly mixed, taken in polyethylene bags and properly labelled before transportation to the laboratory for analyses (Estefan *et al.*, 2013). At laboratory, the samples were air dried, crushed and sieved before soil characterization. The

samples of each soil were collected and analyzed in triplicates.

Selected physicochemical properties of soils are listed in (Table 1). The percentage of sand, silt and clay in the soil samples were determined by Hydrometer Method (Bouyoucos, 1936). Walkley-Black method was followed to determine soil organic matter (Walkley and Black, 1934). The values of pH, electrical conductivity (EC_e), cation exchange capacity (CEC) and calcium carbonate of each sample were also determined by standard procedures of soil analyses (Estefan *et al.*, 2013).

Fractions of potassium

Different chemical fractions of K in the soil samples were quantified in the laboratory as explained by Helmke and Sparks (1996). The amount of water soluble K was determined from the filtrate of 1:5 soil to water solution. The contents of exchangeable K were computed from the difference of ammonium acetate-extractable K and soluble K. The amount of fixed or none exchangeable K was extracted from filtrate obtained after digestion in 1M HNO_3 . The amount total K was determined after aqua regia digestion (Rao *et al.*, 2011). The contents of structural K were calculated by subtracting the sum of all other fractions from the total K. Potassium in filtrates and digests was determined on a flame photometer (PFP7, Jenway, U.K.).

Extractable potassium

Extractable soil K was examined with six different standard methods as described by Jones (2001). For calcium chloride extraction, 3.0g soil sample was shaken with 30mL of 0.01M calcium chloride for 120min on reciprocal shaker. For Morgan extraction, 5.0g soil sample was taken with 25mL of 0.54 N acetic acid in 0.7 N sodium acetate adjusted at pH 4.8. The above mixture was shaken for 30 min on reciprocal shaker. For Mehlich-I extraction, 5.0g soil was shaken with 25mL of 0.025N H_2SO_4 in 0.05N HCl for 5min. For AB-DTPA extraction, 15g soil sample was shaken with 30mL 0.005 M DTPA in 1.0M ammonium bicarbonate adjusted at pH 7.6 for 15min. For ammonium acetate extraction, 5.0g soil sample was shaken with 25mL of 1N ammonium acetate adjusted at pH 7.0. The shaking time was 30 min. In Mehlich-III extraction, 2.5g soil was shaken for 5min in 25mL of extracting reagent (0.015N NH_4F + 0.2N acetic acid + 0.25 N ammonium nitrate + 0.001M EDTA + 0.013 N nitric acid). For each,

the filtrates were extracted and used for K determination on flame photometer (PFP7, Jenway, U.K.). Each extraction method explained above use different extraction solution and this extraction solution has its own ability to replace the K contents form the soil colloids to the soil water.

Adsorption of potassium

Using potassium chloride, 10mg K L⁻¹ was prepared in 0.01M calcium chloride. Soil samples (2.5g), each of differently-textured soils, were shaken on reciprocal shaker with 25mL of the above solution for five different time periods (2, 6, 12, 24, and 36 hours). After that, the samples were immediately centrifuged to collect the supernatant for the determination of K on flame photometer. Adsorbed K (*q*) in mg kg⁻¹ was calculated from the difference of final K contents in filtrates and initial solution K contents. Employing five models (Table 2), kinetic K adsorption was studied by plotted quantity adsorbed on Y- axis against time on X-axis (Rezaei and Naeni, 2009).

Statistical analysis

Soil properties, K fractions and extracted K in soils were statistically analyzed based on analysis of variance test followed by mean ranking based on Tukey’s HSD test at *P*≤0.05 (Quinn and Keough, 2002). Pearson correlation coefficients were computed to determine relationships among studied variable. For K adsorption, suitability of model fit was ranked on values R².

RESULTS

Fractions of potassium

The studied soils significantly (*P*≤0.05) differed in contents of K fractions (Table 3). The total K contents in soils were ranged from 3438mg kg⁻¹ in sand to 28517mg kg⁻¹ in sandy clay loam (Table 3). Soluble and exchangeable K was respectively 52 and 215mg kg⁻¹ in sandy clay loam. Structural, fixed, exchangeable and soluble K contents in differently-textured soils were respectively 2936mg kg⁻¹ to 26362mg kg⁻¹, 438mg kg⁻¹ to 1836mg kg⁻¹, 33mg kg⁻¹ to 215mg kg⁻¹, and 15mg kg⁻¹ to 52mg kg⁻¹ of total K. Lowest contents of soluble (8mg kg⁻¹), exchangeable (13mg kg⁻¹) and fixed (438mg kg⁻¹) K were found in loam, loamy sand and sand, respectively. Structural K (2936mg kg⁻¹) was also lowest in sand. Relative to other soils, percentages of fixed K out of the total K were greater in sand and loam, and percentages of

soluble and exchangeable K out of the total were more in sand.

Total K contents had significant (*P*≤0.05) positive relationship with clay and significant (*P*≤0.05) negative relationship with sand contents in the soils (Table 4). The forms of K had positive and significant relationship with clay contents except the soluble K. An inverse relationship was found between K fractions and sand contents in soils. Sand contents of soils had significant (*P*≤0.05) negative relationship only with structural K. The significant positive relationship of EC_e was found with exchangeable K and structural K.

Table 1. Physico-chemical properties of differently-textured soils used in the study

Properties	Sandy clay loam	Loam	Sandy loam	Loamy sand	Sand
Clay (%)	26.0	15.3	4.5	2.0	0.3
Silt (%)	26.5	40.8	23.8	25.5	0.8
Sand (%)	47.5	43.9	71.7	72.5	98.9
pH (1:1 extract)	9.2	8.7	8.6	8.7	9.1
EC _e (dS m ⁻¹)	4.3	3.3	1.1	1.0	0.7
CEC (cmol _c Kg ⁻¹)	115	98	12	14	4
Organic matter (%)	1.3	0.4	0.7	0.9	0.1
Calcium carbonate (%)	8.84	5.4	5.9	3.4	0.8

Table 2. Expressions of potassium adsorption (*q* in mg kg⁻¹ at time *t*) by kinetic models as a function of *α* (adsorbed K in mg kg⁻¹ or model derived units at *t* = 0) and *β* (rate constant in mg K Kg⁻¹ s⁻¹ or model derived units)

Kinetic model	Expression
Zero Order	$q = \alpha_z + \beta_z t$
First Order	$\ln q = \ln \alpha_F - \beta_F t$
Parabolic Diffusion	$q = \alpha_{PD} + \beta_{PD} t^{1/2}$
Power Function	$\ln q = \ln \alpha_{PF} + \beta_{PF} \ln t$
Elovich	$q = \alpha_E + \beta_E \ln t$

Extractable potassium

Potassium extraction by AB-DTPA, ammonium acetate and Mehlich-III had positive significant relationship with clay contents of differently-textured soils (Table 4). Total K, Soluble K and Exchangeable K contents had highly significant (*P*≤0.001-0.05) positive relationship with all the extraction methods of K (Table 5). Compared to other soils, the amount of K released by different extractions was significantly higher in sandy clay loam (114 to 298mg kg⁻¹) (Figure 1).

In the soils, calcium chloride extractable K contents were lowest than K extracted by other

methods Calcium chloride extracted the lowest K (24mg kg⁻¹) contents from loamy sand. The contents of Mehlich-I and Morgan extracted K were nearly equal to each other but lower than AB-DTPA, ammonium acetate and Mehlich-III extracted K. Mehlich-I (16mg kg⁻¹) and Morgan (22mg kg⁻¹) extracted lowest amount of K in loam with respect to other soils. Compared to other soils, extractable K was lowest in loamy

sand when extracted with AB-DTPA (30mg kg⁻¹), ammonium acetate (24mg kg⁻¹) and Mehlich-III (33mg kg⁻¹) extraction.

Potassium contents extracted by ammonium acetate were greater than calcium chloride, Mehlich-I, Morgan and AB-DTPA extracted K. The maximum amount of K was extracted by Mehlich-III extraction in all textured soils than other extractions.

Table 3. Fractions of potassium (K) in five differently-textured soils

Soils	Total K (mg kg ⁻¹)	Soil K fractions (mg kg ⁻¹)			
		Soluble	Exchangeable	Fixed	Structural
Sandy Clay Loam	28517 ± 951 a	52 ± 7 a	215 ± 2 a	1836 ± 17 a	26362 ± 981 a
Loam	20613 ± 763 b	8 ± 0 b	64 ± 2 b	811 ± 11 b	19723 ± 767 b
Sandy Loam	9468 ± 61 c	16 ± 2 b	29 ± 4 c	635 ± 22 d	8773 ± 22 c
Loamy Sand	7942 ± 611 c	11 ± 1 b	13 ± 4 d	712 ± 11 c	7195 ± 615 c
Sand	3438 ± 382 d	15 ± 1 b	33 ± 3 c	438 ± 11 e	2936 ± 378 d

Note: Values are means of three replications ± SD. For each fraction, different letters indicate significant difference based on Tukey's HSD test at P= 0.05.

Table 4. Relationship (Pearson correlation coefficients, *r*) of soil properties with contents of K in different fractions, contents of K extracted in different methods and parameters of kinetic models of K adsorption

Soils properties	EC	CEC	pH	Clay	Silt	Sand	Calcium carbonate	Organic matter
Total K	0.99***	0.97**	0.35	0.99***	0.65	-0.90**	0.88*	0.63
Soluble K	0.66	0.58	0.73	0.76	-0.02	-0.35	0.69	0.72
Exchangeable K	0.87**	0.82	0.70	0.93**	0.22	-0.59	0.77	0.65
Fixed K	0.87	0.81	0.54	0.92**	0.36	-0.68	0.85	0.82
Structural K	0.99***	0.98**	0.33	0.99***	0.67	-0.91**	0.88*	0.61
Calcium chloride extract	0.76	0.69	0.73	0.84	0.08	-0.46	0.73	0.72
Mehlich-I	0.70	0.62	0.75	0.78	0.00	-0.38	0.68	0.72
Morgan	0.67	0.60	0.73	0.77	0.00	-0.37	0.68	0.74
AB-DTPA extraction	0.86	0.81	0.68	0.92*	0.23	-0.60	0.78	0.70
Ammonium acetate K	0.84	0.78	0.71	0.91*	0.18	-0.56	0.77	0.67
Mehlich-III	0.84	0.78	0.70	0.90*	0.18	-0.55	0.77	0.70
Parabolic Diffusion α_{PD}	0.89*	0.92*	0.01	0.82	0.86	-0.96**	0.68	0.33
Parabolic Diffusion β_{PD}	-0.30	-0.39	0.15	-0.14	-0.49	0.39	0.17	0.35
Power Function $\ln \alpha_{PF}$	0.88*	0.90*	-0.06	0.83	0.91*	-0.99***	0.77	0.46
Power Function β_{PF}	-0.80	-0.84	0.14	-0.71	-0.92*	0.94*	-0.60	-0.34
Elovich α_E	0.88*	0.92*	0.00	0.82	0.87	-0.96**	0.68	0.33
Elovich β_E	-0.28	-0.38	0.17	-0.12	-0.49	0.38	0.18	0.37

*Significant at level P≤ 0.05, **Significant at level P≤ 0.01, *** Significant at level P≤ 0.001

Table 5. Relationship (Pearson correlation coefficients, *r*) of K in different fractions with contents of K extracted in different methods and parameters of kinetic models of K adsorption

Soils properties	Total K	Soluble K	Exchangeable K	Fixed K	Structural K
Calcium chloride extract	0.988**	0.9766**	0.956**	0.757	0.7762
Mehlich-I	0.9951***	0.9544*	0.9336*	0.6965	0.7178
Morgan	0.9956***	0.9417*	0.9312*	0.6784	0.7006
AB-DTPA extraction	0.9455*	0.9969***	0.9794**	0.8586	0.8734*
Ammonium acetate K	0.9576**	0.998***	0.9645**	0.8365	0.8517
Mehlich-III	0.9617**	0.9961***	0.9717**	0.832	0.8479
Parabolic Diffusion β_{PD}	-0.2041	0.4284	0.1219	0.1241	-0.2261
Parabolic Diffusion α_{PD}	0.8726*	0.2492	0.5497	0.5843	0.8865*
Power Function β_{PF}	-0.7853	-0.1153	-0.4149	-0.4935	-0.8007
Power Function $\ln \alpha_{PF}$	0.8895*	0.2933	0.563	0.6325	0.9014*
Elovich β_E	-0.1868	0.4557	0.1477	0.1518	-0.2096
Elovich α_E	0.8705	0.2446	0.5457	0.58	0.8845*

*Significant at level P≤ 0.05, **Significant at level P≤ 0.01, *** Significant at level P≤ 0.001

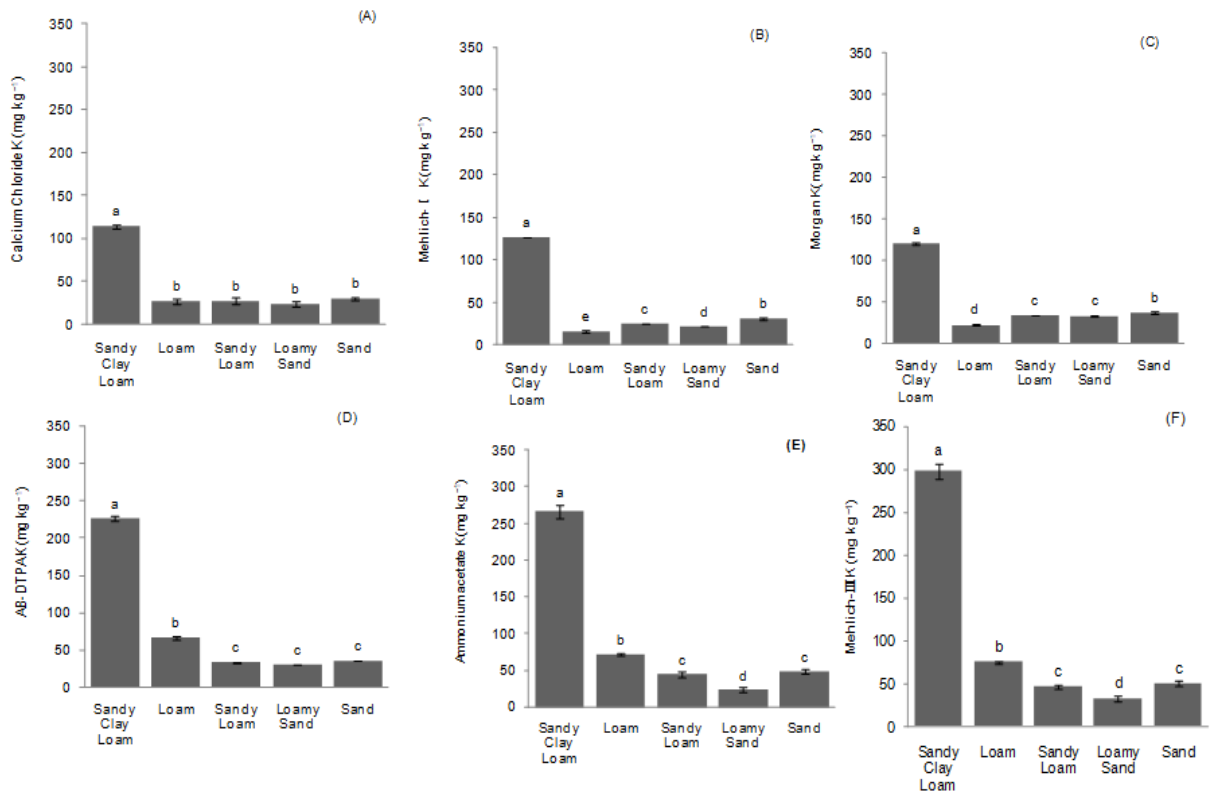


Figure 1. Contents of potassium (K) extracted from five differently-textured soils with (A) calcium chloride, (B) Mehlich-I, (C) Morgan (D), AB-DTPA, (E) ammonium acetate and (F) Mehlich-III

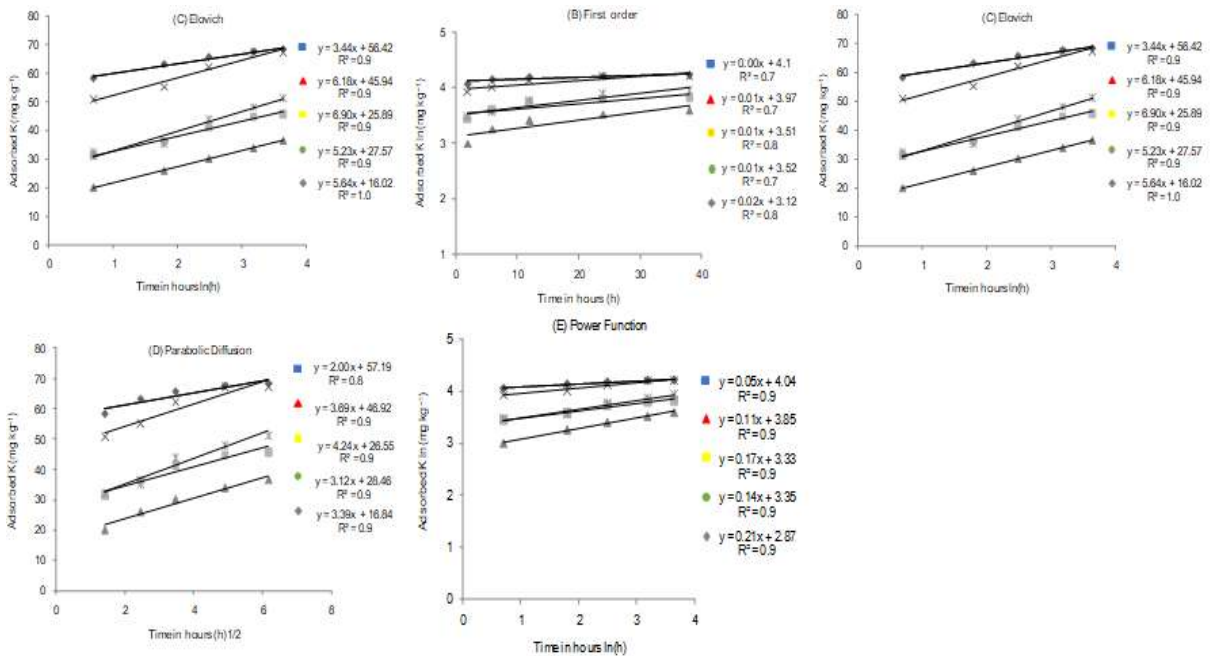


Figure 2. Isotherms of kinetic models of potassium (K) adsorption for five differently-textured soils (▲ Sandy Clay Loam, ■ Loam, ● Loamy Sand, ◆ Sand, ■ Sandy Loam)

Kinetics of potassium adsorption

In Figure 2, R^2 values (<0.95) of zero and first order left these models unfit for the explanation of kinetic K adsorption on differently-textured calcareous soils. The parabolic diffusion model was able to describe the kinetic K adsorption process only in sandy loam ($R^2=0.95$) and sand ($R^2=0.96$). Power function and Elovich were the best models for the explanation of kinetic K adsorption in differently-textured soils because of their R^2 values were >0.95.

The parameters α_{PD} , $\ln \alpha_{PF}$ and α_E (adsorbed K in mg kg^{-1} or model derived units at $t = 0$, represent the amount of K in soils before the initiation of Kinetic adsorption mechanism) respectively of parabolic diffusion, power function and Elovich models had significant positive relationship with EC_e and CEC of the soil while significant negative relationship was noticed with sand contents of the soils (Table 4). The $\ln \alpha_{PF}$ also had significant positive relationship with silt contents in soils. The β_{PF} (rate constant in $\text{mg K kg}^{-1}\text{s}^{-1}$ or model derived units) had significant positive relationship with sand and significant negative relationship with silt contents of soil. There was no significant relationship between the kinetic equations and contents of soil pH. Parabolic Diffusion α_{PD} and Power Function $\ln \alpha_{PF}$ both had positive ($P \leq 0.05$) significant correlation with fraction of Total K and structural K (Table 5). There was no significant relationship between K release from extraction method and kinetic model applied for K adsorption.

DISCUSSION

The total K contents in differently-textured soils ranged from 12 (Wani and Kumar, 2008) to 18 g kg^{-1} (Sharma *et al.*, 2006). Most of the soil K is present in the form of structural K, generally ranging from 86% (Babar *et al.*, 2015) to 98% (Elbaalawy *et al.*, 2016). In the present study, the contents of fixed K are more than available K. The water soluble and exchangeable K contents in soils relate with CEC, clay contents and organic matter; and exchangeable K can reach up to 270 mg kg^{-1} in different soils ((Singh *et al.*, 2013). Similar to our findings (Table 3), Elbaalawy *et al.* (2016) reported 5 to 49 mg kg^{-1} of water soluble K in differently-textured soils. The water soluble K generally constitutes less than 0.2% of total K (Kundu *et al.*, 2014).

The higher contents of soluble K in sandy clay loam (Table 3) were possibly due to the presence of high clay contents in the soil

(Table 1). Soluble K was independent of soil properties (Kalbande and Swamynatha, 1976) or EC_e , CEC and organic matter may have only minor additive effects (Table 4). Compare to other soils, greater K contents in various fractions, except soluble K, in sandy clay loam is because of significant positive relationship of K fractions with clay contents in soils (Table 4). Clay size particles contain minerals that provide large charged surface areas for K attachment (Elbaalawy *et al.*, 2016). The other possible reasons may be application of K in soils (Gurumurthy *et al.*, 2011) and presence of illite (Taleb *et al.*, 2010) and mica (Portela *et al.*, 2019). Total K and structural K have positive and significant relation with calcium carbonate (Portela *et al.*, 2019), is because of the metal retention property of calcium carbonate (Bashir *et al.*, 2019). A significant positive relationship of K contents in various fractions with clay contents (Table 4) clarify the importance of soil texture in controlling the total and available K contents in soils. Therefore, recommendations of K fertilizer for crops should be based on soil texture and K fractions. The soil textural class and clay contents of soils vary from place to place lead to the change in ability of soils to adsorb applied K. So, understanding the ability of soils to absorb K, with kinetic equations will help to determine site specific requirements of K for crops.

The extraction methods are handy tool for determining the actual available K contents in soil. During comparison of different extraction methods greater contents of K were extracted by Mehlich-III in all differently-textured calcareous soils than other methods of K extraction (Figure 1). Similar findings were reported by other researchers (Hosseinpur and Zarenia, 2012; Prasad *et al.*, 2016). Lower contents K extracted by calcium chloride extraction than other extraction methods in differently-textured non-calcareous soils is also reported (Srinivasa and Takkar, 1997; Najafi-Ghiri and Jaber, 2013). The higher contents of extractable K in sandy clay loam than other soils may relate with clay contents, as shown in Table 4 and elsewhere (Kundu *et al.*, 2014). Compared to other soils, lower K contents were released from loam by Mehlich-I and Morgan (Figure 1) may be because of suitability of the methods for soils having $\text{CEC} < 10 \text{ cmol}_c \text{ kg}^{-1}$ and $< 20 \text{ cmol}_c \text{ kg}^{-1}$, respectively (Jones, 2001). The higher K released by the AB-DTPA, ammonium acetate and Mehlich-III method is due to significant positive correlation of extractable with clay contents in soils. Moreover, the positive

significant relationship of all extraction methods with soluble K and exchangeable K clearly represent that a significant amount of K extracted by these methods is related to these fraction while the K release by the AB-DTPA also contain fraction of structural K because of its specific extracting reagent (Table 5). This suggests that the suitability of a particular K extraction method depends on soil texture including clay and sand contents, EC, CEC and calcium carbonate (Zebec *et al.*, 2017). More experiments are warranted in pot and field conditions to test the hypothesis.

Similarly, for the K fertilizer application it is necessary to understand the amount of K adsorb with the passage of time. In this regard, parabolic diffusion model, based on R^2 values, revealed that the law is suited to explain the K adsorption merely in sand and sandy loam (Figure 2). Diffusion is the main phenomenon that describe K adsorption on exchange sites after the formation of water film surrounding the soil particles (Ioannou *et al.*, 1994). Parabolic diffusion model less described the kinetic K adsorption for other soils due to the fact that with the increase in initial concentration of K, α_{PD} increases and R^2 decreases (Dimirkou and Ioannou, 1994). Loam and sandy clay loam soil had higher initial K (Table 3). Previous studies explain the suitability of different adsorption models depending on the soil physiochemical properties (Portela *et al.*, 2019). In our study Elovich and power function models well suited to explain the kinetic K adsorption in differently-textured soils (Figure 2). Jalali and Khanlari (2014) also reported the suitability of Elovich power function and parabolic diffusion equation. The Elovich model is very useful in highly heterogeneous adsorbent (Joseph *et al.*, 2016), and also describe the various processes such as diffusion over surface, catalytic surface inactivation or activation and diffusion in bulk form (Wu *et al.*, 2009). Experimental comparison of seven different equation for K release also showed that the Elovich equation is highly significant among these equation (Xiao-Nan *et al.*, 2007). Inyang *et al.* (2016) reported the sorption of lead and cadmium is greatly explained by Elovich equation.

The significant positive relationship of α_{PD} , $\ln\alpha_{PF}$ and α_E with CEC represent more K absorption in short time (<2 h) if soil have high CEC values (Table 4). Figure 2 shows that the soils having more CEC also have more intercept values than other soils. A significant negative relationship of α_{PD} , $\ln\alpha_{PF}$ and α_E with sand also

clarified that more will be the sand less will be adsorption in a short time duration (<2 h). In Table 5 the positive significant relationship of power function $\ln\alpha_{PF}$ and parabolic diffusion α_{PD} with total K and structural K showed that the soils have more value of these two fraction for K (mg) before the adsorption procedure take place.

The model factors related with sand and clay contents of soils (Table 4). Clearly indicate the importance of K dynamics and adsorption in soils is function of soil texture. Soil texture may control the right amount of K fertilizer by influencing K adsorption capacity and K adsorption kinetics in soils.

In (Table 4) the significant relationship among fractions, extraction methods and kinetic equation represent that parameters are interlinked while in (Table 5) the significant relationship of fractions, extraction methods and adsorption kinetic with soil properties showed that these parameters or components are controlled by the textural soil properties and once again the K fertilization of different soil must be considered by keeping in view these components. Further study is needed for fertilizer recommendation.

CONCLUSION

Varying amounts of K fractions were observed in differently-textured calcareous soils. The forms of K relate with soil properties such as EC, CEC, pH, calcium carbonate and soil texture. In our case, sandy clay loam soil has high K contents of all fractions compared to other soils. The extraction methods varied in contents of K extracted from soils and depended on soil texture. The model parameters showed the significant negative relationship with the sand, concluded that more will be the sand in soil lesser will be the value of K (mg). This study clearly depicts the importance of soil texture in recommending a K extraction method and predicting adsorption of applied K. Therefore, recommendation of K fertilization to crops must be based on soil texture along with available K contents and crop demand.

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AUTHOR'S CONTRIBUTION

M. Aurangzeib: Conceptualization, methodology, software, formal analysis, investigation, writing- original draft preparation
S. Hussain: Conceptualization, software, formal analysis, writing- original draft preparation, writing review and editing
A. Rehim: Conceptualization, methodology, software, validation, resources, writing- review and editing, supervision
M. A. Bashir: Methodology, validation, resources, writing- review and editing and co-supervision
H. M. A. Raza: Software, writing- review and editing, formal analysis

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