

Organic Matter and pH Effects on Base Exchange in Coarse Textured Soils

KHALID MAHMOOD ZIA, HAQ NAWAZ AND GHULAM MURTAZA†

Departments of Chemistry and †Soil Science, University of Agriculture, Faisalabad-38040, Pakistan

ABSTRACT

Two coarse textured soils, having different soil properties were investigated for base exchange equilibria. Various physico-chemicals properties like pH_s , EC_e , soluble ions, exchangeable cations, SAR, ESP, BSCP and CEC were determined. In homovalent (K^+ - Na^+) exchange, both the soils showed an increase in the values of selectivity coefficient with an increase in pH and organic matter showing preferential adsorption of K^+ over Na^+ . In heterovalent (K^+ - Ca^{2+}) exchange, both the soils showed an increase in Kerr, Vanselow and Gapon selectivity coefficients with an increase in pH and organic matter showing greater affinity for Ca^{2+} than for K^+ .

Key words: Heterovalent; Cation exchange; pH; Organic matter; Coarse texture; Soils

INTRODUCTION

Cation exchange are important reactions affecting solution composition, pH, ionic strength, etc. Kerr (1928), Vanselow (1932) and Gapon (1933) used concentration of cations, mole fraction and activities, respectively, for the soluble cations while studying the cation exchange equilibria in soils. Informations pertinent to the effect of organic matter on exchange equilibria of potassium is limited in Pakistani soils. The present investigation was planned to investigate the effect of pH and organic matter on the Kerr, Vanselow and Gapon coefficients in coarse textured soils on the base cation exchange equilibria.

MATERIALS AND METHODS

Two coarse textured soil samples varying in clay and carbon contents belonging to two different soil series (Soil A - Rasulpur Soil Series, Soil B - Wazirabad Soil Series) were collected. After the preparation of soil samples for analyses, the physico-chemical properties of soil samples were determined (Table I). The pH of the saturated soil paste (pH_s), Electrical Conductivity of the saturation extract (EC_e), soluble ions, exchangeable cations, Sodium Adsorption Ratio (SAR), Exchangeable Sodium Percentage (ESP), Basic Cation Saturation Percentage (BCSP) and cation exchange capacity (CEC) were determined {U.S. Salinity Lab. Staff (USSLS, 1954)}. 250 gm of each soil were saturated with 1N ammonium acetate and allowed to stand overnight, oven-dried at $105^\circ C$, ground and sieved. Five gram of soil was taken for three replications of each treatment. The soil was washed with 95% ethanol and saturated with K using 1N KCl solution to make the soil

homoionic at three pH levels of soil i.e. original soil pH 8 ± 0.1 , 9 ± 0.1 . The pH was maintained using HCl and NaOH. Each soil sample was again washed with 95% ethanol and equilibrate suspensions were prepared by shaking the K saturated sample with 100 mL of 1N KCl:NaCl(1:1) and KCl:CaCl₂ (1:1) for homovalent and heterovalent systems, respectively for half an hour. It was then allowed to stand overnight and centrifuged. The equilibrate extract was analysed for Na and K.

Exchangeable bases were determined using CH_3COONH_4 (pH 7.0), as extractants by centrifuging the suspensions and analyzing the supernatants. To study the effect of organic matter, soils were mixed with well decomposed organic matter to get three levels of OM i.e. original soil 2 and 4%. The remaining process was carried out in the same as to estimate the effect of pH, keeping the pH constant and using ammonium chloride in place of ammonium acetate. The data obtained were analysed by the ANOVA technique following completely randomized design with two factors (Steel & Torrie, 1992).

RESULTS AND DISCUSSION

Homovalent Exchange. The selectivity coefficient, K_K calculated for K^+ - Na^+ exchange ranges from 1.11 to 1.23 for soil A and 0.14 to 2.21 for soil B under different soil conditions. These values are near to Vanselow (1932) who found that K_K values ranged from 1.7 to 25.0 in bentonite for such study. An increase in pH increased the CEC due to deprotonation of OH^- , $-COOH$ or phenolic group of organic matter minerals, thus increasing pH dependent charges. Increase in CEC increased the adsorption of K^+ (Murtaza, 1997). For soil B, the K_K value increased first

Table I. Physico-chemical characteristics of soils

Soil Characteristics	Rasulpur Soil Series	Wazirabad Soil Series
Sand %	64.08	74.10
Silt %	23.10	15.65
Clay %	12.82	10.25
Textural class	Sandy loam	Loamy sand
pH _s	7.68	7.69
EC _e dS m ⁻¹	3.39	1.97
TSS mmol _c L ⁻¹	33.90	19.70
SAR (mmol L ⁻¹) ^{1/2}	5.48	2.0
Exchangeable cations		
Na ⁺ cmol _c kg ⁻¹	0.50	0.44
K ⁺ cmol _c kg ⁻¹	0.26	0.39
Ca ²⁺ +Mg ²⁺ cmol _c kg ⁻¹	8.37	5.08
CEC cmol _c kg ⁻¹	9.13	5.91
ESP %	4.47	7.39
BCSP %	100.00	99.99
Lime(CaCO ₃) %	2.83	1.59
Organic carbon %	0.40	0.27
Organic matter %	0.69	0.46

when pH increased from 7.69 to 8.00 and then decreased when pH increased to 9.00. Both the soils showed preference for K adsorption with increasing pH as the hydrated size of K is small as compared to Na. Helfferich (1962) stated that in homoivalent systems, the preferentially adsorbed ion is usually the ion with the smaller hydrated radii. Therefore, more K adsorption occurred. For the three levels of OM in soil (original 2 and 4%) there is a little change in K_K value for soil A but for soil B, K_K value increased with increasing OM level of soil. This increase in K_K values indicated increased replacability of Na by K as the quantity of OM increased. The difference in both the soils could be

due to low CEC of soil B compared to soil A (Table II) which increased with an increase in soil organic matter. The low CEC soils are easily accessible to the cations with greater hydrated radii compared to high CEC soils to become neutral. Mehta *et al.* (1983) and Poonia *et al.* (1986) reported that a soil high in organic carbon had higher preference for K than the soil low in organic carbon. Overall it could be concluded that K_K values for the K⁺-Na⁺ exchange differ from treatment to treatment of different soils.

Heterovalent exchange. Kerr, Vanselow and Gapon selectivity coefficient are calculated for K⁺-Ca²⁺ exchange. The values of K_V showed variations from soil to soil. According to Udo (1978) the value of K_V at 10°C and 30°C for K⁺-Ca²⁺ exchange are 17.1 and 6.4, respectively. In a similar study, Mehta *et al.* (1986) showed that the value ranges from 5.41 to 108 L mol⁻¹ for K⁺-Ca²⁺ exchange. The value of K_V obtained in the present study ranges from 248.25 to 803.29 kg cmol_c⁻¹ for soil A and from 369.05 to 1347.9 kg cmol_c⁻¹ for soil B (Table III). The values of all the three selectivity coefficients, K_K , K_V and K_G increased with an increase in adsorbed Ca over K as pH increased showing that availability of pH dependent charge sites in both soils caused greater affinity for Ca over that of K (Eriksson, 1952; Anderson & Sposito, 1992) as the CEC increased (Bower, 1959). The K_V values for K⁺-Ca²⁺ exchange increased from 0.4 to 9.7 L mol⁻¹ when pH was increased from 4.5 to 6.5 (Rhue & Mansell, 1988).

Organic matter has also significant effect on K⁺-Ca²⁺ exchange. The selectivity coefficient K_K , K_V and K_G increased with an increase in OM. Organic matter has been known to result in a greater preference for Ca²⁺

Table II. pH and organic matter effect on K⁺ - Na⁺ exchange in soils (average of three replications)

Soil	Trt	Levels	Equilibrium solution			Exchangeable bases		Equilibrium constant	
			K ⁺ (me L ⁻¹)	Na ⁺ (me L ⁻¹)	$\frac{[K^+]}{[Na^+]}$	KX (me100g ⁻¹)	NaX (me100g ⁻¹)	$\frac{[NaX]}{[KX]}$	K_K
A	pH	Control (7.68)	506.62	469.04	1.08	2.15	2.22	1.03	1.11
		8.00	488.15	445.13	1.09	2.54	3.46	1.36	1.48
		9.00	461.76	452.17	1.02	2.26	2.44	1.08	1.10
A	OM	Control(0.69%)	506.62	469.04	1.08	2.15	2.22	1.03	1.11
		2.00%	680.33	772.94	0.89	4.62	5.70	1.23	1.10
		4.00%	590.71	628.00	0.94	5.10	6.70	1.31	0.14
B	pH	Control (7.69)	40.43	106.40	0.38	4.22	1.75	0.37	0.14
		8.00	37.38	99.80	0.37	4.22	4.80	1.14	0.42
		9.00	35.35	99.35	0.36	2.23	4.80	2.15	0.774
B	OM	Control(0.46%)	40.43	106.40	0.38	4.22	1.75	0.37	0.14
		2.00%	712.90	679.82	1.04	6.56	9.20	1.40	1.46
		4.00%	639.59	1136.14	1.18	6.32	11.85	1.87	2.21

Table III. pH and organic matter effect on K^+ - Ca^{2+} exchange in soil (average of three replications)

Trt. Levels	Equilibrium solution						Exchangeable Bases				Equilibrium Constant		
	K^+	Ca^{2+}	Ca^{2+}	$\frac{[K^+]^2}{[Ca^{2+}]}$	$\frac{K^+}{Ca^{2+}}$		KX	CaX_2	$\frac{[CaX_2]}{[KX]^2}$	$\frac{CaX_2}{KX}$	K_K	K_v	K_G
pH ^a	7.68*	254.63	525	262.5	246.99	15.72	3.45	2.14	0.18	0.62	44.41	248.25	9.75
	8.00	250.22	550	275.0	248.15	15.75	3.04	2.88	0.31	0.94	76.93	455.42	14.81
	9.00	238.48	625	312.5	182.00	13.49	2.60	3.46	0.51	1.33	93.15	546.49	17.94
M ^a	0.69%	254.63	525	262.5	246.99	15.72	3.45	2.14	0.18	0.62	44.41	248.25	9.75
	2.00%	321.84	600	300.0	345.27	18.58	3.41	2.45	0.21	0.72	72.51	424.90	13.38
	4.00%	325.63	600	300.0	354.05	18.81	3.39	3.70	0.32	1.09	113.30	803.29	20.53
pH ^b	7.69*	189.8	662.5	331.25	108.75	10.42	1.74	2.45	0.81	1.41	88.08	369.05	14.69
	8.00	174.85	750.0	375.00	81.53	9.03	1.49	2.85	1.28	1.91	104.36	452.92	17.27
	9.00	182.8	887.5	443.75	75.3	8.68	1.34	2.95	1.64	2.20	123.49	529.77	19.70
M ^b	0.46%	189.8	662.5	331.25	108.75	10.42	1.74	2.45	0.81	1.41	88.08	369.05	14.69
	2.00%	303.52	1050.0	575.00	160.21	12.65	1.76	3.38	1.09	1.92	174.63	897.59	24.28
	4.00%	319.8	1300.0	650.00	157.34	12.54	1.87	4.62	1.32	2.47	207.69	1347.90	30.98

Note: The units of various parameters are the same as given in Table I. M=Organic matter; *=Control; ^a= Soil A; ^b=Soil B

than do the clay minerals (Black, 1968). Both the soils showed preference for Ca adsorption in equilibrium solution of K and Ca. This selectivity of Ca over K can be explained in accordance with Jardine and Sparks (1984). According to them, the exchange sites that were readily accessible for cation exchange reactions had a preference for Ca ions and those of with difficult accessibility showed a preference for K ions due to its compatible hydrated size.

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