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Q/I Relationship as a Measure of Non-Exchangeable Potassium (NEK) Release to Plant Roots under Temperate Conditions

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ABSTRACT

The release of NEK from three soils of different physiographic region of Kashmir Valley was investigated using the Q-1 relationship of potassium. A plot of change in each K (±ΔK) against activity ratio of K, $^{a}K/^{a}(Ca+Mg)^{1/2}$, gave a linear relationship in all the soils with a curved part at low K activity ratio. The value of labile-K (K_1) obtained as intercept of Q/I plot on Y-axis ranged from 0.25 to 0.6 cmol kg^{-1}. Total removal of K in maize, brown sarson and oat was closely related to the activity ratio of K measured at graded levels of K application. The relationship between the activity ratio of K and the amount of K (K_{ee}) obtained after subtracting K uptake (K_{up}) by crop plants from the sum total of K present on nonspecific sites and adding or subtracting the amount by which exchangeable K increased or decreased, respectively. On equilibrium with different K-levels, (±ΔK) gave a negative intercept on quantity axis. This suggests the release of initially non liable K into the labile pool during plant growth. There had been no such release; the plot would have passed through the origin. The value of negative intercept gave a measure of the amount of NEK released. This value was 0.94 cmolkg^{-1} (733.2kgha^{-1}) for *Kokarnag* soil, 0.62 cmol Kg^{-1} (483.6kg ha^{-1}) for *Kreeri* soil and 0.70 cmol kg^{-1}(546.0 kg ha^{-1}) for *Mazhama* soils each cropped with maize, brown sarson and oat.

Key words: NEK, Q/I relationship, K-release

Major crop species are not giving much response to fertilizer K, as has been often observed in India (Yadvinder, *et al.*, 1999) and abroad (Woodruff and Parks, 1980). A number of reasons could be responsible for such observations but in illitic soils, release of K during plant growth from non-exchangeable potassium (NEK) pool could be one of the causes. Wani and Datta (2007) measured the kinetics of NEK release and found that the release of K from insoluble to soluble sources is quite rapid. The sink for the released K provided by the plant roots could be the reason for the rapid release. There are a number of reports on the use of physico chemical approaches for the determination of K-supplying power of soils, which are based on Schofield's ratio law. Beckett (1964 a) proposed the fraction of exchangeable-K, obtained as intercept of Q/I relationship on quantity axis, as labile-K. As the plant utilize this form of K, some more comes into the labile pool, the amount of which may vary with the crop species and soil condition. A graphical method for quantifying such a fraction of K can only be based on the knowledge of Q/I relationship. The techniques and theories to study these relationships were largely developed and described in studies of soil K by Bechett (1964 a, b, c). Pasricha (1983), however, used Q/I technique of K^+-(Ca + Mg) exchange to study the K nutrition of rice grown under submerged soil conditions in glasshouse, and obtained evidence of release of NEK in paddy soils.

In the resent study, K-Q/I relationship were investigated in K deficient soil samples taken from selected fields in alluvial soils of lesser Himalayas with objective of estimation the release of NEK when cropped with maize, mustard and oat.

MATERIALS AND METHODS

Bulk soil samples were collected from 0-20 cm depth from three locations representing all the three physiographic regions of Kashmir valley. The samples separately processed and passed thorough 2mm sieve, the relevant physiochemical characteristics of the soil samples are presented in the table-1. The physiochemical properties of the soils were determined by following the standard procedures (Piper, 1966; Jakson, 1967; Black 1965).

The parameters of the Q-I relationship were determined by the procedure outlined by Beckett (1964). Solutions containing 0 to 2.0 mM KCl L^{-1} was made up in 0.01M $CaCl_2$ solutions in 100 ml centrifuge tube. The samples were equilibrated on a reciprocating shaker at 25^0C for 0.5 hour and solution was analyzed for K on flame photometer and Ca+Mg versenate method. The activity ratio (AR^k) in equilibrium solution was calculated from the molar concentrations and activity coefficient of K, Ca+Mg below;

$$AR^k = \frac{^{a}K^+}{\sqrt{^{a}(Ca^{2+} + Mg^{2+})}} = \frac{^{c}K^+}{\sqrt{^{c}(Ca^{2+} + Mg^{2+})}} \times \frac{^{f}K^+}{\sqrt{^{f}(Ca^{2+} + Mg^{2+})}}$$

Table 1: Physico-chemical properties of soils under investigation

S. No.	Physiographic zone	Location	Site code	Textural class	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	NH_4OAc-K ($cmol\ kg^{-1}$)	CEC [$cmol(P^+)\ kg^{-1}$]
1.	High altitude zone	Kokarnag	S_1	Clayloam	6.75	0.05	20.4	0.44	17.07
2.	Mid altitude zone	Kreeri	S_5	Clayloam	6.65	0.04	11.7	0.15	13.80
3.	Low altitude zone	Mazhama	S_9	Siltyloam	7.95	0.11	21.3	0.23	17.80

Table 2: Value of quantity-intensity parameters of soils under investigation

S. No.	Physiographic zone	Location	Site code	AR_e^K ($mol\ L^{-1})^{1/2}$ x10^{-3}	K_L($cmol\ kg^{-1}$)	PBC^K ($cmol\ kg^1)/(mol\ L^{-1})^{1/2}$	Relative affinity (K_G) ($L\ mol^{-1})^{1/2}$
1.	High altitude zone	Kokarnag	S_1	1.6	0.63	43.75	2.42
2.	Mid altitude zone	Kreeri	S_5	1.2	0.26	25.00	1.81
3.	Low altitude zone	Mazhama	S_9	3.1	0.25	17.86	1.10

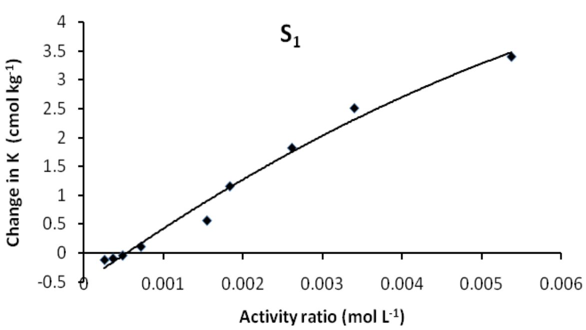

Figure-1: Q/I relationship of High Altitude Zone Kokarnag soil

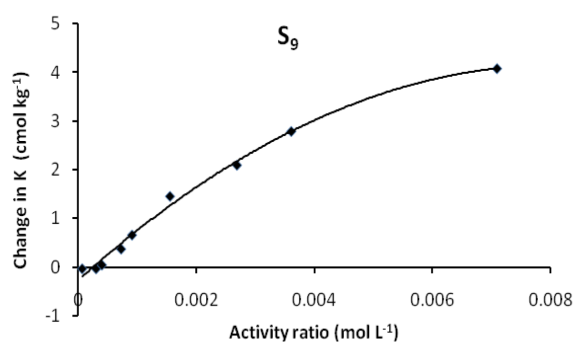

Figure-3: Q/I relationship of Low Altitude Zone Mazham

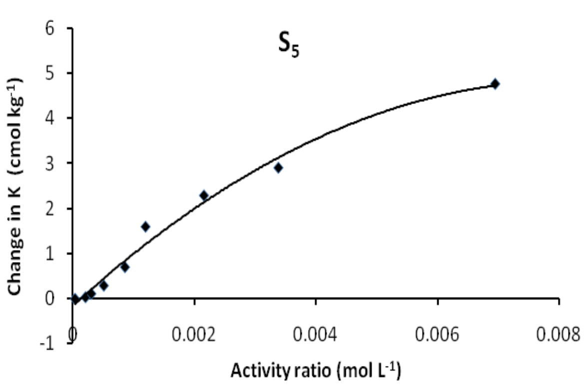

Figure-2: Q/I relationship of Mid Altitude Zone Kreeri soil

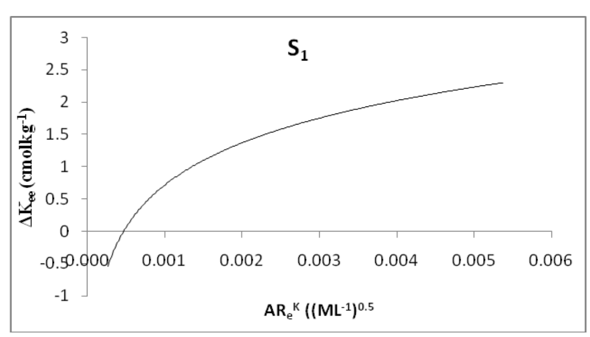

Figure-4: Relationship between AR^K with the quantity, K_{ee} of Kokarnag Soil of High Altitude Zone

Table 3: Effect of graded levels of K on drymatter yield and K-uptake by crop plants of three soils

Site	K Fertilizer rate (mg kg^{-1})	Drymatter yield (g pot^{-1})				K-uptake(mg g^{-1})			
		Mustard	Maize	Oat		Mustard	Maize	Oat	
				Ist cut	IInd cut			Ist cut	IInd cut
1.	0	6.72	70.72	17.17	7.55	5.51	107.49	24.56	9.07
	15	7.05	72.00	18.20	7.28	10.49	120.87	28.24	11.10
	30	7.35	75.50	20.00	7.72	14.70	138.85	31.39	12.13
	60	7.70	79.57	22.55	7.95	21.71	161.77	33.20	13.92
	Mean	7.21	74.44	19.47	7.63	13.10	132.25	29.37	11.56
	C.D (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
2.	0	12.13	36.52	15.75	7.26	10.70	59.76	21.25	8.14
	15	12.56	37.28	16.64	8.00	16.30	76.40	27.35	10.63
	30	12.94	39.02	17.90	8.53	21.68	81.64	36.07	14.37
	60	13.05	41.05	19.02	9.20	23.68	88.67	39.56	17.41
	Mean	12.67	38.47	17.33	8.25	18.09	76.62	31.06	12.64
	C.D (p=0.05)	N.S	3.01	0.86	0.83	N.S	25.12	14.66	N.S
3.	0	14.30	47.23	15.32	7.93	10.76	71.78	18.62	7.57
	15	15.72	49.25	15.80	7.41	19.25	92.47	22.12	8.78
	30	15.53	52.25	16.49	7.83	23.65	111.29	33.27	13.69
	60	15.84	60.57	17.27	8.20	29.52	131.44	37.13	16.40
	Mean	15.35	52.33	16.22	7.84	20.80	101.75	27.79	11.61
	C.D (p=0.05)	N.S	N.S	0.67	N.S	9.80	N.S	4.67	2.23

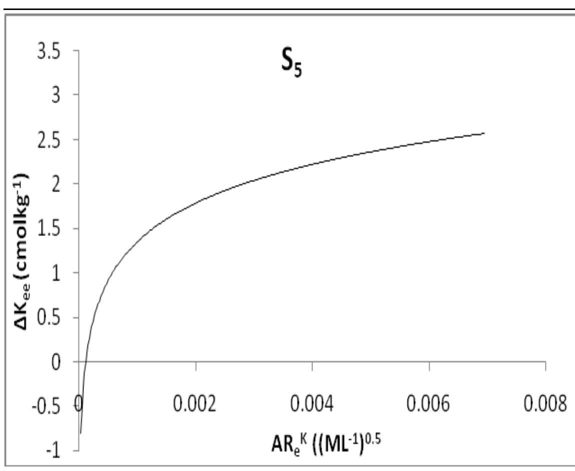

Figure-5: Relationship between AR^K with the quantity, K_{ee} of Kreeri Soil of Mid Altitude Zone

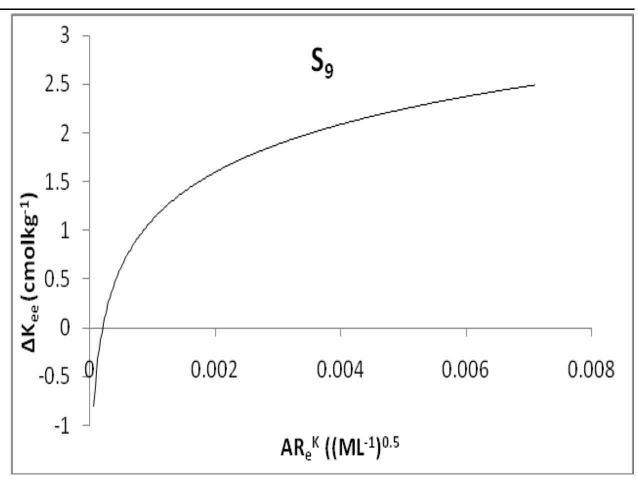

Figure-6: Relationship between AR^K with the quantity, K_{ee} of Mazhama soil of Low Altitude Zone where **a** and **c** represented the activity and concentration of the respective ions. $^fK^+$ and ^{f}**$(Ca^{2+} + Mg^{2+})$** are activity coefficient of K^+ and **$(Ca^{2+} + Mg^{2+})$** ions and were calculated from the relationship given by Dubey and Huckle.

$$-\log f = \frac{AZ^2\sqrt{\mu}}{1 + \alpha\beta\sqrt{\mu}}$$

Where **A** is constant and its value is:

i. 0.509 for water at 25^0C and
ii. 0.520 for water at 35^0C (Maron and Pruton, 1969)

B is dielectric constant for water its value is

i. 3.29 x 10 at 25^0C and
ii. 0.331 x 10^8 at 35^0C. (Maron and Pruton, 1969)

α is mean activity diameter,

i. For Ca^{2+}, it is $6A^0$ and
ii. For K^+ it is $3A^0$. (Wicklander, 1964)

Z is valency of the ions.

μ is the strength of the solution and is calculated by using the empirical relationship;

μ = 16 x EC (mmhos cm^{-1})

(Ponnamperuma *et al*., 1966)

The Q/I diagram was constructed by plotting the solution K adsorbed or desorbed from the soil (±ΔK) against AR^k values. Values of selectivity coefficient. K_G or relative affinity of exchange complex for K was calculated by;

$$K_G = PBC^K / CEC$$

Where, PBC^K is potential buffering capacity for K calculated from the linear part of Q/1 plot.

Five (5) Kg Portion each of the three air dried soils in polyethylene lined plots were treated with graded levels of K (0 to 2.0 cmol kg^{-1}) as KCl. The levels of K for the plots were same as used in laboratory for working out Q/I relationship of these soils. Each treatment was replicated three times. Basal dose of N and P as per package of practice were applied as urea and DAP. Soils in the pots were mixed and brown sarson crop was sown and irrigated with deionized water. The plants were allowed to grow to pre-flowering growth stage, when the above ground portions were harvested. These soils were further cropped with maize immediately after the harvesting of brown sarson crop. Only five plants were allowed to grow up to flowering per pot. The crop was given basal N and P as per the package. No fresh application of K was made. These plants were harvested after 45DAS. Finally the third crop of oat was grown. Two cuts of oat were taken prior to flowering. The crop was fertilized with recommended dose of N and P with no application of K.

The release of non – exchangeable K was evaluated by plotting the quantity K_{ee} against AR^K. K_{ee} was calculated as:

$$K_{ee} = \Delta K_0 \pm \Delta K_{ex} - K_{up}$$

Where, ΔK_0 = K held at non-specific sites measured as extrapolated Y intercept of tangent drawn on Q/I plot at AK_e^K, ± ΔK_{ex} is the quantity of exchangeable K gained or lost by soil on equilibrium with graded K solutions and K_{up} is the amount of K removed in crop plants. All the quantities are expressed in cmol kg^{-1} soil.

RESULTS AND DISCUSSION

The Q/I relationship for the Kokarnag soil of high altitude zone was curved at low activity ratios. A linear relationship between activity ratio (AR^K) and change in exchangeable content (±ΔK_{ex}) occurred in all the soils (Figure 1-3) at higher values of AR^K in the solution. This confirms to Schofield's ratio law. The curved part of the isotherm at lower AR^K in case of Kokarnag (S_I) soil of high altitude zone (Figure-1) could indicate that some of the adsorption sites have a higher affinity for K ions. Amount of liable-K, K_L for Kokarnag soil of high altitude zone was 0.63 cmolkg^{-1}, 0.26 cmolkg^{-1} for Kreeri soil of mid altitude zone and 0.25 cmolkg^{-1} for Mazhama soil of low altitude zone (Table-2). Potential buffering capacity (PBC^K) for Kokarnag soil was 43.75 (cmolkg^{-1})/(mol L^{-1})$^{1/2}$, for Kreeri soil was 25.00 (cmolkg^{-1})/(mol L^{-1})$^{1/2}$ and for Mazhama soil was 17.86 (cmolkg^{-1})/(mol L^{-1})$^{1/2}$. This shows that for each equivalent of K, the amount of K released in the solution will be lower in Kokarnag soil than Kreeri soil and least in Mazhama soil. Higher BC of Kokarnag soil is attributed to its finer texture. Relative affinity of each complex for K (K_G) for Mazhama and Kreeri soils was lower than for Kokarnag soil (Table-2). Although the difference could be explained by a number of factors, much of the difference could be explained by differences in clay contents. A greater content of clay fraction should be expected to result in higher CEC and low K_G when other factors remain constant.

AR^K at varying fertilizer K treatment correlated significantly with K uptake by mustard ($r = 0.960^*$), maize ($r = 0.965^*$), oat ($r = 0.964^*$), in Kokarnag soil of high altitude zone, mustard ($r = 0.972^*$), maize ($r = 0.969^*$), oat (r = 0.977*) in Kreeri soil of mid altitude zone and mustard ($r = 0.993^{**}$), maize ($r = 0.994^{**}$), oat (r = 0.949) in Mazhama soil of low altitude zone. All the soils are rated low in NH_4OAc extractable-K (< 45.5 kg ha^{-1}). However, no significant effect was observed on dry matter of crop plants except maize and oat in Kreeri soil (Table-3). Release of non-liable-K into liable pool could be responsible for poor response to fertilizer K. The quantity, K_{ee} was plotted against corresponding AR^K. Relationship of Kokarnag soil of high altitude zone cropped with mustard, maize and oat (Figure-4) showed a negative intercept on the quantity axis of the tangent as AK_e^K. Negative intercept indicates that plants had derived a part of their K requirement from non-labile reserves of K and during plant growth this fraction has come into the liable pool. If such a release was not there, the Q/I plot between K_{ee} and AR^k would not have shown a negative intercept at quantity axis and would have passed through origin. The value of negative intercept is a measure of amount of non-liable K that comes into the liable pool during the time scale of plant growth and becomes available to plants as the concentrations of K in the soil solution is depleted through uptake. This value for Kokarnag soil cropped with mustard, maize and oat was 0.94 cmolkg^{-1} soil (Figure-4), which when calculated on per hectare basis, comes out 733.2 Kg ha^{-1} (taking 2x10^{6} kg as weight of plough layer soil in one hectare). In Kreeri soil of mid altitude zone cropped with mustard, maize and oat, this quantity was cooperatively much less, 0.62 cmolkg^{-1}, which is equivalent to 483.6 kg ha^{-1} (Figure-5). In Mazhama soil of low altitude zone also cropped with mustard, maize and oat, the quantity was 0.70 cmolkg^{-1}, which is equivalent to 546.0 kg ha^{-1} (Figure-6). Pasricha (1976) showed that the form of Q/I relationship was unaffected by change in soil: solution ratio. In narrow soil: solution ratios, most of the data points lie on the positive side of the quantity axis. Therefore, relating activity ratios measured at 1:10 soil to solution ratio of K uptake by plants grown at much narrow soil**:**solution ratio should not in any way affect the interpretation of results.

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