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Availability and fixation of added potassium in rice soils of West Bengal

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ABSTRACT

An incubation experiment on potassium fixation and availability in six rice soils of West Bengal was conducted at varying levels of added K. Amount of K fixed increased in all the soils with the increase in applied K from 15 to 240 mg kg^{-1} soil, however, the percentage of added K fixed decreased gradually. The K fixation could still increase upon addition of higher levels of added K beyond 240 mg kg^{-1} soil. Illite and smectite dominant Inceptisols with high available and reserve K showed a lower K fixation (4.9 to 39.6 mg kg^{-1} soil) as compared to illite dominant Entisols (5.5 to 41.0 mg kg^{-1} soil) containing moderate available and reserve K. Conversely, kaolinite dominant Alfisol with low available and reserve K registered the lowest amount of K fixation (2.5 to 14.9 mg kg^{-1} soil). Maximum per cent K fixation was observed at 15 mg kg^{-1} of added K in all the soils, the more so in Entisols than in Inceptisols and Alfisol. Fertilizer K requirement per unit increase in available K in soil was relatively higher in Entisols and Inceptisols (1.15 to 1.19) and lower in Alfisol (1.06).

Key words: *Potassium fixation, available and reserve K, added K, rice soils, West Bengal*

Potassium fixation in soil is the phenomenon of conversion of water-soluble and exchangeable K into moderately or slowly available non-exchangeable K, which is not readily taken up by the growing plants (Mortland, 1961). Soil texture, soil reaction, complementary cations, organic matter content, addition of potassic fertilizers, amount and type of clay minerals and moisture regimes are some of the factors determining the extent of K fixation in soils (Srinivasa Rao and Khera, 1995). This process assumes great importance, because it not only regulates the dynamics of different forms of K in soil, but also indicates the soil potentiality to long-term K supply to plants. Fixation of K in soil is not considered completely unfavourable since it helps to conserve the nutrient from leaching loss. Similarly, fixed K becomes available to plants over a longer period upon depletion of water-soluble and exchangeable K (Patra and Debnath, 1998). The variability of K fixation in soil indirectly influences the response of crops to added fertilizer K and the potassium requirement to maintain soil available K status for optimum plant growth (Chakravorty and Patnaik, 1990). The present investigation was undertaken to assess the availability and fixation of added potassium in six wetland rice soils of West Bengal with a view to make meaningful K management strategies for higher crop productivity.

MATERIALS AND METHODS

Six surface (0-15 cm) soil samples representing three new alluvial soils belonging to Entisols (Alipurduar, Burdwan and Gayeshpur), two old alluvial soils under Inceptisols (Dankuni and Kakdwip) and one red soil under Alfisol (Jhargram) were collected from different locations representing regions of intensive rice- based cropping system in West Bengal during winter season of 2004. The different forms of soil K was estimated with suitable extractants. HCl extractable or lattice K was determined according to the AEA method (Piper, 1966) while non-exchangeable K by boiling soil sample with 1N HNO_3 (Wood and De Turk, 1941). Available K was extracted by shaking soil with neutral 1N NH_4OAc (Jackson, 1973) and water soluble K with distilled water (1:5). Exchangeable K was calculated by subtracting water soluble K from available K. For an evaluation of the availability and extent of K fixation in K-enriched rice soils under low to high level of fertilizer K application at field moist condition, a controlled incubation experiment was conducted. Five grams each of soil samples in duplicate were taken in several plastic screw-cap bottles to which 5 doses of K @ 15, 30, 60, 120 and 240 mg kg^{-1} in the form of reagent grade KCl were added in one mL solution for each gram of soil. The soils were equilibrated for two weeks at room temperature (28 ± 1 ºC) maintaining the moisture level at field capacity. The soil moisture loss due to evaporation was corrected in alternate day by adding distilled water on weight loss basis. At the end of incubation period, available K was extracted with neutral 1N NH_4OAc and K in the extract was estimated using flame photometer. The fixed K of the soil was computed following the formula as suggested by Sahu and Gupta (1987):

$K_{fixed} = K_{applied} - (\text{Available K}_{treated} - \text{Available K}_{control})$

Where, K_{fixed} = amount of added K fixed, mg kg^{-1} soil

$K_{applied}$ = amount of applied K, mg kg^{-1} soil

Available $K_{treated}$ = available K in K-treated soil after incubation, mg kg^{-1} soil

Available $K_{control}$ = amount of available K before incubation, mg kg^{-1} soil

RESULTS AND DISCUSSION

The soils were air-dried, ground to pass through a 2-mm sieve and the processed samples were analyzed for particle size, organic carbon content, pH, EC and CEC following standard procedures (Jackson, 1973). The soils were sandy loam to clay loam in texture and differed markedly in pH, electrical conductivity, organic carbon content and cation exchange capacity (Table 1). There was a large variation in the contents of different forms of K in these soils (Table 2). However, Inceptisols and Entisols possessed higher labile and non-labile K reserves as compared to Alfisol. The predominant clay minerals were illitic and smectitic in all soils except Jhargram soil which was kaolinitic in nature. Irrespective of varying initial soil-K reserves and clay minerals, available K content and increase in available K over control consistently increased with increase in level of K application (Fig.1, Table 3). In general, illitic and smectitic Inceptisols with higher initial K status registered the higher availability of K, medium in illitic Entisols and lower for kaolinitic Alfisol having low initial K status. Out of six soils, Jhargram soil containing kaolinite as the dominant clay mineral recorded the higher increase in available K over control from 12.5 to 225.1 mg kg^{-1} soil at each level of added K from 15 to 240 mg kg^{-1} soil (Table 3). On the contrary, relatively a lower increase in available K from 8.5 to 203.6 mg kg^{-1} soil due to same doses of applied K was noticed in the remaining five soils containing illite and smectite as the dominant clay minerals. The variable increase in available K in these soils upon addition of incremental doses of K could be due to the differences

Table 1. Important properties of the rice soils

Location and soil type	pH (1:2.5)	EC (dSm^{-1})	Organic C (%)	CEC [cmol (p^+)kg^{-1}]	Soil separates (%) Sand	Silt	Clay	Texture	Dominant clay minerals (%) #
Typic Haplaquent									
Alipurduar	6.2	0.15	0.75	7.6	52	34	14	sl	Illite (55), chlorite (28), smectite (8), & kaolinite
Burdwan	7.3	0.14	0.73	12.3	68	22	10	sl	Illite (32), chlorite (18), smectite(15), kaolinite(10)
Gayeshpur	6.5	0.05	0.30	9.1	80	12	8	ls	Illite (50), smectite (9), chlorite (29), kaolinite (11)
Typic Haplaquept									
Dankuni	7.7	0.44	0.54	15.7	34	34	32	cl	Illite (28), smectite (33), chlorite (17), kaolinite (6)
Kakdwip	8.0	0.21	1.02	14.5	32	36	32	cl	Illite (47), smectite (24), chlorite (7), kaolinite (7)
Typic Haplustalf									
Jhargram	5.0	0.04	0.27	6.8	78	10	12	ls	Kaolinite (60), illite (17), smectite (6), chlorite (5)

sl : sandy loam, ls : loamy sand, cl : clay loam, # Anon (2003)

Table 2. Different forms of K (mg kg^{-1}soil) in the rice soils of West Bengal

Location and soil type	Water soluble K	ExchangeableK	Available K	Non-exchangeable K	Lattice K
Typic Haplaquent					
Alipurduar	35.2	81.3	116.5	1036	2905
Burdwan	54.3	147.1	202.4	1947	3718
Gayeshpur	31.1	133.2	164.3	689	4653
Typic Haplaquept					
Dankuni	238.2	962.1	1200.3	3492	9228
Kakdwip	62.3	339.0	401.3	3194	7566
Typic Haplustalf					
Jhargram	17.3	45.2	62.5	442	1357

Table 3. Increase in available K over control (mg kg^{-1}soil) at different levels of added K in the rice soils

Location and soil type	Added K (mg kg^{-1} soil)				
	15	30	60	120	240
Typic Haplaquent					
Alipurduar	9.5	20.7	44.9	95.5	199.0
Burdwan	9.3	19.5	43.1	96.8	199.4
Gayeshpur	8.5	18.9	42.7	96.9	203.6
Typic Haplaquept					
Dankuni	10.1	21.5	46.1	96.7	200.9
Kakdwip	9.7	21.3	43.9	95.6	200.4
Typic Haplustalf					
Jhargram	12.5	26.1	53.5	109.6	225.1

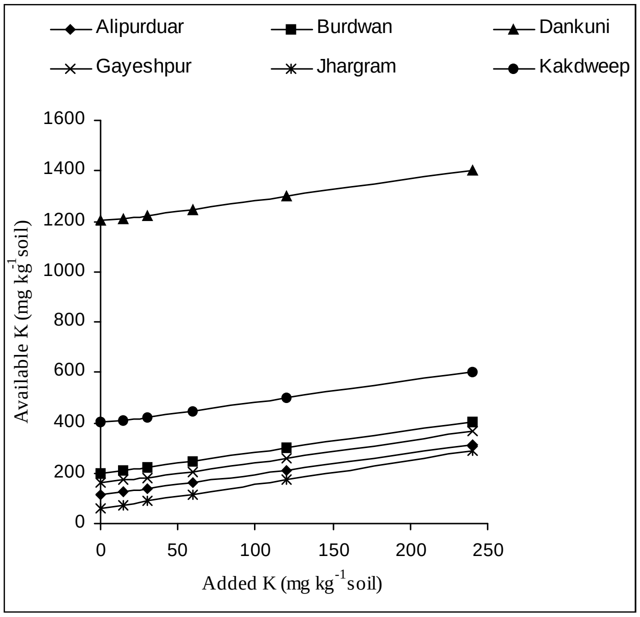

Fig 1. Relationship between added K and available K in the rice soils of West Bengal

in the magnitude of initial soil K status, soil texture, the amount and composition of clay minerals (Srinivasa Rao *et al.*, 2000) and the affinity for K fixation (Patra and Debnath, 1998). Higher recovery rates of K in the Alfisol (0.94) and relatively lower recovery rates of K for Entisols and Inceptisols (0.84 to 0.87) per unit of added K supported this observation (Table 5).

The amount of K fixation irrespective of initial K status and dominant clay minerals increased with increase in K application rate from 15 to 240 mg kg^{-1} soil (Table 5). These findings suggested that the added K levels were not adequate to determine the higher K fixation of the soils. The K fixation could still increase upon addition of higher levels of added K beyond 240 mg kg^{-1} soil. This increased added K fixed might be attributed to the increase in ionic strength of potassium in solution resulting a portion of K from labile pool being forced to occupy into the inter-lattice position of expanding minerals (Masilamani *et al.*, 1993). The amount of K fixation with increasing K application rate was, however, variable from soil to soil. Illitic and smectitic Inceptisols with higher available K reserve showed the K fixation to the extent of 4.9 to 39.6 mg kg^{-1} soil, while illitic Entisols containing moderate amounts of available and reserve K recorded comparatively a larger amount of K fixation in the range of 5.5 to 41.0 mg kg^{-1} with K addition from 15 to 240 mg kg^{-1} soil. Kaolinitic Alfisol with lower available and native soil K appeared to fix a smaller quantity of applied K ranging from 2.5 to 14.9 mg kg^{-1} soil with the same K application rates. These differences in K fixation in the soils were ascribed to the variations in soil texture, quantity and composition of clay minerals, native soil K status and K saturation of the inner lattice of micaceous minerals (Patra and Debnath, 1998; Singh

Table 4. K fixation (mg kg^{-1}) and per cent K fixed at different levels of added K in the rice soils

Location and soil type	Added K (mg kg^{-1} soil)				
	15	30	60	120	240
Typic Haplaquent					
Alipurduar	5.5 (36.7)	9.3 (31.0)	15.1 (25.2)	24.5 (20.4)	41.0 (17.1)
Burdwan	5.7 (38.0)	10.5 (35.0)	16.9 (28.2)	23.2 (19.3)	40.6 (16.9)
Gayeshpur	6.3 (42.0)	10.9 (36.3)	17.1 (28.5)	22.9 (19.1)	36.2 (15.1)
Typic Haplaquept					
Dankuni	4.9 (32.7)	8.5 (28.3)	13.9 (23.2)	23.3 (19.4)	39.1 (16.3)
Kakdwip	5.3 (35.3)	8.7 (29.0)	16.1 (26.8)	24.4 (20.3)	39.6 (16.5)
Typic Haplustalf					
Jhargram	2.5 (16.7)	3.9 (13.0)	6.5 (10.8)	10.4 (8.7)	14.9 (6.2)

Figures within brackets indicate per cent K fixed of added K

Table 5. Potassium recovery rate and fixation rate from unit fertilizer K required in the rice soils of West Bengal

Location and soil type	Equation connecting increase in available K (Y) with added K (X)	K recovery rate/unit	K-fixation rate/unit	Units fertilizer K rate required for unit increase in available K
Typic Haplaquent				
Alipurduar	Y = -4.704 + 0.84 X	0.84	0.16	1.19
Burdwan	Y = -5.683+ 0.85 X	0.85	0.15	1.17
Gayeshpur	Y = -7.221+ 0.87 X	0.87	0.13	1.15
Typic Haplaquept				
Dankuni	Y = -4.050+ 0.85 X	0.85	0.15	1.17
Kakdwip	Y = -4.967+ 0.85 X	0.85	0.15	1.17
Typic Haplustalf				
Jhargram	Y = -2.596+ 0.94 X	0.94	0.06	1.06

et al., 1999). Contrary to this, the per cent of added K fixed decreased gradually with increasing levels of K application. Maximum per cent K fixation was observed at 15 mg kg^{-1} of added K in all the soils, the more so in the illitic Entisols, followed by Illitic and smectitic Inceptisols and Kaolinitic Alfisol. This could be attributed to the gradual saturation of the K-fixing sites due to the regular application of higher doses of fertilizer K in these cultivated soils (Patel *et al.,* 1989; Singh *et al.,* 1999). Similar observation was reported earlier by Sahu and Gupta (1987). It is presumed that the mechanism of K fixation is preceded by moving the K ions from the edges and surface to the interior of the soil mineral fabric and increasing amount of K influenced the ion diffusion (Chakravorty and Patnaik, 1990).

Regressions equations showing the relationship of increase in available K (Y) with added K (X) for the soils are presented in Table 5. The analysis of data revealed that recovery rate of K per unit of added K was observed to be relatively higher in kaolinitic Alfisol (0.94) as compared to illitic and smectitic Inceptisols and illitic Entisols (0.84 to 0.87). Conversely, K fixation per unit of added K was considerably higher for Inceptisols and Entisols (0.13 to 0.16) and lower for Alfisol (0.06). Based on slope values of regression equations, the unit fertilizer K requirement per unit increase in available K in soils was computed and the value was relatively higher for Inceptisols and Entisols (1.15 to 1.19) and lower for Alfisol (1.06).

The overall results of the present study suggest that Entisols and Inceptisols enriched with moderate to high amounts of available and reserve K showed moderate K fixation and hence need K fertilizer application at moderate doses for optimal plant K nutrition. In contrast, Alfisol with low available and reserve K registered the lower K fixation and thus need frequent K application at lower doses to meet K requirement of crop. In addition, regular monitoring in the change of the available and reserve K in these soils under intensive rice- based cropping system is also imperative for a meaningful K management strategy for sustainable crop production.

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