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Changes in non-exchangeable K in an acid and the corresponding limed soil as affected by addition of nitrogenous and potassic fertilizers

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ABSTACT

A laboratory experiment was conducted to study the changes in non-exchangeable K in a half limed, full limed as well as the corresponding unlimed soil. All three soils were treated with nitrogen (urea) and potassium (MOP) fertilizers either alone or in combination. Soils were maintained at 60% of the water holding capacity. The results showed that, irrespective of treatments, full limed soil recorded highest amount of non-exchangeable K over that of half limed as well as unlimed systems. Results further showed that irrespective of treatments, non-exchangeable K in unlimed acid soil increased up to 30th day then decreased on 60th day but again increased on 90th day of the incubation. However, limed soil did not show similar trend of results. Non-exchangeable K decreased up to 60th day in half limed soil and up to 30th day in full limed soil and then showed an increasing trend thereafter. Results further showed that during the 90 day period of incubation, nitrogenous and potassic fertilizer did not show any significant effect on non-exchangeable K content in soil.

Keywords: Exchangeable, non-exchangeable and labile K, limed soil, water holding capacity

Potassium is one of the essential macronutrient element required by plants in larger amounts than any other nutrient except nitrogen. It involves in many physiological processes which ultimately affect the crop quality. Thus while nitrogen is commonly known to be yield increasing plant nutrient, K is most important in stabilizing the yield. With intensification of agriculture the importance of potassium in Indian agriculture has increased and also it has been demonstrated convincingly (Dhar, 2000; Sanyal, 2001) that continued cropping with only N and P without K leads to such depletion of K reserve in soil. Therefore, for sustaining soil fertility and crop productivity on long term basis, nutrient removed by crops should be replenished through balanced and adequate fertilization.

Brady and Well (2007) reported that the very less amount of K is present in soil solution (0.1-0.2%) and available (1-2%) forms as compared to non-exchangeable form (1-10%). As there is a dynamic interaction among the different forms of K, soil solution and exchangeable form of K is continuously replenished by non-exchangeable form of K reserves (Wang *et al.*, 2004). According to Singh and Sanyal (2001), all these forms of K in soil are affected by liming. However, the actual relationship between liming and potassium availability is not clear yet. Some researchers found a positive influence of liming on non-exchangeable K content in soil (Sarkar, 2009 and Kumar *et al.*, 2010). Not only liming but also application of nitrogenous and potassic fertilizers may affect non-exchangeable K in soil. It was found that application of nitrogenous fertilizers influences non-exchangeable K content in soils (Lehmann *et al.*, 1991). Keeping above information in view, the present investigation was conducted to study the effect of liming on changes in non-exchangeable K in an acid soil along with addition of nitrogenous and potassic fertilizers either alone or in combination.

MATERIALS AND METHODS

The soil (0-15 cm depth) used in the present investigation was collected from Anandapur Tea State (26^{0}78'N and 88^{0}39'E), Malbazar, Jalpaiguri (West Bengal) during the year 2010-11. According to USDA system, soil was classification as 'Fluventic eutrochrepts'.

The soil was air dried ground and passed through 2mm sieve. This soil is considered as unlimed soil in the experiment. Lime requirement of that acid soil was determined by Shoemaker, McLean and Pratt method in short SMP buffer method (Jackson, 1973). The lime requirement of that soil was 30 tons ha^{-1}. Based on this lime requirement half limed soil and full limed soil were prepared by uniform mixing of the liming materials ($CaCO_3$), equivalent to half dose (at 15 tons ha^{-1}) and full dose (at 30 tons ha^{-1}) of lime requirement respectively, Liming was done in two separate plastic containers, containing 1 kg of soil each and allowed the liming material to react with soil mass for 3 months with repeated wetting up to its water holding capacity, followed by air drying to its field capacity to prepare half limed and full lime soil. Before use, both the half and full limed soils were air dried, ground by a wooden pestle and mortar and passed through 2 mm sieve.

Altogether six sets of treatments were adopted for three sets of both limed and unlimed soils. For every treatment 10 g of both half limed and full limed as well as unlimed acid soil were taken

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separately in 100 mL beakers for the incubation study. First set was maintained as control without addition of nitrogen and potassium fertilizers. In the second set, K was added as treatment material at 30 mg kg^{-1} in the form of Muriate of Potash (MOP). In the third set N was added at 30 mg kg^{-1} as urea. The fourth set was maintained with both K and N addition at 30 mg kg^{-1} as MOP and urea respectively. In the fifth set, nitrogen was added at 60 mg kg^{-1} as urea. The sixth set of soil was maintained where, K (as MOP) and N (as urea) were added at 30 mg kg^{-1} and 60 mg kg^{-1} respectively. Application of all these fertilizers were done by dissolving those in distilled water at their respected doses and the soil samples were moistened to 60% of the moisture holding capacity. After moistening, the soil samples were allowed to incubate at room temperature (30±2^{0}C) for period of 90 days. Five separate sets were maintained for laboratory analysis on 0th, 15th, 30th, 60th, and 90th day of incubation. Soil samples for all sets along with three replications were identically collected for analysis of non-exchangeable K. Non-exchangeable K was calculated by subtracting available K (Scholenberger and Simon, 1945) from 1 N boiling HNO_3 extractable K (Wood and De Turk, 1941). Loss of moisture due to evaporation was replenished by the addition of distilled water on every alternate day by difference in weight. The treatments included in incubation study for each soil (unlimed, half limed and full limed soil) are represented as follows.

T_0 = Soil
T_1 = Soil + K at 30 mg kg^{-1} as MOP
T_2 = Soil + N at 30 mg kg^{-1} as urea
T_3 = T_1+ N at30 mg kg^{-1} as urea
T_4 = Soil + N at 60 mg kg^{-1} as urea
T_5 = T_1 + N at 60 mg kg^{-1} as urea

All the data were statistically analyzed following methods meant for completely randomized design (CRD). Their mean effect were further subjected to Post-Hoc test to identify homogeneous means at 5% level of significance.

RESULTS AND DISCUSSION

Results of changes in the amount of non-exchangeable K in an acid soil treated singly or combinedly with or without inorganic nitrogen and potassium fertilizer are presented in table 1. Results revealed that irrespective of treatments, non-exchangeable K increased up to 30th day, then decreased on 60th day and again increased on 90th day of the investigation. However, highest amount of accumulation of non-exchangeable K was observed on 30th day of the incubation. This trend of results is observed for all the treatments under study. The present result thus clearly pointed out that incubation of an acid soil showed highest amount of non-exchangeable K within 30 days. This is due to the dynamic interactions among its different chemical forms which lead to shifting of K from its available form to non-exchangeable form (Wang *et al.,* 2004).

Results of changes in the amount of non-exchangeable K in half and full limed acid soil treated with or without inorganic N and K fertilizer are presented in table- 2 and 3 respectively. Examination of the data in table- 2 and 3 revealed that half limed soil showed a decrease in non-exchangeable K up to 60th day and increased thereafter. But the results depicted that in full limed soil, amount of non-exchangeable K decreased during initial period of incubation up to 30th day, then increased on 60th day, there after again decreased on 90th day of incubation (Table 3). These changes of non-exchangeable K might be due to the existence of dynamic equilibrium between exchangeable and non-exchangeable forms of K (Sanyal and Majumder, 2001). Highest amount of non-exchangeable K was recorded where K fertilizer was added alone.

Presence of K in exchange phase is the prerequisite for its fixation. Saturation of the exchangeable complex with respect to K leads to entry of K into wedge zone and interlayer spaces. This leads to fixation of exchangeable K ions into non-exchangeable form. Chen *et al.* (1989) also reported that a portion of fertilizer K is converted into non-exchangeable form. Presence of N along with K decreased the fixation of K in soils. This is due to the competition of both NH_4^+ and K^+ for the same fixing sites in the clay minerals. Nommik (1957) demonstrated that mechanism of fixation is same for both these ions. Presence of higher amount of N along with K further reduced the non-exchangeable form of K. This is perhaps due to mass action of N. But all the changes due to variation of treatments are insignificant.

The effect of liming on non-exchangeable K without considering the effect of different treatments is presented in table 4. Results revealed that liming increased non-exchangeable K content in soils. It is due to the precipitation of hydroxyl aluminium and hydroxyl iron polymers, by blockage would cause difficulty in the release of K from initially non-exchangeable position, hence would lead to an increase in the pool of non-exchangeable K in limed soil. Another reason for increase in non-exchangeable K by liming is the expansion and weathering of lattice of clay minerals in soils which facilitate the release of lattice K.

Table 1: Changes in the amount of non-exchangeable K (mg kg^{-1}) in an acid soil treated singly or combinedly with or without N and K fertilizers

Treatments	Incubation period (days)					
	0	**15**	**30**	**60**	**90**	**Mean**
$Soil_0$	1658.00	1660.87	1664.73	1654.73	1660.00	**1659.67**
$Soil_0$+K_{30}	1659.83	1664.38	1670.33	1658.63	1663.00	**1663.23**
$Soil_0$+N_{30}	1657.09	1659.36	1661.65	1649.47	1657.85	**1657.08**
$Soil_0$+K_{30}+N_{30}	1658.00	1663.33	1667.00	1653.17	1660.00	**1660.30**
$Soil_0$+N_{60}	1657.23	1658.49	1660.82	1647.67	1653.00	**1655.44**
$Soil_0$+K_{30}+N_{60}	1657.83	1665.17	1664.17	1651.20	1655.93	**1658.86**
Mean	**1657.99**	**1661.93**	**1664.78**	**1652.48**	**1658.29**	

Treatments		Incubation		Treatments × Incubation	
SEm (±)	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**
0.89	2.54	0.82	2.31	2	NS

Table 2: Changes in the amount of non-exchangeable K (mg kg^{-1}) in an acid soil treated with half dose of its lime requirement in presence and absence of N and K fertilizers

Treatments	Incubation period (days)					
	0	**15**	**30**	**60**	**90**	**Mean**
$Soil_{1/2}$	2132.33	2128.17	2123.00	2116.64	2118.29	**2123.69**
$Soil_{1/2}$+K_{30}	2132.00	2131.17	2125.33	2118.92	2124.29	**2126.34**
$Soil_{1/2}$+N_{30}	2132.33	2129.40	2122.50	2115.14	2116.60	**2123.19**
$Soil_{1/2}$+K_{30}+N_{30}	2130.80	2130.67	2124.00	2114.57	2121.96	**2124.40**
$Soil_{1/2}$+N_{60}	2132.50	2125.33	2119.93	2113.30	2115.78	**2121.37**
$Soil_{1/2}$+K_{30}+N_{60}	2130.13	2126.63	2122.97	2115.33	2120.83	**2123.18**
Mean	**2131.68**	**2128.56**	**2123.00**	**2115.65**	**2119.62**	

Treatments		Incubation		Treatments × Incubation	
SEm (±)	**LSD (0.05)**	**SEm(±)**	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**
0.81	2.29	0.74	2.09	1.81	5.12

Table 3: Changes in the amount of non-exchangeable K (mg kg^{-1}) in an acid soil treated with full dose of its lime requirement in presence and absence of N and K fertilizers

Treatments	Incubation period (days)					
	0	**15**	**30**	**60**	**90**	**Mean**
$Soil_1$	2267.50	2265.13	2259.00	2273.20	2260.77	**2265.12**
$Soil_1$+K_{30}	2272.00	2272.00	2270.47	2282.00	2266.47	**2272.59**
$Soil_1$+N_{30}	2267.37	2264.60	2260.00	2273.20	2258.67	**2264.77**
$Soil_1$+K_{30}+N_{30}	2272.40	2270.00	2266.00	2287.00	2266.33	**2272.35**
$Soil_1$+N_{60}	2267.00	2260.60	2259.00	2271.00	2255.93	**2262.71**
$Soil_1$+K_{30}+N_{60}	2272.07	2262.73	2265.93	2281.50	2267.00	**2269.85**
Mean	**2269.72**	**2265.84**	**2263.40**	**2277.983**	**2262.53**	

Treatments		Incubation		Treatments × Incubation	
SEm (±)	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**	**SEm (±)**	**LSD (0.05)**
1.60	4.52	1.46	4.13	3.58	NS

Note: $Soil_1$ indicate full limed soil, K_{30} indicate K at 30 mg kg^{-1} MOP, N_{30} indicate N at 30 mg kg^{-1} as urea, N_{60} indicate N at 60 mg kg^{-1} as urea

Table 4: Changes in mean value of non-exchangeable K (mg kg^{-1}) of different treatments, treated with different doses of lime

Liming	Incubation period (days)				
	0	**15**	**30**	**60**	**90**
Unlimed soil	1657.98	1661.93	1664.79	1652.48	1658.29
Half limed soil	2131.55	2128.56	2122.96	2115.65	2119.62
Full limed soil	2269.72	2265.84	2263.40	2276.76	2262.53
SEm (±)	**0.87**	**1.04**	**0.74**	**1.51**	**0.87**
LSD (0.05)	**2.50**	**2.99**	**2.14**	**4.34**	**2.49**

It is also clear from the data that not only liming but also its doses significantly affect the non-exchangeable K content in soils (Table 4). As a result of which comparatively higher amount of non-exchangeable K is accumulated in full limed soil compared to that of half limed soil. This trend of result is observed irrespective of treatments and stages of incubation. The results corroborate the findings of earlier work of Sarkar (2009).

Closer examination of the data presented in table 4 revealed that the changes in non- exchangeable K followed an opposite trend of results for full limed as was found for unlimed soil. The amount of non-exchangeable K decreased up to 30th day in full limed soil, then increased on 60th day, thereafter decreased again. But in case of half limed soil non-exchangeable K decreased up to 60th day period, thereafter slightly increased on 90th day. The decrease of non-exchangeable K in half limed soil is due to the cumulative release of K from non-exchangeable to exchangeable form (Ghosh *et al.,* 2001). Liming increases the negative sites on clay surface which cause greater accumulation of K on exchangeable phase and due to the dynamic equilibrium the exchangeable K transform to the non-exchangeable form with time. Therefore in case of full limed soil there was a higher accumulation of K on non-exchangeable phase compared to half limed soil. Thus it is clear from the results that liming not only affect the amount of non-exchangeable K but also its transformation process throughout the period of investigation (Table 4).

Simultaneous application of nitrogenous and potassic fertilizer did not show any significant effect on non-exchangeable K content in soil. However, liming positively influenced the non-exchangeable K content in soil. Full limed soil accumulates higher amount of non exchangeable K than that of half limed system.

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