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K-Dynamics in a Continuously Submerged Limed and the Corresponding Unlimed Soil Subjected to One and Two Cycles of Drying Phase

Tapa Debnath, Sayan Majumder*, Dipankar Saha

Department of Agricultural Chemistry and Soil Science, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, India

Email address:

tapadebnath69@gmail.com (T. Debanth), 1991sayan@gmail.com (S. Majumder), d_saha11@yahoo.com (D. Saha)

*Corresponding author

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Abstract: A laboratory experiment was carried out to study the effect of drying phases on transformation of different fractions of K in submerged limed and the corresponding unlimed soil in presence and absence of N and K fertilizers. Changes in different fractions of K were monitored with time. Results showed that irrespective of treatments, available K increased in the limed soil throughout the period of incubation. However, non-exchangeable K showed an exactly opposite trend of results particularly in limed situation indicating a dynamic equilibrium between these forms of K in soils. Although, the trend of results of both available and non-exchangeable forms are totally different in unlimed situation. The decrease in 1N boiling HNO_3 extractable K is comparatively more in limed soil subjected to single drying phase. No drastic variation in lattice and total K is observed under different treatment combinations. It indicates, maintenance of drying phase has little effect on lattice and total K in soils.

Keywords: Different Forms of K, Drying Phases, Liming, Submerged Soil, N and K Fertilizers

1. Introduction

Potassium plays important role in plant nutrition [1]. It is involved in activation of dozens of enzymes which are responsible for different plant processes like energy transfer, starch synthesis, nitrate reduction and sugar degradation [2]. The issue of soil potassium fertilization was partially ignored during the last few decades while, nitrogen and phosphorus were considered more important [3]. Potassium has often been given less importance because of the myth that it is already present in soil in large amount [4]. Now, it is well established that heavy mining of nutrients due to multiple cropping systems are causing rapid depletion potassium in soil.

Soil Potassium can be classified into four forms i.e. solution K, exchangeable K, non-exchangeable K and structural K [5]. The solution form is readily available for plant uptake. Exchangeable form is held by the negative exchange sites of clay and organic matter. Soil solution and exchangeable potassium are collectively known as the available potassium pool. These bioavailable K pools constitute only a minor fraction of the total soil potassium reserve [6], which is generally quite large. Non-exchangeable K is present as fixed ion in the lattice structure (surrounded by oxygen atoms) of clay minerals [7]. It plays important role in plant K-supply [8]. Mineral or structural forms constitute the K-bearing minerals like mica, feldspar etc [9]. There is a continuous but slow conversion of potassium from the mineral and fixed forms to the available forms and vice-versa [7]. The K availability is a function of various soil K pools and the amount of K stored in each pool [2]. So, precise knowledge of all these forms are necessary to understand the K supplying capacity of a particular soil.

Some studies suggest significant influence of liming on non-exchangeable K in soil [10]. Application of nitrogenous and potassic fertilizers also affect K dynamics in soil [11].

The influence of N on K behaviours in soils has been largely reported because of their interaction on exchangeable or fixed sites of the clay minerals [12]. The increase in soluble K^+ in soil solution after submergence is mainly due to its displacement by ferrous (Fe^{2+}) and manganous (Mn^{2+}) ions. On the other hand, K adsorption increases with drainage of the soil [13]. So, K availability for plants is likely to decrease after drying. Wetting and drying of soils markedly influence the fixation of potassium [14].

The combined effect of wetting drying cycles and liming on soil potassium dynamics has not been studied in detail. In this background, a laboratory experiment was conducted in a continuously flooded limed and the corresponding unlimed soil subjected to one and two drying phases in presence and absence of N and K fertilizers.

2. Materials and Methods

2.1. Soil Collection

Surface soil (0-15 cm depth) used for the present investigation was collected from RRS farm, BCKV, Jhargram, West Bengal, India (22°27'47"N, 87°0'45"E, 81 m above mean sea level). The collected soil was air dried, ground and passed through 2 mm sieve. This soil is designated as unlimed soil in the experiment.

2.2. Soil Preparation

The limed soil was prepared by calculating lime requirement according to SMP buffer method [15]. Based on that, liming material ($CaCO_3$) was added (for 3.6 kg soil 7.67 gm) to the acidic soil uniformly and allowed to react with soil mass for 3 months with repeated wetting followed by air drying. The soil so prepared is termed as limed soil. Before use, the limed soils were air dried, ground and passed through 2 mm sieve.

2.3. Treatments

Treatments adopted in the present investigation may be written as follows:

T_1 = Continuous submergence was maintained in unlimed soil upto 45th day. Then a drying phase was given. The soil was again remoistened to waterlogged situation on 60th day and maintained upto 90th day of incubation.

$T_2 = T_1$ + K at 60 kg K_2O ha^{-1} in the form of MOP.

$T_3 = T_1$ + N at 120 kg ha^{-1} in the form of urea + K at 60 kg K_2O ha^{-1} in the form of MOP.

T_4 = Continuous submergence was maintained in limed soil upto 45th day. Then a drying phase was given. The soil was again remoistened to waterlogged situation on 60th day and maintained upto 90th day of incubation.

$T_5 = T_4$ + K at 60 kg K_2O ha^{-1} in the form of MOP.

$T_6 = T_4$ + N at 120 kg ha^{-1} in the form of urea + K at 60 kg K_2O ha^{-1} in the form of MOP.

T_7 = Continuous submergence was maintained in unlimed soil upto 30th day. Then the 1st drying phase was given. The soil was remoistened to waterlogged situation on 45th day and maintained upto 60th day. Then the 2nd drying phase was given. The soil was again remoistened to waterlogged situation on 75th day and maintained upto 90 days of incubation.

$T_8 = T_7$ + K at 60 kg K_2O ha^{-1} in the form of MOP.

$T_9 = T_7$ + N at 120 kg ha^{-1} in the form of urea + K at 60 kg K_2O ha^{-1} in the form of MOP.

T_{10} = Continuous submergence was maintained in limed soil upto 30th day. Then the 1st drying phase was given. The soil was remoistened to waterlogged situation on 45th day and maintained upto 60th day. Then the 2nd drying phase was given. The soil was again remoistened to waterlogged situation on 75th day and maintained upto 90 days of incubation.

$T_{11} = T_{10}$ + K at 60 kg K_2O ha^{-1} in the form of MOP.

$T_{12} = T_{10}$ + N at 120 kg ha^{-1} in the form of urea + K at 60 kg K_2O ha^{-1} in the form of MOP.

2.4. The Experiment

Both limed and unlimed soils were incubated at room temperature (30± 2° C) under submerged condition for a period of 90 days. Moisture loss due to evaporation was replenished by addition of distilled water on every alternate day. A completely randomized design (CRD) was employed in the experiment. All the treatments were replicated thrice. For every replication 80g of soil is taken in a 500 ml plastic container. Soil samples were collected on 0th, 30th, 45th, 60th, 75th and 90th day of incubation.

2.5. Parameters Analyzed

The physical, chemical and physico-chemical properties of both the limed and unlimed soil are determined (Table 1) considering them as initial soils for the experiment.

Soil samples collected on 0th, 30th, 45th, 60th, 75th and 90th day of incubation were analyzed for water soluble K, available K, exchangeable K (available K - water soluble K), 1N boiling HNO_3 extractable K, non-exchangeable K (1 N boiling HNO_3 extractable K - available K), lattice K (Total K - 1N boiling HNO_3 extractable K) and total K.

2.6. Statistical Analysis

All the variables were statistically tested with the help of SPSS software (SPSS 20, 2011) following methods meant for Completely Randomized Design (CRD). The mean values (from 3 replications) were subjected to Post-Hoc test like CD (Critical difference) test at 5% level of significance.

Table 1. *The physical, chemical and physico-chemical properties of the un-limed and limed soils used for the investigation.*

Soil Character	Unlimed	Limed	Methodology
Physical Character			
a) Mechanical analysis			
i. Sand (%)	43.52		Hydrometer method [16]
ii. Silt (%)	24.00		
iii. Clay (%)	32.48		
iv. Textural Class	Clay loam		Soil textural triangle (according to USDA)
b) Water Holding Capacity (%)	34.35	36.35	Keen-Raczkowski box [17]
Physico-chemical Character			
a) pH (soil: water = 1:2.5)	5.87	7.2	Glass Electrode pH meter [18]
b) EC (dS m^{-1})	0.002383	0.005473	Electrical Conductivity Meter [18]
Chemical Character			
a) CEC (cmol (p+) Kg^{-1})	11.5	13.0	Ammonium acetate method [19]
b) Organic Carbon (%)	0.53	0.73	Chromic acid wet oxidation method [20]
c) Available N (%)	0.00182	0.00098	Bremner and Keeney's Method [21]
d) Total N (%)	0.0896	0.0630	Bremner's Method [22]
e) Available P (mg kg^{-1})	0.136	0.168	Unlimed Soil – Bray and Kurtz's Method [23] Limed Soil – with Olsen's sodium bicarbonate method [24]
f) Water soluble K (mg kg^{-1})	33.77	48.50	
g) Exchangeable K (mg kg^{-1})	103.84	117.50	
h) Available K (mg kg^{-1})	137.61	166.00	
i) Non-exchangeable K (mg kg^{-1})	234.89	174.00	Jackson [19]
j) 1 N HNO_3 extractable K (mg kg^{-1})	372.50	340.00	
k) Lattice K (mg kg^{-1})	6827.50	6860.00	
l) Total K (mg kg^{-1})	7200.00	7200.00	

3. Results and Discussion

3.1. Changes in Water Soluble K

Results revealed that, in general, water-soluble K decreased with increase in the period of investigation (Table 2). Irrespective of drying phases and fertilizer treatments, comparatively higher amount of water soluble K is accumulated in limed over unlimed systems. The decrease is more prominent in limed soil over 90-day period of incubation. Higher order of decrease in water soluble K is recorded in flooded soils subjected to two cycles of drying than that of single drying. Application of liming material and maintenance of two drying phases under waterlogged condition creates favourable environment for releasing water soluble K which could be utilized by growing crops. The present trend of results finds support of previous works carried out by Das and Saha (2013) [11].

3.2. Changes in Exchangeable K

Irrespective of treatments, exchangeable K decreased in unlimed but increased in limed soil over 90 day period of incubation (Table 3). Liming increased pH dependent charges which led to accumulate comparatively higher amount of K in exchangeable form in limed over that of the unlimed systems.

Table 2. *Effect of one or two drying phases on changes in the amount (mg kg^{-1}) of water soluble K in a limed and the corresponding unlimed soil treated with or without N and K fertilizers.*

Treatments	Fertilizer dose	Liming	Incubation Period (days)						
			0	30	45	60	75	90	Mean
Continuous Submergence	N_0K_0	Unlimed	36.99	34.44	33.97	31.50	24.74	23.06	30.78
		Limed	57.00	31.20	30.23	28.81	25.71	19.75	32.12
Drying phase at 45th day		Unlimed	38.19	37.40	34.50	31.25	27.96	20.26	31.59
		Limed	75.76	33.05	31.20	27.86	25.75	21.50	35.85
Continuous Submergence	N_0K_{60}	Unlimed	48.38	48.19	45.00	43.82	43.38	24.65	42.24
		Limed	61.24	43.20	43.01	40.48	37.89	25.75	41.93
Drying phase at 45th day		Unlimed	56.00	55.48	55.00	51.22	41.59	29.02	48.05
		Limed	55.58	46.75	44.80	43.71	39.75	33.25	43.97
Continuous Submergence	$N_{120}K_{60}$	Unlimed	52.93	50.02	48.24	47.50	40.87	28.62	44.70
		Limed	50.18	43.53	43.20	39.67	37.73	30.00	40.72
Drying phase at 45th day		Unlimed	50.75	46.00	45.53	44.22	31.19	27.43	40.85
		Limed	60.54	48.00	41.20	38.69	31.50	29.75	41.61
Mean				53.63	43.11	41.32	39.06	34.01	

Statistical Analysis					
Treatments		**Incubation**		**Treatments x Incubation**	
S.Em (±)	**CD (P=0.05)**	**S.Em (±)**	**CD (P=0.05)**	**S.Em(±)**	**CD (P=0.05)**
0.77	2.16	0.54	1.53	1.89	5.29

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash].

***Table 3.** Effect of one or two drying phases on changes in the amount (mg kg^{-1}) of exchangeable K in a limed and the corresponding unlimed soil treated with or without N and K fertilizers.*

Treatments	**Fertilizer dose**	**Liming**	**Incubation Period (days)**						
			0	**30**	**45**	**60**	**75**	**90**	**Mean**
Drying phase at 45th day	N_0K_0	Unlimed	122.75	182.55	97.50	125.00	107.20	85.00	120.00
		Limed	75.00	100.00	67.28	135.94	181.30	267.98	137.92
Drying phase at 30th day and 60th day		Unlimed	114.77	193.29	199.90	146.15	172.81	85.02	151.99
		Limed	77.50	85.65	88.40	107.50	109.61	231.54	116.70
Drying phase at 45th day	N_0K_{60}	Unlimed	170.00	198.13	108.19	211.18	112.50	105.00	150.83
		Limed	92.50	117.50	79.97	174.77	242.62	282.14	164.92
Drying phase at 30th day and 60th day		Unlimed	150.59	212.50	216.28	135.00	144.63	110.00	161.50
		Limed	90.00	108.05	115.80	152.50	156.46	268.50	148.55
Drying phase at 45th day	$N_{120}K_{60}$	Unlimed	145.44	213.22	117.19	150.00	114.15	90.00	138.33
		Limed	119.45	112.17	97.03	160.33	249.44	273.53	168.66
Drying phase at 30th day and 60th day		Unlimed	125.44	218.22	220.30	141.31	164.34	95.00	160.77
		Limed	90.00	105.70	109.60	151.81	156.50	246.44	143.34
Mean			114.45	153.92	126.45	149.29	159.30	178.35	

Statistical Analysis					
Treatments		**Incubation**		**Treatments x Incubation**	
S.Em(±)	**CD(P=0.05)**	**S.Em(±)**	**CD(P=0.05)**	**S.Em(±)**	**CD(P=0.05)**
2.23	6.23	1.57	4.41	5.45	15.26

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash].

Exchangeable K is found to decrease in unlimed waterlogged soil subjected to two drying phases due to its conversion to non-exchangeable form [25]. However, exchangeable K increased in limed waterlogged soils especially with single drying phase. It is clear from the results that maintenance of two drying phases in limed waterlogged soils released more exchangeable and water soluble K [26]. Moreover, the decrease in exchangeable K is greater in submerged unlimed soils subjected to single drying phase. Addition of K further accentuates the phenomenon. Thus, the results indicated that comparatively higher amount of exchangeable K is retained in continuously submerged limed soil subjected to single rather than two drying phases.

3.3. Changes in Available K

Available K is the summation of water soluble K and exchangeable K. The major portion of available K is exchangeable K. So, more or less similar pattern of changes in available K is observed as was found for exchangeable K (Table 4). The effect of liming, drying phases and treatments are very much alike for both these forms [26]. The explanation furnished earlier for the changes in water soluble K and exchangeable K is equally applicable for available K as well.

***Table 4.** Effect of one or two drying phases on changes in the amount (mg kg^{-1}) of available K in a limed and the corresponding unlimed soil treated with or without N and K fertilizers.*

Treatments	**Fertilizer dose**	**Liming**	**Incubation Period (days)**						
			0	**30**	**45**	**60**	**75**	**90**	**Mean**
Drying phase at 45th day	N_0K_0	Unlimed	159.74	216.99	131.47	156.50	131.94	108.06	150.78
		Limed	132.00	131.20	97.51	164.75	208.81	287.73	170.33
Drying phase at 30th day and 60th day		Unlimed	152.96	230.69	234.40	177.40	200.77	105.28	183.58
		Limed	153.26	118.70	119.60	135.36	135.36	253.04	152.55
Drying phase at 45th day	N_0K_{60}	Unlimed	218.38	246.32	153.19	255.00	155.88	129.65	193.07
		Limed	153.74	160.70	122.98	215.25	280.51	307.89	206.85
Drying phase at 30th day and 60th day		Unlimed	206.59	267.98	271.28	186.22	186.22	139.02	209.55
		Limed	145.58	154.80	160.60	196.21	196.21	301.75	192.53
Drying phase at 45th day	$N_{120}K_{60}$	Unlimed	198.37	263.24	156.43	197.50	155.02	118.62	181.53
		Limed	169.63	155.70	140.23	200.00	287.17	303.53	209.38
Drying phase at 30th day and 60th day		Unlimed	176.19	264.22	265.83	185.53	195.53	122.43	201.62
		Limed	150.54	153.70	150.80	190.50	188.00	276.19	184.96
Mean			168.08	197.02	167.03	188.35	193.45	204.43	

Statistical Analysis					
Treatments		**Incubation**		**Treatments x Incubation**	
S.Em(±)	**CD(P=0.05)**	**S.Em(±)**	**CD(P=0.05)**	**S.Em(±)**	**CD(P=0.05)**
2.24	6.26	1.58	4.43	5.48	15.33

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash]

3.4. Changes in Non-Exchangeable K

Irrespective of drying phases and fertilizer treatments, non-exchangeable K decreased in limed but increased in unlimed systems over 90 day period of incubation. An increase in exchangeable K and the concomitant decrease in non-exchangeable K clearly indicated the existence of a dynamic equilibrium between these two pools. The present results find support of the earlier investigations carried out by Sarkar et al, 2013 [25]. The decrease in non-exchangeable K over 90 day period is more marked in limed waterlogged soils subjected to single drying phase than that of two drying phases. This phenomenon points out that maintenance of a single drying phase in limed waterlogged soil transformed higher amount of non-exchangeable K to the available pool. However, a non-significant increase in non-exchangeable K is observed in unlimed submerged soils subjected to two drying phases over 90 day period of investigation. The results thus pointed out that maintenance of two drying phases in waterlogged soils converted comparatively lower amount of exchangeable K to non-exchangeable form.

Table 5. *Effect of one or two drying phases on changes in the amount (mg kg^{-1}) of non-exchangeable K in a limed and the corresponding unlimed soil treated with or without N and K fertilizers.*

Treatments	**Fertilizer dose**	**Liming**	**Incubation Period (days)**						
			0	**30**	**45**	**60**	**75**	**90**	**Mean**
Drying phase at 45th day	N_0K_0	Unlimed	107.76	48.01	123.53	83.50	123.06	141.94	104.63
		Limed	273.00	258.80	262.49	110.25	21.19	29.77	159.25
Drying phase at 30th day and 60th day		Unlimed	97.04	19.31	20.60	52.60	79.23	99.72	61.42
		Limed	216.74	231.30	180.40	122.14	124.64	74.46	158.28
Drying phase at 45th day	N_0K_{60}	Unlimed	106.62	78.68	136.81	45.00	174.12	145.35	114.43
		Limed	371.26	359.30	292.02	104.75	39.49	42.11	201.49
Drying phase at 30th day and 60th day		Unlimed	103.41	42.02	53.72	63.78	103.78	115.98	80.45
		Limed	389.42	375.20	179.40	78.79	113.79	60.75	199.56
Drying phase at 45th day	$N_{120}K_{60}$	Unlimed	144.13	71.76	129.57	50.00	159.98	146.38	116.97
		Limed	320.37	184.30	159.77	90.00	52.83	21.47	138.12
Drying phase at 30th day and 60th day		Unlimed	138.81	60.78	44.17	81.97	74.47	142.57	90.46
		Limed	379.46	376.30	264.20	173.50	62.00	91.31	224.46
Mean			220.67	175.48	153.89	88.02	94.05	92.65	

Statistical Analysis					
Treatments		**Incubation**		**Treatments x Incubation**	
S.Em(±)	**CD(P=0.05)**	**S.Em(±)**	**CD(P=0.05)**	**S.Em(±)**	**CD(P=0.05)**
3.96	9.68	2.44	6.84	8.47	27.70

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash].

3.5. Changes in 1 N Boiling HNO_3 Extractable K

Regardless of drying phases and liming, 1 N boiling HNO_3 extractable K decreased over 90 day period of incubation (Table 6). Comparatively higher amount of 1 N boiling HNO_3 extractable K is accumulated in limed over unlimed soil. Moreover, the decrease is comparatively more in limed waterlogged soil subjected to single drying phase. It is noteworthy to mention that 1 N boiling HNO_3 extractable K and non-exchangeable K decreased whereas, available K increased over 90 day period of incubation. It certainly indicates that all fractions of K are interconvertible within themselves [27].

Table 6. *Effect of one or two drying phases on changes in the amount (mg kg^{-1}) of 1 N boiling HNO_3 extractable K in a limed and the corresponding unlimed soil treated with or without N and K fertilizers.*

Treatments	Fertilizer dose	Liming	Incubation Period (days)						
			0	30	45	60	75	90	Mean
Drying phase at 45th day	N_0K_0	Unlimed	267.50	265.00	255.00	240.00	255.00	250.00	255.42
		Limed	405.00	390.00	360.00	275.00	230.00	317.50	329.58
Drying phase at 30th day and 60th day		Unlimed	250.00	250.00	255.00	230.00	280.00	205.00	245.00
		Limed	370.00	350.00	300.00	257.50	260.00	327.50	310.83
Drying phase at 45th day	N_0K_{60}	Unlimed	335.00	325.00	290.00	300.00	330.00	275.00	309.17
		Limed	525.00	520.00	415.00	320.00	320.00	350.00	408.33
Drying phase at 30th day and 60th day		Unlimed	310.00	310.00	325.00	250.00	290.00	255.00	290.00
		Limed	535.00	530.00	340.00	275.00	310.00	362.50	392.08
Drying phase at 45th day	$N_{120}K_{60}$	Unlimed	342.50	335.00	295.00	247.50	315.00	265.00	300.00
		Limed	490.00	340.00	300.00	290.00	340.00	325.00	347.50
Drying phase at 30th day and 60th day		Unlimed	315.00	325.00	310.00	267.50	270.00	265.00	292.08
		Limed	530.00	530.00	415.00	370.00	250.00	367.50	410.42
Mean			389.58	372.50	321.67	276.87	287.50	297.08	

Statistical Analysis					
Treatments		Incubation		Treatments x Incubation	
S.Em(±)	CD(P=0.05)	S.Em(±)	CD(P=0.05)	S.Em(±)	CD(P=0.05)
2.53	7.07	1.79	5.00	6.19	17.33

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash].

3.6. Changes in Lattice K

Irrespective of drying phases, fertilizer treatments and liming, in general, lattice K decreased over 90 day period of incubation (Table 7). Comparatively larger amount of lattice K is accumulated in limed over unlimed systems. Liming shifted the K equilibrium and thus lattice K is also altered according to different treatment combinations [12]. No drastic variation in lattice K is observed under both unlimed and limed submerged soils subjected to one or two drying phases. However, the flooded limed soil with single drying phase released significantly more K within short period of time. Fertilizer treatment had little effect on lattice K in submerged soil. Statistical analysis of the results showed that not only treatments but also stages of sampling significantly influenced the amount of lattice K over 90-day period of incubation.

Table 7. *Effect of one or two drying phases on changes in the amount (mg kg^{-1}) of lattice K in a limed and the corresponding unlimed soil treated with or without N and K fertilizers.*

Treatments	Fertilizer dose	Liming	Incubation Period (days)						
			0	30	45	60	75	90	Mean
Drying phase at 45th day	N_0K_0	Unlimed	7032.5	7335.0	7345.0	7320.0	7425.0	7350.0	7301.3
		Limed	7445.0	7370.0	7290.0	7385.0	7440.0	7182.5	7352.1
Drying phase at 30th day and 60th day		Unlimed	7750.0	7855.0	7845.0	7820.0	7720.0	7795.0	7797.5
		Limed	8030.0	7855.0	7905.0	7957.5	7935.0	7862.5	7924.2
Drying phase at 45th day	N_0K_{60}	Unlimed	7265.0	6875.0	6810.0	6700.0	6780.0	6745.0	6862.5
		Limed	7575.0	7530.0	7795.0	7795.0	7790.0	7310.0	7632.5
Drying phase at 30th day and 60th day		Unlimed	7790.0	7905.0	7890.0	7945.0	7890.0	7895.0	7885.8
		Limed	7880.0	7670.0	7870.0	7920.0	7880.0	7817.5	7839.6
Drying phase at 45th day	$N_{120}K_{60}$	Unlimed	7407.5	7365.0	7355.0	7302.5	7185.0	6835.0	7241.7
		Limed	7615.0	7775.0	7805.0	7810.0	7660.0	7575.0	7706.7
Drying phase at 30th day and 60th day		Unlimed	7790.0	7840.0	7840.0	7882.5	7830.0	7785.0	7827.9
		Limed	7890.0	7690.0	7780.0	7820.0	8930.0	7802.5	7985.4
Mean			7622.5	7588.8	7627.5	7638.1	7705.4	7496.3	

Statistical Analysis					
Treatments		Incubation		Treatments x Incubation	
S.Em(±)	CD(P=0.05)	S.Em(±)	CD(P=0.05)	S.Em(±)	CD(P=0.05)
5.05	14.14	3.57	10.00	12.38	34.64

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash].

3.7. Changes in Total K

Irrespective of treatments, total K significantly decreased over 90 day period of incubation (Table 8). Results further showed that comparatively higher amount of total K is accumulated in limed over unlimed systems. This increase is due to the accumulation of available K under congenial microenvironment [10, 28], which is added to the total K-pool of soil. Statistical analysis of the results showed that treatments has a significant effect on accumulation of total K in soil. Furthermore, irrespective of liming, significantly higher amount of total K is accumulated in flooded soils subjected to two drying phases and treated with only K fertilizer. Statistical analysis of the results also showed that treatments have significant effect on total K build up in submerged soils.

Table 8. *Effect of one or two drying phase on changes in the amount (mg kg^{-1}) of total K in a limed and the corresponding unlimed soil treated with and without N and K fertilizers.*

Treatments	Fertilizer dose	Liming	Incubation Period (days)						
			0	30	45	60	75	90	Mean
Drying phase at 45th day	N_0K_0	Unlimed	7300.0	7600.0	7600.0	7560.0	7680.0	7600.0	7556.7
		Limed	7850.0	7760.0	7550.0	7660.0	7670.0	7500.0	7665.0
Drying phase at 30th day and 60th day		Unlimed	8000.0	8105.0	8100.0	8050.0	8000.0	8000.0	8042.5
		Limed	8400.0	8205.0	8205.0	8215.0	8195.0	8190.0	8235.0
Drying phase at 45th day	N_0K_{60}	Unlimed	7600.0	7200.0	7100.0	7000.0	7110.0	7020.0	7171.7
		Limed	8100.0	8050.0	8210.0	8115.0	8110.0	7660.0	8040.8
Drying phase at 30th day and 60th day		Unlimed	8100.0	8215.0	8215.0	8195.0	8180.0	8150.0	8175.8
		Limed	8415.0	8200.0	8210.0	8195.0	8190.0	8180.0	8231.7
Drying phase at 45th day	$N_{120}K_{60}$	Unlimed	7750.0	7700.0	7650.0	7550.0	7500.0	7100.0	7541.7
		Limed	8105.0	8115.0	8105.0	8100.0	8000.0	7900.0	8054.2
Drying phase at 30th day and 60th day		Unlimed	8105.0	8165.0	8150.0	8150.0	8100.0	8050.0	8120.0
		Limed	8420.0	8220.0	8195.0	8190.0	9180.0	8170.0	8395.8
Mean			8012.1	7961.3	7940.8	7915	7992.9	7793.3	

Statistical Analysis					
Treatments		Incubation		Treatments x Incubation	
S.Em(±)	CD(P=0.05)	S.Em(±)	CD(P=0.05)	S.Em(±)	CD(P=0.05)
4.42	12.37	3.13	8.75	10.83	30.00

[N_0K_0=Control, N_0K_{60}= K_2O at 60 kg ha^{-1} as Muriate of Potash, $N_{120}K_{60}$= N at 120 kg ha^{-1} as Urea and K_2O at 60 kg ha^{-1} as Muriate of Potash].

4. Conclusion

The increase in available and decrease in non-exchangeable K along with 1 N boiling HNO_3 extractable K over 90-day period of incubation pointed out that there exists an equilibrium between different fractions of K in soil. Maintenance of a single drying phase is more congenial in releasing non-exchangeable K than that of double drying phases under submerged limed situation. Relatively greater amount of total K is accumulated in flooded soil subjected to two drying phases especially in presence of K fertilizer.

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