Research Article

Effect of Continuous Cropping and Fertilization on Distribution of Potassium Fractions under Rice-Wheat Cropping System in Calciorthents

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Abstract

A long term field experiment was conducted during rabi 1988-89 at Rajendra Agricultural University, Pusa, Samastipur in split plot design with three replications. The treatment comprised of four levels of inorganic fertilizers in main plot and four levels of organic manure in sub-plot. Rice and Wheat as 28th and 29th were grown for present study Soil Samples were collected from six different depths for distribution analysis of potassium. The available and waters soluble potassium content was higher in surface layer (0-15 cm) and decreased and downward up to 90 cm depth whereas exchangeable and non-exchangeable potassium decreased downward only up to 60 cm depth and afterward it increased up to 90 cm.

Keywords: Potassium fractions, potassium distribution, Calciorthents, organics, Inorganics fertilizer, Rice-wheat cropping system

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Introduction

Potassium is the major nutrient and also a most abundant element in soil. It is important for activation of several enzymes in plants, involvement in photosynthesis, protein synthesis, stomata regulation and water retention, translocation of assimilates and improvement of crop quality. The removals of K from soil in intensive cereal based cropping system are equal or more than N. It is a great threat to Indian Agriculture that large K mining is happening and K reserve are depleting. Ultimately it will effect crop productivity, soil health and environment quality. The K content of the soil varies from place to place based on physico-chemical properties of soil. Potassium exist in soil in different forms viz., water soluble, exchangeable, non exchangeable, mineral-K, lattic-K and total-K. The dynamics of potassium in soil depends on the magnitude of equilibrium among various forms. The bulk of soil potassium usually exists in unavailable form. The available and exchangeable K is generally readily available for plants.

Materials and Methods

A long term field experiment was started during *rabi* 1988-89 in calcareous soil with rice-wheat cropping sequence. The details of the materials used and method adopted for carrying out the present study are described as below. The experimental site is located at 25^o 59' North latitude and 85^{o}48' East longitude with an altitude of 52.92 meters above mean sea level. The climate of the experimental area is sub-tropical with a mean annual precipitation of 1270 mm and mean annual temperature of 25.3^{o}C. The crop reported in this report was 28th crop of rice (cv. Rajshree) in *kharif* season and 29th crop of wheat (cv. Rajeshwari) in *rabi* season 2003with continuous application of compost @ 10 tha^{-1} and/or crop residue of the respective plot alone or in combination with different levels of NPK. The experiment was conducted in a split plot design with four levels of NPK namely; No NPK, 50% NPK, 100% NPK& 150% NPK in the main treatment and organic sources such as no manure, compost, crop residue and compost + crop residue in sub-plot treatment. The treatments were replicated thrice. The recommended N, P_2O_5 and K_2O doses were 120, 60 and 40 kg ha^{-1}. Soil samples were collected from six different depths such as 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm depth. The physico-chemical properties of surface soil (0-15 cm) analysed at the start of the experiment is presented in **Table 1**.

Available potassium was extracted with neutral 1N-NH_4OAC and determined with the help of flame photometer [1]. Water soluble K was determined by adopting appropriate methods [2] whereas exchangeable K was determined by the suitable method [3]. Non exchangeable K was calculated by the difference between NH_4OAC extractable and water soluble K.

Table 1 Physico-chemical properties of soil of experimental plot

Sl. No.	Particulars	Value obtained
1.	Sand (%)	46.85
2.	Silt (%)	41.35
3.	Clay (%)	11.8
4.	Texture	Sandy loam
5.	pH (1:2 Soil: water)	8.5
6.	Electrical conductivity (dSm^{-1}) at 25^{o}C	0.80
7.	Organic carbon (%)	0.35
8.	Available N (kg ha^{-1})	219.0
9.	Available P_2O_5 (kg ha^{-1})	17.5
10.	Available K_2O (kg ha^{-1})	114.2
11.	Free $CaCO_3$(%)	21.6

Results and Discussion

Available Potassium

The data on depth wise distribution of available potassium as influenced by long term application of compost, crop residue and fertilizers under rice-wheat cropping system are depicted in **Table 2**. The available K content in surface soil (0-15 cm) varied from 77.9 to 111.8 kg ha-1 while that in 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 cm depth ranged from 75.1 to 97.6 kg ha-1, 66.7 to 91.7, 64.4 to 89.8, 58.5 to 86.5 and 56.7 to 81.0 kg ha-1, respectively decreased downwards upto 90 cm in all the treatment. The decrease was more pronounced where addition of organic sources was highest as compared to control in all the depths.

Table 2 Effect of organic and inorganic fertilizers on depth wise distribution available K (kg ha^{-1}) after harvest of wheat (29th crop) under rice-wheat cropping system

Fertilizers levels	Organic Sources				
	No compost and No residue	Compost	Crop residue	Compost + Crop residue	Mean
0-15 cm					
No NPK	77.9	85.01	84.1	93.2	85.0
50% NPK	84.9	94.3	91.9	90.5	95.6
100% NPK	88.1	99.4	95.9	103.4	96.7
150% NPK	94.70	105.4	103.7	111.8	103.9
Mean	86.4	96.0	93.9	104.9	-
15-30 cm					
No NPK	75.1	76.1	15.1	79.0	76.5
50% NPK	77.4	82.6	84.2	87.7	82.9
100% NPK	84.9	89.3	87.3	89.9	87.6
150% NPK	86.8	94.2	91.8	97.6	92.5
Mean	81.8	85.5	84.5	88.5	-
30-45 cm					
No NPK	66.7	70.3	69.2	72.7	69.7
50% NPK	75.0	76.0	75.5	79.3	76.4
100% NPK	79.9	82.5	80.0	89.2	82.9
150% NPK	82.8	89.5	86.96	91.7	87.7
Mean	76.1	72.5	77.9	83.2	-
45-60 cm					
No NPK	64.4	68.6	68.7	71.2	68.2
50% NPK	76.6	75.0	74.0	84.8	77.6
100% NPK	76.7	79.1	77.8	88.3	80.4
150% NPK	83.0	85.3	85.4	89.8	85.8
Mean	74.9	77.0	76.4	83.5	-
60-75 cm					
No NPK	58.5	65.2	62.4	67.5	63.4
50% NPK	71.7	74.1	74.2	83.1	75.7

100% NPK	76.0	75.1	77.5	85.0	76.4
150% NPK	79.0	80.9	81.6	86.5	82.0
Mean	71.5	75.8	73.9	80.5	-
75-90 cm					
No NPK	56.7	59.2	60.8	64.4	60.2
50% NPK	66.7	71.4	69.2	75.8	70.7
100% NPK	70.8	73.2	71.2	80.0	73.8
150% NPK	75.1	76.6	75.8	81.0	77.1
Mean	67.3	70.1	69.2	75.3	-

Higher value of available K may be due to higher organic matter content which retained available K+ on exchange sites. Similar results on available K distribution in their long term experiment at Ludhiana [4]. The present findings are in accordance with these results [5] and [6]. The data also explained that lowest value of available K content of soil were found in control and maximum recorded in treatment receiving both compost and crop residue in all the fertilizer levels in all the depth. Application of compost, crop residue and compost + crop residue resulted in only small increase in available K content in calcareous soil. It was likely that large fraction of K from organic material was either lost through leaching from the soil or was taken up by wheat. The order of effectiveness was: Compost + Crop residue > Compost > Crop residue > No compost + No residue. Increase in available K by addition of crop residue was also observed [7].

Water soluble potassium

The distribution of water soluble potassium in different soil depth as influenced by graded levels of NPK and different organic sources under rice-wheat cropping system in calcareous soil is presented in **Table 3**. The water soluble-K in surface soil (0-15cm) varied from 10.2 to 26.9 kg ha^{-1} while that in 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 cm depth ranged from 9.2 to 23.8, 7.1 to 21.2, 6.5 to 18.9, 5.2 to 16.5 and 4.5 to 15.3 kg ha^{-1}, respectively. The data revealed that higher amount of water soluble-K was higher in surface layer and it progressively decreased downwards upto 90 cm in all the treatments. Higher amount of water soluble-K in surface was attributed to the accumulation of K applied through organic materials as well as fertilizers. Data also revealed that lower value of water soluble-K content of soil were found in control whereas highest was found in treatment receiving both compost and crop residue at all the fertilizer levels in all the depth. This increased in K content might be due to mineralization and decomposition of organic material, which contains substantial quantities of K and finally increased K availability in soil on their incorporation. The results supported to the findings [4] and [8].

Table 3 Effect of organic and inorganic fertilizers on depthwise distribution of water soluble K (kg ha^{-1}) after harvest of wheat (29^{th} crop) under rice-wheat cropping system

Fertilizers levels	**Organic Sources**				
	No compost and No residue	**Compost**	**Crop residue**	**Compost + Crop residue**	**Mean**
0-15 cm					
No NPK	10.2	12.4	12.2	17.6	13.1
50% NPK	13.8	14.6	14.3	19.5	15.55
100% NPK	16.2	19.5	19.0	23.8	19.6
150% NPK	18.8	24.6	24.1	26.9	23.6
Mean	14.8	17.8	17.4	21.9	-
15-30 cm					
No NPK	9.2	11.4	11.5	14.6	11.6
50% NPK	12.5	12.8	12.4	16.9	13.65
100% NPK	14.3	17.6	17.1	20.6	17.4
150% NPK	16.8	21.6	21.8	23.8	21.0
Mean	13.2	15.8	15.7	18.9	-
30-45 cm					
No NPK	7.1	9.4	9.0	12.1	9.4
50% NPK	10.5	11.5	11.1	13.6	11.6
100% NPK	11.4	15.1	14.8	18.8	15.0
150% NPK	14.8	18.6	18.5	21.2	18.2

Mean	10.9	13.6	13.3	16.4	-
45-60 cm					
No NPK	6.5	8.4	8.1	9.8	8.2
50% NPK	9.4	10.6	10.5	12.0	10.6
100% NPK	10.5	13.9	13.8	15.6	13.4
150% NPK	13.4	16.6	16.6	18.9	16.3
Mean	9.9	12.3	12.2	14.0	-
60-75 cm					
No NPK	5.2	7.0	7.1	8.6	6.9
50% NPK	7.2	8.8	8.5	11.3	8.95
100% NPK	9.2	11.4	11.6	13.6	11.4
150% NPK	11.4	13.9	14.0	16.5	13.9
Mean	8.2	10.2	10.3	12.5	-
75-90 cm					
No NPK	4.5	6.1	6.1	8.0	6.1
50% NPK	6.4	7.6	7.4	10.2	7.9
100% NPK	7.4	10.0	9.8	11.5	9.6
150% NPK	10.8	11.9	12.0	15.3	12.5
Mean	7.2	8.9	8.8	11.25	-

Exchangeable Potassium

The results of exchangeable-K in different depth from long term experiments after wheat harvest are depicted in **Table 4**. The exchangeable-K content in surface soil (0-15 cm) varied from 67.7 to 84.5 kg ha^{-1} while that in 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 cm depth ranged from 66.3 to 73.8, 58.6 to 70.5, 57.9 to 70.9, 65.3 to 70.00 and 63.9 to 82.5 kg ha^{-1}, respectively. The data itself explained that exchangeable-K was higher in surface layer and it progressively decreased downwards upto 60 cm depth and afterwards it increased upto 90 cm. Higher amount of exchangeable-K in surface layer might be due to relatively more organic carbon content in the surface layer which increased the exchange surface areas. The distribution pattern observed in the present study is in accordance with those reported [9] and [10].

Table 4 Effect of organic and inorganic fertilizers on depth wise distribution of exchangeable K (kg ha^{-1}) after harvest of wheat (29th crop) under rice-wheat cropping system

Fertilizers levels	**Organic Sources**				
	No compost and No residue	**Compost**	**Crop residue**	**Compost + Crop residue**	**Mean**
0-15 cm					
No NPK	67.7	72.6	71.9	75.6	71.5
50% NPK	71.1	75.7	81.6	80.4	77.2
100% NPK	71.5	75.9	76.9	75.6	75.0
150% NPK	75.9	86.8	75.6	84.5	80.8
Mean	71.6	77.7	76.5	79.1	-
15-30 cm					
No NPK	66.3	64.7	63.6	64.4	64.7
50% NPK	66.0	65.8	71.8	76.8	70.1
100% NPK	71.3	71.7	76.2	65.8	71.2
150% NPK	76.4	72.6	65.8	73.8	72.1
Mean	70.0	68.7	69.3	70.2	-
30-45 cm					
No NPK	58.6	60.9	57.1	60.6	55.3
50% NPK	64.5	64.5	61.9	65.7	64.1
100% NPK	66.5	67.4	67.2	70.4	67.9
150% NPK	68.0	70.9	65.7	70.5	76.2
Mean	64.4	65.5	62.9	66.8	-
45-60 cm					
No NPK	57.9	66.2	60.6	61.4	61.5

50% NPK	67.2	64.4	63.5	72.8	66.9
100% NPK	66.2	65.2	62.2	72.7	66.5
150% NPK	66.6	66.7	66.8	70.9	67.7
Mean	64.4	65.5	63.2	69.4	-
60-75 cm					
No NPK	65.3	71.6	66.2	72.8	67.4
50% NPK	64.5	65.3	62.9	71.8	66.1
100% NPK	66.8	63.7	65.9	71.4	66.5
150% NPK	67.6	67.0	67.6	70.0	68.0
Mean	66.05	66.90	65.65	71.5	67.0
75-90 cm					
No NPK	63.9	65.3	67.2	68.6	66.2
50% NPK	74.0	76.5	76.0	81.2	76.9
100% NPK	74.6	76.4	76.0	84.9	77.9
150% NPK	75.8	80.5	75.4	82.5	78.5
Mean	72.07	74.67	73.65	79.30	-

The addition of inorganic K fertilizer increased the exchangeable-K fraction in all the depth in similar fashion in decreasing trend upto 60 cm soil depth. The highest amount was observed at highest dose of fertilizer as well as highest amount of organic incorporation. Higher value of exchangeable-K at surface might be due to addition of fertilizers, compost and crop residues in each crop [11]. By addition 50, 100 and 150 percent optimal dose of NPK, this form of K increased by 7.9, 4.8 and 13.0 over control, respectively whereas, 8.5, 6.8 and 10.4 percent over control in case of compost, crop residue and compost + crop residue, respectively in surface layer.

Non-exchangeable Potassium

Distribution pattern of non-exchangeable-K in different soil depth is obtained from long experiment after harvest of wheat is recorded in **Table 5**. The amount of non-exchangeable-K varied from 1127.0 to 1756.0, 1025.0 to 1622.0, 953.0 to 1546.0, 896.0 to 1490.2, 842.0 to 1267.0 and 763.3 to 1359.0 kg ha^{-1}, respectively in 0 to 15, 15 to 30, 30 to 45, 45 to 60, 60 to 75 and 75 to 90 cm. A critical examination of data revealed that non-exchangeable-K content is a measure of reserve of K in soil. The amount of this form of K was also decreasing with increasing depth in similar fashion like exchangeable-K. Higher value of non-exchangeable-K at surface might be due to addition of fertilizers compost and crop residues in each crop [12]. By addition 50, 100 and 150 percent of optimal dose of NPK, this form of K increased by 18.30, 25.6 and 38.9 percent over control, respectively whereas 5.6, 4.4 and 11.5 percent over control in case of compost, crop residue and compost + crop residue, respectively in surface layer. The non-exchangeable-K was always lower in control and higher in 150 percent NPK fertilizer level in all the depth. This increase might be due to more addition of K by organic and inorganic fertilizer application in rice-wheat cropping system. This increase in non-exchangeable-K as well as other forms of K with addition of K indicates that some amount of K from K bearing minerals was released due to the dissolution of K bearing minerals by organic acid and other complexing agents produced during decomposition of roots and crop residue and compost [13]. Value of non-exchangeable-K at higher depth (15-90 cm) and decreasing with increasing depth indicated that the K movement in profile was restricted due to lower permeability of the soil in lower horizon. This might have slowed down the movement of aqueous phases providing ample time for the diffusion into the clay lattice in upper layers and finally increased in upper layers [6] and [14].

Table 5 Effect of organic and inorganic fertilizers on depth wise distribution of non-exchangeable K (kg ha^{-1}) after harvest of wheat (29th crop) under rice-wheat cropping system

Fertilizers levels	**Organic Sources**				
	No compost and No residue	**Compost**	**Crop residue**	**Compost + Crop residue**	**Mean**
0-15 cm					
No NPK	1127	1194	1185	1222	1183
50% NPK	1325	1395	1376	1503	1400
100% NPK	1432	1481	1465	1565	1486
150% NPK	1535	1655	1631	1756	1644
Mean	1354	1430	1414	1511	-

15-30 cm					
No NPK	1025	1074	1065	1169	1083
50% NPK	1203	1237	1216	1312	1242
100% NPK	1295	1341	1328	1465	1356
150% NPK	1423	1496	1486	1622	1507
Mean	1236	1287	1274	1392	-
30-45 cm					
No NPK	953	996	991	1092	1008
50% NPK	1125	1164	1144	1241	1169
100% NPK	1220	1268	1250	1386	1281
150% NPK	1047	1421	1413	1546	1357
Mean	1086	1212	1200	1316	-
45-60 cm					
No NPK	896	941	931	1034	950
50% NPK	1063	1105	1066	1175	1102
100% NPK	1164	1211	1102	1327	1223
150% NPK	1267	1365	1355	1490	1369
Mean	1097	1156	1113.5	1256	-
60-75 cm					
No NPK	842	885	878	975	896
50% NPK	1006	1046	1027	1117	1044
100% NPK	1104	1155	1133	1270	1165
150% NPK	1231	1305	1296	1267	1275
Mean	1046	1098	1084	1158	-
75-90 cm					
No NPK	763	811	795	901	817
50% NPK	933	967	951	1044	974
100% NPK	1025	1077	1057	1155	1075
150% NPK	1155	1233	1304	1359	1263
Mean	969	1022	1027	1115	-

Conclusion

It was concluded that addition of compost and crop residue either alone or in combination increased the exchangeable K content of the soil. This results in higher availability of potassium in soil which ultimately increased the availability of potassium to plants.

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References

[1] Jackson, M.L. (1978). Soil Chemical Analysis Prentice Hall of India Pvt. Ltd New Delhi.
[2] Grewal, J.S. and Kanwar J.S. (1966). Forms of potassium in Punjab soil. Journal of Indian Society of Soil Science 14: 63-67.
[3] Quemener, J. (1979). The measurement of soil potassium. IPI research Topic No. 4. International Potash Institute, Beric, Switzerland.
[4] Pannu, R.P.S., Singh, Yadvinder, Singh, Bijay and Khind, C.S. (2002). Long term effect of organic materials on depth wise distribution of different K-fractions in soil profile under rice-wheat cropping system. Journal of Potassium Research 18: 1-5.
[5] Dixit, A.R., Sachan R.S., Srivastava, P.C. and Mishra, M.K. (1993). Distribution of different forms of potassium in some soil series of western Uttar Pradesh. Journal of Potassium Research 9: 259-314.

[6] Singh, M., Tripathi, A.K. and Reddy, D.D. (2002). Potassium balance and release kinetics of non exchangeable-K in a typic Haplustert as influenced by cattle manure application under soyabean - wheat system. Australia Journal of Soil Research 40: 533-541.
[7] Roy, H.K. and Sarkar, A.K. (1997). Status, forms and Q/I parameters of potassium in some soil series of Chhotanagpur region. Journal of Potassium Research 13: 37-44.
[8] Ram, C.S., Prasad, J., Singh, S.P. and Takkar, D.N. (1997). Distribution of forms of K and K release kinetics in some vertisol profile. Journal of Indian Society of Soil Science 95: 465-468.
[9] Ghosh, S.K. and Bhattacharya, T. (1984) Mineralogy of soils of Bihar, Uttar Pradesh, Gujarat and Rajasthan. Mineralogy of soil potassium PRII Res. Rev. Series 1; 15-29.
[10] Raskar, B.N. and Pharande, A.L. (1997). Different forms of potassium and their distribution in some important soil series of vertisol and alfisol of Western Maharashtra. Journal of Potassium Research 13: 21-30.
[11] Singh, K. and Tripathi, D. (1993). Different forms of potassium and their distribution in some representative soil group of Himachal Pradesh. Journal of Potassium Research 9: 196-205.
[12] Singh, O.P. and Datta, B. (1986). Forms of potassium in some soil of Mizoram. Journal of Indian Society of Soil Science 34: 187-190.
[13] Prasad, B. and Prasad, J. (1992). Availability and critical limits of potassium in rice and calcareous soil. Oryza 29: 310-316.
[14] Tiwari, A.K. and Bansal, K.N. (1992). Vertical distribution of forms of K in some soil series of Northern M.P. Journal of Potassium Research 8: 223-230.

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