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Potassium dynamics under integrated nutrient management system in a typic ustifluvents

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Abstract
To assess the effect of water hyacinth compost, vermicompost and inorganic fertilizers a field experiment was undertaken during *rabi* 2015-16 in light textured sandy loam soil of Mandan Bharti Agriculture College, Agwanpur, Saharsa, Bihar in split plot design with four levels of NPK in main plot and four levels of organic sources in sub-plot treatment in three replications. The experimental site was located in between 25º52'50" North latitude and 86º48'62" East longitude in agro-climatic zone-II of Bihar having hot moist sub-humid climate with average annual rainfall of 1050 mm and mean maximum and minimum annual temperature of 26ºC and 18ºC, respectively. Wheat (cv. DBW- 14) was grown as test crop during the reputed period of 2015-16. Vermicompost, compost made from aquatic weed water hyacinth (water hyacinth compost) alone or in combination with different levels of NPK of recommended dose of fertilizers were applied. Water soluble, exchangeable and non-exchangeable K recorded maximum in surface layer (0-15 cm). They decreased with the depth upto 75-90 cm. The available K, water soluble, exchangeable and non-exchangeable K increased significantly with increasing levels of fertilizers as well as water hyacinth compost and vermicompost over control.

Keywords: Potassium dynamics, INM, Ustifluvents

Introduction
The main reasons of low system productivity even in irrigated area are the inadequate and imbalanced fertilizer use (Sharma *et al.,* 2003) [19]. The advantage of combining organic and inorganic sources of nutrients in integrated nutrient management has been proved superior to the use of each component separately (Palaniappan and Annadurai, 2007) [12]. Potassium is the third important essential major plant nutrients with numerous function. It play vital roles in enzyme activation, water relations, energy relations, translocation of assimilates, photosynthesis, protein & starch synthesis and underpinning agronomic productivity & sustainability (Mengel, 1985) [10]. Availability of K to plant is controlled by dynamic interactions among its different chemical forms (Wang *et al.,* 2004) [25]. The component of dynamic interactions are water soluble K which is taken up directly by plants, exchangeable K held by negatively charged sites of clay particles, non exchangeable K which is a trapped between layers of expanding lattice clay and lattice K, an integral part of the primary minerals (Rao *et al.,* 1997) [15]. Potassium is present in soil in different forms. Most important forms of potassium are water soluble and exchangeable K which contribute to available form of K. The distribution of these forms in soil is important in understanding the conditions controlling their availability to growing crops. There is interconversion of one form to another under specific soil condition which determines their availability to plants. A large portion of the total K in soil occurs as structural component of soil minerals and is unavailable to plants. Plant can use only the exchangeable K present on the surface of soil particles and the K dissolved in soil water. This often constitute very small fraction of the total K. The dynamics of K in soil depends on the management of equilibrium among various forms which have relationship with physic-chemical properties (Sharma *et al.,* 2009) [17]. Under intensive cultivation, readily available K is removed by crop. This is followed by further release of exchangeable K from non-exchangeable forms. The level of soil solution K depends upon equilibrium and kinetic reactions that occur between different forms of soil K, the soil moisture content and the concentration of bivalent cations in solution and exchange phase (Sparks and Hung, 1985) [23]. Continuous mining of native soil K and decline in available K highlight the need to re-examine the current fertilizer K recommendation for different cropping system on different soil to arrest the decline in native K fertility and improve sustainability of production system.

Materials and methods

To assess the effect of water hyacinth compost, vermicompost and inorganic fertilizers, a field experiment was conducted during *rabi* 2015-16 in light textured sandy loam soil and Mandan Bharti Agriculture College, Agwanpur, Saharsa. The experiment site is located in agro climatic zone-II of Bihar in between 25º52"50' North latitude and 86º48"62' East longitude having hot moist sub humid climatic with medium to high water capacity with average annual rainfall of 1050 mm and mean yearly temperature of 33.8ºC. The experiment comprised 16 treatments replication three times in split plot design with four levels of NPK in main plot and four levels of organic sources in sub plot treatments. Wheat (*cv.* DBW 14) was grown as test crop during the reported period of 2015-16. Vermicompost, water hyacinth compost alone or in combination with different levels of NPK *viz*., 0, 50, 100 and 150 per cent of recommended dose of fertilizer. Different doses of fertilizers in terms of N, P_2O_5 and K_2O were applied @ 120:60:40 kg ha^{-1}, respectively. Nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate and muriate of potash. Soil sample were collected plot wise representing 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 after harvest of wheat during 2015-16 and air dried processed and analyzed for available P & K, water soluble K, exchangeable K, non-exchangeable K and total K. Available potassium in soil was determined by neutral normal ammonium acetate extraction method using flame photometer (Jackson, 1973) [4]. Water soluble K was determined by extracting the soil with distilled water in soil: water ratio (1:5) and potassium in the filtrate was estimated with the help of flame photometer as per method described by MacLean**,** 1961 [8]. Exchangeable K or normal neutral ammonium acetate-K of soil was estimated in the leachable which was obtained by equilibrating the soils with the extractant 1N neutral NH_4OAC for 5 minutes as per method described by Muhr *et al.*, 1965 [11]. Exchangeable K was determined by deducting water soluble K from normal neutral NH_4OAC-K. The non exchangeable K known as fixed K or 1N HNO_3 (boiling) extractable K was estimated in the soil as per standard method of Helmke and Sparks, 2000 [3]. Non exchangeable K was determined by deducting N neutral NH_4OAC-K from boiling 1N HNO_3-K. For determination of total K finally ground soil sample was placed in a 30 ml platinum crucible and digestion was carried out using HF and $HClO_4$ as described by Jackson, 1973 [4].

Results and discussion

Available Potassium

The available K was larger in surface layer (0-15 cm) and decreased downwards upto 90 cm. The available K status ranged from 74.34 to 104.90, 71.80 to 93.33, 66.03 to 87.11, 62.07 to 84.72, 56.00 to 83.20 and 54.67 to 76.88 kg ha^{-1} in 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm depth, respectively (Table-1). The decrease was more pronounced where addition of organic sources was highest as compared to control in all the depth. The application of 150% NPK + vermicompost and water hyacinth compost recorded highest (104.90 kg ha^{-1}). the build-up of soil available K due to application of NPK along with organic manure may be due to solubilising action and certain organic acid produced during decomposition and greater capacity to hold K in the available form. Yaduvanshi *et al.*, 2013 [27] reported that available K increased in treatment receiving green manure or FYM with 120-26-42 kg ha^{-1} NPK. Kumar *et al.*, 2007 [6] reported that addition of inorganic along with organics showed an improvement in the build-up of K whereas omission of fertilizer K and organics did not exhibit profound influence on status of K.

Application of vermicompost and water hyacinth compost alone or in combination recorded small increase in available K states. This may be due to that large fraction of K from organic material was either lost through leaching from the soil or was taken up by the wheat crop. Rajneesh *et al.,* 2017 also reported that the content of potassium was higher in top soil layer (0-15 cm) compared to lower depth.

Water soluble potassium

The water soluble K or soil solution K is the form of potassium that is directly taken up by the plants and also is the form of subjected to must leaching in soil. Being a readily available source of soil K may be subjected to change either under cropping or external K supply in the form of inorganic K fertilizers and FYM. The form of K is in dynamic equilibrium with exchangeable K whatever changed induced by crop removal of K is compensated by the release of exchangeable K into solution (Mazumdar *et al.,* 2014) [9]. The water soluble K in the NPK applied plots was higher than those of without NPK application or unfertilized (control) plots at all soil depth studied. Under different treatment the water soluble K ranged from 9.94 to 26.31, 8.97 to 23.20, 6.90 to 20.07, 6.21 to 18.13, 4.97 to 15.84 and 4.32 to 11.95 kg ha^{-1} in 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm soil depths, respectively (Table-2). Decrease in the water soluble form of K increasing soil depth was also reported by Tomar *et al.,* 2017 [24]. There was a further increase in water soluble K under NPK + vermicompost + water hyacinth compost amended plots over the NPK treated plot at all the soil depth. Such an increase in the content of water soluble K might be due to addition of organic material as reported earlier (Sood *et al.*, 2008) [22]. Highest water soluble K was recorded with the application of 150% NPK + vermicompost + water hyacinth compost (26.31 kg ha^{-1}) as compared to other treatments indicating greater release of K into solution. Yaduvanshi and Swarup (2006) [26] also confirmed this finding. Such increase in water soluble K content with NPK and organics may be due to stimulating effect of vermicompost and water hyacinth compost in reducing K fixation, thereby bringing in more K in to available form. Similar results have also been reported by Jatav *et al.*, 2010 [5]. The highest water soluble K value in surface layer could be due to cultivation practices and higher organic matter content, application of K bearing fertilizers and upward translocation of the element from lower depth with capillary rise of ground water. Similar trends were also reported by Singh *et al.*, 2002 [20] and Singh *et al.*, 2006 [21].

Exchangeable K

The exchangeable K represents the fraction of potassium which is adsorbed on external and accessible internal surfaces. It has been considered as reliable index of K removal by crops. It is held by negatively charges of organic matter and clay minerals. The exchangeable K status in surface soil (0-15 cm) varied from 66.37 to 80.78 kg ha^{-1} while that in 15-30, 30-45, 45-60, 60-75 and 75-90 cm depth it varied from 63.71 to 70.99, 56.37 to 67.74, 55.58 to 67.19, 62.36 to 66.64 and 61.08 to 78.86 kg ha^{-1}, respectively (Table-3). the data revealed that exchangeable K was higher in surface layers and is progressively decreased downwards upto 60 cm depth and afterward increased upto 90 cm. High 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 area. Sharma *et al.*, 2009 [17] reported that exchangeable K decreased with depth and the highest concentration of exchangeable K, under K fertilized plots in surface soil could be attributed to the addition of K through plant residue, manures and fertilizers. The exchangeable K was highest in the treatment fertilized with 150% NPK (88.78 kg ha^{-1}), which can be attributed to effect if manures on exchangeable site of soil and resulted in maximum accumulation of this fraction. Blake *et al.*, 1999 [2] reported that although FYM is not a performed source of K, but due to increased cation exchange capacity of soil, increased organic surfaces help in ion exchange and plant available K. Similarly, Bhattacharyya *et al.*, 2006 [1] noted that higher amount of K is attributed to the process of structural K released through increasing area of exchangeable surfaces and due to the accelerated weathering of the interlayer K by application of organic manure. The concentration of exchangeable K was numerically lower in sub surface soil as compared to surface soil in all the treatments, which may be due to comparatively more weathering, vegetation and supply of K from organic residue in surface layer than in lower depth (Sharma *et al.*, 1994) [18].

Non-exchangeable K

Non exchangeable K content varied from 1042 to 1624, 952 to 1501, 886 to 1434, 828 to 1424, 810 to 1206 and 737 to 1291 kg ha^{-1} in 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm depth, respectively under different treatment (Table-4). The data revealed that non exchangeable K content was also decreasing with increasing depth and follow the pattern as in case of exchangeable K. Higher value of non exchangeable K at surface layer might due to addition of K through potassic fertilizer as well as vermicompost and water hyacinth compost. The 150% NPK resulted in greater non exchangeable K over all other treatment. Application of potassic fertilizers maintained the content of non-exchangeable K at highest level. The non-exchangeable K status was lower in 100% NPK + vermicompost + water hyacinth compost treatment than 100% NPK alone because of higher K uptake and accumulation of organic matter, there would be a shift in cation exchangeable sites towards divalent selectivity (Salmon, 1964) [16] which would decrease percentage K saturation of cation exchange capacity, resulting in the shift of equilibrium of non-exchangeable K to exchangeable K in favour of latter, thereby releasing more non-exchangeable K. Lower value of non-exchangeable K at higher soil depth (75-90 cm) indicated that the movement of potassium in profile was restricted due to lower permeability of the soil in lower horizon. This might have slow down the movement of aqueous phase providing ample time for the diffuse in to the clay lattice in upper layers and finally increased in upper layers (Pannu *et al.*, 2002) [13]. Kumar and Narwal, 2016 [7] also reported that exchangeable K was higher in surface soil.

Table 1: Effect of water hyacinth compost, vermicompost and chemical fertilizer on available potassium (Kg ha^{-1}) after harvest of wheat

Fertilizer Level	Organic Sources				
	Control	Vermicompost	Water hyacinth compost	Vermicompost + water hyacinth compost	Mean
0-15 cm					
No NPK	74.34	79.45	79.48	87.66	80.23
50% NPK	81.02	88.13	86.72	84.52	85.09
100% NPK	84.08	92.89	90.49	96.98	91.11
150% NPK	90.39	98.55	97.86	104.90	97.92
Mean	82.45	89.75	88.63	93.51	
15-30 cm					
No NPK	71.80	72.49	71.72	74.73	72.68
50% NPK	73.59	79.00	80.32	84.12	79.25
100% NPK	81.18	85.28	83.45	85.90	83.95
150% NPK	83.09	89.86	87.67	93.33	88.48
Mean	77.41	81.65	80.79	84.52	
30-45 cm					
No NPK	63.03	66.08	65.55	69.44	66.02
50% NPK	71.37	72.60	71.80	75.65	72.85
100% NPK	75.66	78.04	76.32	85.23	78.81
150% NPK	78.44	86.00	82.91	87.11	83.61
Mean	72.12	75.68	74.14	79.35	
45-60 cm					
No NPK	62.07	65.37	63.97	67.08	66.02
50% NPK	73.17	71.23	69.39	80.58	72.85
100% NPK	73.61	75.20	73.74	83.90	78.81
150% NPK	79.01	81.45	82.56	84.72	83.61
Mean	72.12	75.68	74.14	79.35	
60-75 cm					
No NPK	56.00	62.20	58.69	64.76	60.41
50% NPK	67.66	70.84	70.58	79.68	72.19
100% NPK	72.50	71.35	73.97	81.32	74.78
150% NPK	74.89	77.13	78.08	83.20	78.32
Mean	67.76	70.38	70.33	77.24	
75-90 cm					
No NPK	54.67	56.65	58.24	61.11	57.66
50% NPK	64.36	68.68	66.81	72.80	68.16
100% NPK	67.25	69.90	68.35	76.16	70.41

150% NPK	71.12	72.77	72.22	76.88	73.24
Mean	64.35	67.00	66.40	71.73	

Table 2: Effect of water hyacinth compost, vermicompost and chemical fertilizer on water soluble potassium (Kg ha^{-1}) after harvest of wheat

Fertilizer Level	Organic Sources				
	Control	Vermicompost	Water hyacinth compost	Vermicompost + water hyacinth compost	Mean
0-15 cm					
No NPK	9.94	11.92	11.89	17.05	12.70
50% NPK	13.65	14.27	14.01	19.06	15.24
100% NPK	15.79	19.49	18.56	23.29	19.28
150% NPK	18.52	23.98	23.39	26.31	23.05
Mean	14.47	17.41	16.96	21.42	
15-30 cm					
No NPK	8.97	11.03	11.17	14.21	11.34
50% NPK	12.20	12.46	12.08	16.55	13.32
100% NPK	14.01	17.19	16.56	20.18	16.98
150% NPK	16.41	21.00	21.32	23.20	20.48
Mean	12.89	15.42	15.28	18.53	
30-45 cm					
No NPK	6.90	9.19	8.88	11.79	9.19
50% NPK	10.21	11.21	10.76	12.89	11.26
100% NPK	11.13	14.78	14.29	17.84	14.51
150% NPK	14.14	17.55	17.35	20.07	17.27
Mean	10.59	13.18	12.82	15.64	
45-60 cm					
No NPK	6.21	8.03	7.84	9.36	7.86
50% NPK	9.01	10.10	10.05	11.47	10.15
100% NPK	10.05	13.24	13.24	14.92	12.86
150% NPK	12.82	15.78	15.80	18.13	15.63
Mean	9.52	11.78	11.73	13.47	
60-75 cm					
No NPK	4.97	6.67	6.78	8.18	6.65
50% NPK	6.89	8.32	8.10	10.78	8.52
100% NPK	8.80	10.87	11.00	13.01	10.92
150% NPK	10.85	13.23	13.33	15.84	13.31
Mean	7.87	9.77	9.80	11.95	
75-90 cm					
No NPK	4.32	15.85	5.87	7.69	8.43
50% NPK	6.15	7.26	7.10	9.80	7.57
100% NPK	7.11	9.52	9.39	11.04	9.26
150% NPK	10.38	11.44	11.47	14.72	12.00
Mean	6.99	11.01	8.45	10.81	

Table 3: Effect of water hyacinth compost, vermicompost and chemical fertilizer on exchangeable potassium (Kg ha^{-1}) after harvest of wheat

Fertilizer Level	Organic Sources				
	Control	Vermicompost	Water hyacinth compost	Vermicompost + water hyacinth compost	Mean
0-15 cm					
No NPK	66.37	68.67	68.37	71.82	68.80
50% NPK	67.23	71.82	78.09	77.02	73.54
100% NPK	67.71	72.10	73.51	72.10	71.35
150% NPK	75.90	82.80	72.65	80.78	78.03
Mean	69.30	73.84	73.15	75.43	
15-30 cm					
No NPK	63.71	62.30	61.05	61.63	62.17
50% NPK	63.55	63.11	69.00	73.57	67.30
100% NPK	68.77	68.92	72.99	62.51	68.29
150% NPK	73.34	69.55	62.51	70.99	69.09
Mean	67.34	65.97	66.38	67.17	
30-45 cm					
No NPK	56.37	58.46	54.71	58.05	56.89
50% NPK	62.18	61.98	59.41	62.87	61.61
100% NPK	63.72	64.63	64.10	67.51	64.99
150% NPK	65.41	67.96	63.43	67.74	66.13
Mean	61.92	63.25	60.41	64.04	
45-60 cm					
No NPK	55.58	63.45	57.99	58.51	58.88
50% NPK	63.84	61.63	60.92	69.30	63.92

100% NPK	63.02	62.52	59.57	69.84	63.73
150% NPK	63.55	63.56	63.86	67.19	64.54
Mean	61.49	62.79	60.58	66.21	
60-75 cm					
No NPK	62.36	69.00	63.35	69.66	66.09
50% NPK	61.53	62.49	60.19	68.78	63.24
100% NPK	63.86	60.88	63.26	68.04	64.01
150% NPK	64.49	63.85	64.42	66.64	64.85
Mean	63.06	64.05	62.80	68.28	
75-90 cm					
No NPK	61.08	62.75	64.24	65.51	63.39
50% NPK	70.30	72.90	72.96	77.30	73.36
100% NPK	71.24	73.03	73.03	81.58	74.72
150% NPK	72.60	76.79	72.33	78.86	75.14
Mean	68.80	71.36	70.64	75.81	

Table 4: Effect of water hyacinth compost, vermicompost and chemical fertilizer on non- exchangeable potassium (Kg ha^{-1}) after harvest of wheat

Fertilizer Level	Organic Sources				
	Control	**Vermicompost**	**Water hyacinth compost**	**Vermicompost + water hyacinth compost**	**Mean**
0-15 cm					
No NPK	10.42	11.80	10.98	11.32	11.13
50% NPK	12.26	12.96	12.76	13.94	12.98
100% NPK	13.28	13.77	13.60	14.51	13.79
150% NPK	14.21	15.34	15.13	16.24	15.23
Mean	12.54	13.46	13.11	14.00	
15-30 cm					
No NPK	9.52	9.97	9.90	10.85	10.06
50% NPK	11.18	11.46	11.32	12.19	11.53
100% NPK	11.67	12.41	12.27	13.58	12.48
150% NPK	13.19	13.88	13.76	15.01	13.96
Mean	11.39	11.93	11.81	12.90	
30-45 cm					
No NPK	8.86	9.25	9.23	10.12	9.36
50% NPK	10.48	10.80	10.66	11.51	10.86
100% NPK	11.34	11.75	11.61	12.90	11.90
150% NPK	9.72	13.20	13.11	14.34	12.59
Mean	10.10	11.25	11.15	12.21	
45-60 cm					
No NPK	8.28	8.75	8.67	9.92	8.90
50% NPK	9.90	10.30	9.93	11.28	10.35
100% NPK	10.86	11.24	10.49	12.71	11.32
150% NPK	11.83	12.71	12.93	14.24	12.92
Mean	10.21	10.75	10.50	12.03	
60-75 cm					
No NPK	8.10	8.53	8.40	9.37	8.60
50% NPK	9.67	9.84	9.89	10.69	10.02
100% NPK	10.55	10.75	10.86	12.12	11.07
150% NPK	11.75	12.42	12.25	12.06	12.12
Mean	10.01	10.38	10.35	11.06	
75-90 cm					
No NPK	7.34	7.70	7.60	8.56	7.80
50% NPK	8.97	9.32	9.07	9.97	9.33
100% NPK	10.31	10.31	10.16	11.11	10.47
150% NPK	11.74	11.74	12.41	12.91	12.20
Mean	9.59	9.76	9.81	10.63	

Conclusion

All the fractions of soil potassium decrease with increasing soil depth. Integrated use of water hyacinth compost, vermicompost and chemical fertilizers results in maximum accumulation of all forms of potassium which also decreases along the depth.

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