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RESEARCH ARTICLE

Effect of organic and inorganic sources on the distribution of different fractions of potassium in vertisol

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ABSTRACT : A field experiment was conducted at Dryland Research Station,Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during 2003-04 and 2004-05 in Vertisol with application of organics and inorganics sources of nutrients under different cropping system *viz.*, soybean- pigeonpea and sorghum- pigeonpea. After these two crop cycles, the added potassium was found to be converted to various potassium fractions. Among the different fractions, maximum potassium was found in the form of total potassium followed by lattice potassium, non-exchangeable K, exchangeable K, Water soluble K. The Water soluble K and exchangeable K in soil decreased with the age of crop due to their utilization by crop for its nutrition. The relationship as simple and multiple regressions between available K and different K fractions was interdependent to each other.

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Sorghum being a high feeder of crops, needs potassium in comparatively in large quantities. However, farmers in Maharashtra, growing sorghum with high / optimum levels of N and P but negligible amount of potassium and sometimes without its results in depletion of potassium reserve.

Potassium dynamics *viz.*, K concentration of the soil solution, its buffer capacity and changes brought about by fertilizer application have a direct effect on crop yields. Generally solution K and exchangeable K are considered to be available to plants but there are several reports showing that the crops can utilize K from non-exchangeable source also (Singh and Ghosh, 1984). On an average 92 per cent of the total K is present as reserve mineral potassium, 6.3 per cent as non-exchangeable K, 1.6 per cent as exchangeable and only 0.2 per cent as water soluble K (Tandon and Sekhon, 1989). Potassium in soil is much buffered by reserve K as the proportion of total K held in water soluble and exchangeable forms are relatively very small.

The four important forms of potassium existing in the soils are the mineral potassium, the non-exchangeable potassium or potassium fixed in between in clay plates, the exchangeable potassium and soil solution potassium. These four forms of potassium are present in all agricultural soils though their relative proportion varies widely. In general, 90 to 98 per cent of total potassium is in mineral form, which is relatively not accessible to a growing crop. 1 to 10 per cent of total potassium is in the fixed form that is slowly available and 1 to 2 per cent may be in non-exchangeable while 10 per cent of total potassium is in the exchangeable and water soluble forms. Out of this 1 to 2 per cent is present in the soil solution. However, all these forms are in a dynamic equilibrium (Martin and Sparks, 1985 and Tandon and Sekhon, 1989).

EXPERIMENTAL METHODOLOGY

The experiments involving two cropping systems such as soybean (cv. JS -335) pigeonpea (cv. BSMR-853) and sorghum (cv.CSH-9) pigeonpea (cv. BSMR - 853) were conducted at organic farming and Dry Land Agricultural Research Farm at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The field experiment was conducted for successive two years *viz.*, 2003-2004 and 2004-2005. The experiment was laid out on fixed site in Randomized Block Design with the ten treatments and three replications. The treatments comprised of inorganic and organics sources such as FYM, glyricidia, vermicompost, plant and weed residues, bio fertilizers, neem seed cake, press mud cake etc which were replicated thrice in a Randomized Block Design.

Composite surface (0-30cm) soil samples collected at the intial flowering and harvesting stages from each plot between rows of each crop. These sample were analyzed for available K by Neutral normal ammonium acetate method (Jackson, 1973) and K fractions such as water soluble K by Flame photometer (Jackson, 1973), exchangeable K by deducting water soluble K from available K, non – exchangeable K by boiling method 1N HNO_3 (Woods and Deturk, 1941), Total K by digestion with HF or $HClO_4$ (Jackson, 1967), Lattice K by sum of value of available K and non – exchangeable K deducting from Total K. The soil was having initial pH 7.80, EC 0.3 dSm^{-1}, organic carbon 4.2 g kg^{-1}, $CaCO_3$ 84.0 g kg^{-1} and available N, P, K 174.52, 14.29, 203.83 gkg^{-1}, respectively.

Table A : Thetreatment details of experiment are as given below

Cropping systems	
	C_1= Soybean + Pigeonpea (4:2)
	C_2 = Sorghum + Pigeonpea (4:2)
Treatment details	
Treatment codes	Treatment details
T_1	50% RDF + FYM@ 2.5t ha^{-1}
T_2	Glyricidia @ 6 t ha^{-1}
T_3	FYM @ 5 t ha^{-1}
T_4	Vermicompost @ 1 t ha^{-1}
T_5	Plant and weed residues (*in situ*)
T_6	Pressmud cake @ 3 t ha^{-1}
T_7	Neem seed cake @ 1t ha^{-1}
T_8	Biofertilizer (Rhizobium and Azotobactor)
T_9	Recommended dose of fertilizer, NPK (30:60:30)
T_{10}	Control (No manures or fertilizers)

EXPERIMENTAL FINDINGS AND DISCUSSION

The data on different potassium fractions as influenced by various doses of fertilizer during 2003-04 and 2004-05 are presented in Tables 1, 2, 3 and 4, respectively.

During 2003-04 after harvest of soybean, the water soluble K ranged from 6.90 (T_{10}) to 10.87 (T_1) mg kg^{-1}

Table 1 : Potassium fraction (mg kg^{-1}) {after harvest of soybean} as influenced by various organic and inorganic sources of nutrients (2003-04)

Treatments	Total potassium	Water soluble potassium	Exchangeable potassium	Non –exchangeable potassium	Lattice potassium
T_1	5141.67	10.03	232.97	415.00	4051.67
T_2	4498.33	8.67	235.33	389.33	3488.33
T_3	4795.00	10.50	236.50	416.67	3583.33
T_4	4738.33	9.50	228.50	406.67	3533.33
T_5	4816.67	10.03	205.97	416.67	3811.67
T_6	4796.67	9.03	225.97	408.33	3818.33
T_7	4896.67	10.27	220.73	413.37	3941.67
T_8	4750.00	9.67	220.33	416.00	3826.67
T_9	4863.33	10.87	203.13	479.33	3993.33
T_{10}	4825.00	6.90	204.10	405.00	3020.33
Mean	4812.20	9.55	221.35	416.67	3706.90
S.E.±	50.90	0.18	15.50	15.50	58.80
C.D. (P=0.05)	150.99	0.54	47.00	45.00	174.50
Initial	4720.00	6.50	198.50	399.20	3000.10

with a mean value of 9.55 mg kg^{-1}. The exchangeable K ranged from 204.10 (T_{10}) to 232.97 (T_1) mg kg^{-1} with a mean value of 221.35 mg kg^{-1}. The non-exchangeable K varied from 405.00 (T_{10}) to 479.33 (T_1) mg kg^{-1} with a mean value of 416.67 mg kg^{-1}. The lattice K ranged from 3020.33 (T_{10}) to 4051.67(T_1) mg kg^{-1} with a mean value of 3706.90 mg kg^{-1}. The total K ranged from 4825.00 (T_{10}) to 5141.67(T_1) mg kg^{-1} with a mean value of 4812.20 mg kg^{-1}.

Whereas, after harvest of pigeonpea, the water soluble K ranged from 7.83(T_{10}) to 12.00 (T_1) mg kg^{-1} with a mean value of 10.00 mg kg^{-1} .The exchangeable K ranged from 210.17 (T_{10}) to 236.00 (T_1) mg kg^{-1} with a mean value of 227.40 mg kg^{-1}. The non - exchangeable K varied from 410.00 (T_{10}) to 481.67 (T_1) mg kg^{-1} with a mean value of 431.03 mg kg^{-1}. The lattice K ranged from 3039.00 (T_{10}) to 4176.67 (T_1) mg kg^{-1} with a mean value of 3762.50 mg kg^{-1}. The total K ranged from 4598.33 (T_2) to 5296.67 (T_1) mg kg^{-1} with a mean value of 4889.00 mg kg^{-1}.

During 2004-05 after harvest of sorghum, the water soluble K ranged from 6.97(T_{10}) to 12.70 (T_1) mg kg^{-1}

Table 2: Potassium fractions (mg kg^{-1}) {after harvest of pigeonpea} as influenced by various organic and inorganic sources of nutrients (2003-04)

Treatments	Total potassium	Water soluble potassium	Exchangeable potassium	Non –exchangeable potassium	Lattice potassium
T_1	5296.67	12.00	236.00	481.67	4099.67
T_2	4598.33	9.37	239.63	393.33	3583.33
T_3	4840.00	9.90	240.10	439.00	3683.33
T_4	4758.33	9.13	235.87	429.00	3633.33
T_5	4881.67	9.80	215.20	439.33	3883.33
T_6	4815.67	8.87	233.13	414.67	3833.33
T_7	4921.67	10.87	229.13	430.67	3963.33
T_8	4793.33	10.83	224.17	432.33	3843.33
T_9	5156.67	11.43	208.57	440.33	4063.33
T_{10}	4826.67	7.83	210.17	410.00	3039.00
Mean	4889.00	10.00	227.97	431.03	3762.50
S.E.±	32.10	0.12	5.00	12.20	67.70
C.D. (P=0.05)	95.10	0.36	16.00	36.20	200.09

Table 3 : Potassium fractions (mg kg^{-1}){after harvest of sorghum} as influenced by various organic and inorganic sources of nutrients (2004-05)

Treatments	Total potassium	Water soluble potassium	Exchangeable potassium	Non –exchangeable potassium	Lattice potassium
T_1	5389.67	12.70	235.30	487.67	4146.67
T_2	4701.67	9.33	245.67	408.33	3676.67
T_3	4863.33	10.90	244.10	458.33	3783.33
T_4	4791.67	9.90	234.10	436.33	3740.00
T_5	4891.67	10.43	217.57	448.33	3893.33
T_6	4858.33	9.80	236.20	416.67	3866.67
T_7	4941.67	10.77	228.23	446.00	3973.33
T_8	4803.33	10.06	227.94	450.67	3890.67
T_9	5260.00	11.93	218.07	461.00	4080.67
T_{10}	4843.33	6.97	209.03	415.00	3056.33
Mean	4993.45	10.28	229.62	442.87	3810.80
S.E.±	95.60	0.08	0.50	15.4	63.70
C.D. (P=0.05)	283.60	0.24	1.30	45.80	188.90
Initial	4760.00	6.70	20330	405.20	3040.00

with a mean value of 10.28 mg kg^{-1}. The exchangeable K ranged from 209.03 (T_{10}) to 235.30 (T_1) mg kg^{-1} with a mean value of 229.62 mg kg^{-1}. The non-exchangeable K varied from 415.00 (T_{10}) to 487.67 (T_1) mg kg^{-1} with a mean value of 442.87 mg kg^{-1}. The lattice K ranged from 3056.33 (T_{10}) to 4146.67 (T_1) mg kg^{-1} with a mean value of 3810.80 mg kg^{-1}. And the total K ranged from 4701.67 (T_2) to 5389.67 (T_1) mg kg^{-1} with a mean value of 4993.45 mg kg^{-1}.

Whereas, after harvest of pigeonpea the water soluble K ranged from 8.47 (T_{10}) to 13.93 (T_1) mg kg^{-1} with a mean value of 11.13 mg kg^{-1} .The exchangeable K ranged from 213.53 (T_{10}) to 239.07 (T_1) mg kg^{-1} with a mean value of 234.47 mg kg^{-1}. The non-exchangeable K varied from 421.67 (T_{10}) to 485.00 (T_1) mg kg^{-1} and total K ranged from 421.67 (T_{10}) to 485.00 (T_1) mg kg^{-1} with a mean value of 452.63 mg kg^{-1}. The lattice K ranged from 3064.33 (T_{10}) to 4176.67 (T_1) mg kg^{-1} with a mean value of 3858.80 mg kg^{-1}.The total K ranged from 4798.33 (T_2) to 5426.67 (T_1) mg kg^{-1} with a mean value of 5000.40 mg kg^{-1}.

The availability of K to plants depends on the relative mobility of the different forms of K in soil. A knowledge regarding various forms of K in soil and conditions controlling this availability to soybean, sorghum and pigeonpea crops is important for the appraisal of the available K. So, it was necessary to study the transformations of applied K to different forms and their influence on yield of crops grown on vertisol.

Dhawan *et al.* (1966) reported that the forms of potassium in soils of Rajasthan indicated that water soluble potassium was more in the sub- surface than in surface soil. In soils of Maharashtra, Kadrekar and Kibe (1972) reported an average of 669 mg kg^{-1} fixed potassium.

Kadrekar (1976) reported 4 to 10 mg kg^{-1} K_2O as water soluble form in the black soils of Maharashtra and also reported that the different forms of K in soils of Maharashtra and reported an average content of 6878 mg kg^{-1} total potassium.

Zende (1978) reported that the exchangeable potassium content of Maharashtra black soil varied from 0.12 to 0.42 mg 100 g^{-1}. He attributed the variation in exchangeable potassium content to the clay content and type of clay minerals present in soil.

Gajbhiye (1985) reported that the water soluble K ranged from 9 to 20 mg 100^{-1} g with a mean of 12 mg kg^{-1} in Inceptisol and 10 to 25 mg kg^{-1} with a mean of 16 mg 100^{-1} g in entisol. Fixed K ranged from 490 to 900 mg kg^{-1} in inceptisol and 665 to 1140 mg kg^{-1}in Entisol forming 1.28 to 3.08 per cent of total K.

Sharma and Dubey (1988) reported that the lattice potassium content ranged from 78.6 to 86.8 per cent of total potassium in a soil series of Indore district.

Mali (1989) studied the medium black soil from North Konkan region and reported that total potassium content varied from 2250 to 3500, 3250 to 3750, 3000 to 3750 and 6000 to 7000 ppm in Karjat, Roha, Repali and Panvel soil series, respectively.

Deshmukh *et al.* (1991) reported that the total K

Table 4: Potassium fractions (mg kg^{-1}) {after harvest of pigeonpea} as influenced by various organic and inorganic sources of nutrients (2004-05)

Treatments	Total potassium	Water soluble potassium	Exchangeable potassium	Non –exchangeable potassium	Lattice potassium
T_1	5426.67	13.93	239.07	485.00	4176.67
T_2	4798.33	9.97	250.03	415.00	3783.33
T_3	4993.33	11.90	248.10	465.00	3890.00
T_4	4891.67	10.33	238.67	448.33	3886.67
T_5	4916.67	10.83	220.17	460.00	3913.33
T_6	4883.33	10.20	238.80	421.67	3883.33
T_7	4993.33	11.20	229.80	463.33	3989.33
T_8	4901.67	12.03	228.97	467.00	3899.67
T_9	5299.67	12.40	237.60	479.33	4101.67
T_{10}	4899.67	8.47	213.53	421.67	3064.33
Mean	5000.40	11.13	237.47	452.63	3858.80
S.E.±	18.70	0.10	0.40	14.50	65.70
C.D. (P=0.05)	55.60	0.29	1.30	43.00	195.00

content in surface soils were higher as compared to sub surface soil in entisol and vertisol.

Kher and Minton (1991) reported that exchangeable K constituted 3.2 per cent of total potassium in wheat growing soils. Talele *et al*. (1992) reported the exchangeable K contents ranging from 12.03 to 46.80 mg kg^{-1}.

Mishra and Singh (1992) reported that non-exchangeable form of potassium in the soils of different agro-climatic zones of Maharashtra and reported the range of 14.6 to 13 g kg^{-1} soil. Sutar *et al.* (1992) reported that soil test methods for assessing available potassium content in latertic soils of Maharashtra and found that lattice potassium values ranged from 2975 to 5625 mg kg^{-1}. They also found that the potassium ranged from 3250 to 6250 mg 100 g^{-1} soil.

Patil and Sonar (1993) reported that water soluble potassium content in surface swell shrink soils representing five agro-climatic zones of Maharashtra was 0.2 per cent of the total potassium.

Sharma and Dixit (1994) recorded that the application of K_2O @ 60 kg ha^{-1} increased 7.7 per cent available K over no potassium application after harvest of soybean. All forms of K significantly increased with graded doses of K at all critical growth stages. Such an increase in K forms with K application could be attributed to the equilibrium existing among different forms.

Gajbhiye *et al.* (1995) reported that exchangeable potassium contributed 5.01 per cent of total K in entisol, inceptisol and vertisol.

Sonar and Patil (1996) reported that the swell shrink soils of Maharashtra contained lattice potassium 83.3 to 97.0 per cent of total potassium.

Phrande and Sonar (1996) reported the different forms of potassium in important vertisol series of Maharashtra. The water soluble K varied from 5 to 25 mg kg^{-1} and non-exchangeable K varied from 130 to 830 mg kg^{-1} in vertisols.

Rao *et al.* (1997) reported that the three soils under vertisol and studied the distribution of different fractions of potassium. Higher level of water–soluble potassium was found in surface horizons when compared with sub-surface horizons. Das *et al.* (1997) reported that the lattice potassium content varied from 1480 to 4280 mg kg^{-1}.

Amrutsagar and Sonar (1999) reported that the application of 60 kg K_2O ha^{-1} to sorghum permitted in decline in water soluble K (21%), exchangeable K (19%), and non-exchangeable K (5%) over the initial status of the soil. At higher levels (90 and 120 kg K_2O ha^{-1}) increase in non-exchangeable K and total K was observed. The highest grain and straw yields of sorghum (45 and 57 q ha^{-1}) were recorded due to application of 120 kg K_2O ha^{-1}.

Table 5 : Simple correlations between available K and different K fractions in soil (2003-04 and 2004-05)

K Fractions	2003-04		2004-05	
	At harvest of soybean	At harvest of pigeonpea	At harvest of sorghum	At harvest of pigeonpea
Exch. K	0.573**	0.550**	0.658**	0.707**
Non-exch. K	0.322	0.380*	0.475**	0.560**
Water soluble K	0.523**	0.400*	0.753**	0.754**
Lattice K	0.450**	0.512**	0.671**	0.754**

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 6 : Multiple regression equations between available K and K fractions (2003-04 and 2004-05)

Sr. No.	Multiple regression equations between available K and K fractions
1.	**After harvest of soybean**
	129.389+ 5.315 (Exch. K)- 0.145 (Non-exch. K)-0.179 (Water soluble K)-0.005 (Lattice K) (R^2 =0.354)
2.	**After harvest of pigeonpea**
	-7.329+10.728 (Exch. K) – 0.589 (Non-exch. K)-11.989 (Water soluble K)+0.009 (Lattice K) (R^2 =0.553)
3.	**After harvest of sorghum**
	449.314 - 4.480 (Exch. K) - 0.338 (Non-exch. K) – 26.06 (Water soluble K) - 0.045 (Lattice K) (R^2 =0.744)
4.	**After harvest of pigeonpea**
	149.347-7.164 (Exch. K) - 0.039 (Non-exch. K) + 10.06 (Water soluble K) + 0.029 (Lattice K) (R^2 =0.694)

Darwe (1999) reported that the water soluble potassium content ranged from 10.62 to 19.80 kg K_2O ha^{-1} and non- exchangeable K content varied from 130 to 830 mg kg^{-1}. Gawali (1999) reported that the water soluble K content varied from 4.5 to 16.00 mg kg^{-1} soils and it was only 0.13 per cent of total potassium in soil.

Pal *et al.* (2001) reported that non- exchangeable K varied from 150 to 900 mg kg^{-1} in laterite soils of Cuttack district.

A close look at the foregoing literature clearly brought out the fact that the fractions of K of soil was favourably influenced by application of organics alone or in combination with chemical fertilizer. This was particularly brought from the findings of long term experimentation on the same site with the same set of treatments

The increase in water soluble K might due to increase in concentration of K in solution. The adsorption of applied K on exchangeable sites might be responsible for high exchangeable K. The total K and non-exchangeable K in soil increased with levels of K application indicating K built up in soil. Total K decreased with advancement of crop growth which may be due to its utilization by the crop. These results indicated that applied K entered into different pools of K in soil. The largest fraction of applied K was transformed to non-exchangeable form followed by lattice K, exchangeable K and water soluble form of K in descending order. Water soluble and exchangeable K in soil decreased with the age of crop due to their utilization by crop for its nutrition.

These potassium fractions constitute potassium pool towards available K and hence, towards potassium nutrition of crop under consideration. The contribution of different K fractions could be predicted both by simple correlation and multiple regressions which were also worked out between different K fractions and available K. The results pertaining to correlation co-efficients (r) between available K and various K fractions for all crops during the years 2003-04 and 2004-05 are reported in Table 5.

From the Table 5, it can be inframed that all fractions of potassium were positively correlated with available K. The 'r' values are in the range of 0.322 to 0.754 and were exhibiting significant positive correlations with K fractions during both the years of experimentation. Highly positive simple correlation co-efficients between individual K fraction and available K indicate significant contribution of these fractions towards available K pool. However, it does not give the holistic picture under field condition when these entire fraction are simultaneously involved in transformation under the dynamic equilibrium between and among the different fractions as well as available K pool.

Therefore, besides simple correlations, the multiple regression equations were also computed to find out the relationships of these fractions in presence of other fractions with that of available K for both the crops during years 2003-04 and 2004-05 and are presented in Table 6.

From the Table 6, it can be noticed that R^2 values obtained for predication of relationships between available K with various K fractions were highly significant and varied from 0.354 to 0.744 indicating 35 to 74 per cent variation in different K fractions to available K. This however, shows the inter dependency of various K fractions among themselves. The very high R^2 values of multiple regression equation indicate the predictability of available K under the influence of various K fractions.

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