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Forms of soil potassium under different soils of paddy growing areas of Nagpur district and their relationship with yield of paddy

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Abstract
The present investigation was carried out during 2018-19 in paddy growing areas of Nagpur district of Maharashtra to ascertain the effect of potassium on yield of paddy. This was carried out by conducting survey of paddy growing farmers field of Nagpur district and therefore, total 25 fields were selected on the basis of GPS and two samples were collected from each field (50 samples) after harvest of paddy. Sampling was done at surface (0-15 cm) and sub-surface (15-30 cm) depth having common management practices. The result revealed that, the available, water-soluble, exchangeable, non-exchangeable, lattice and total K in surface soil depth ranged from 144.86-224.55, 5.1-8.1, 139.76-217.25, 673.13-789.50, 5316.40-7324.64 and 6250-8322 mg kg^{-1},respectively and in subsurface soil, it ranged from 126.64-214.19, 3.9-7.7, 120.84-207.29, 628.12-778.00, 6013.73-7241.60 and 6900-8140 mg kg^{-1}, respectively. A highly significant and positive relationships were observed between different forms of K and yield of paddy. The yield of paddy showed significant and positive coefficient of correlation with available K (r=0.707**), exchangeable K (r=0.697**), water-soluble K (r=0.553**) at 1 % level of significance and with total K (r=0.388*) at 5% level of significance. Further it is observed that, amongst potassium fractions, available K and exchangeable K were strongly positively correlated (r=0.999**) irrespective of soil depth. Also, it had exhibited significant and positive correlation with non-exchangeable K in both surface and sub-surface layer in paddy growing soils. The exchangeable K showed positive and significant correlation with non-exchangeable K (r=0.393*) and (r=0.395*) and lattice K also showed positive and highly significant correlation with total K (r=0.996**) and (r=0.992**) in surface and sub-surface depths, respectively.

Keywords: Forms of soil potassium, potassium dynamics, soil depth, paddy yield

Introduction

Potassium is the major nutrient and also the most abundant element in soils but 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 (fixed), mineral K, lattice K and total K. These fractions exist in dynamic equilibrium among themselves and these forms in turn govern the K nutrition to crops. Among the essential plant nutrients, potassium (K) assumes greater significance since it is required in relatively larger quantities by plants and besides increasing the yield, it immensely improves the quality of the crop produce. The range of the total potassium content which occurs in soils is enormous. Although in the form of simpler chemical compound, it is one of the most soluble elements. In the soil-plant system, potassium behaves with extreme differences of solubility and mobility. Thus, its absorption from solutions and soils is highly efficient; its movement through plant is very rapid. Potassium (K) is an essential nutrient for plant growth. Because large amount of K is absorbed from the root zone in the production of most agronomic crops, it is classified as a macronutrient. Potassium is associated with movement of water, nutrients and carbohydrates in plant tissue, stimulates early growth, increases protein production, improves efficiency of water use, is vital for stand persistence, longevity and improves resistance to diseases and insects. If K is deficient or not supplied in adequate amounts, growth may stunt and yield may reduce. Today, potassium is recognized as an important limiting factor in crop production. The function of K in plant growth has not been clearly defined hence, it is necessary fact to study forms of potassium in relation with plant growth.

Material and Methods

The present investigation was carried out in paddy growing area of Nagpur district of Maharashtra to ascertain the effect of potassium on yield of paddy. Survey of paddy growing farmers field of Nagpur district was conducted and therefore, total 25 fields were selected on the basis of GPS readings for the present study during 2018. The study location lies between the coordinates of 21˚ N to 79˚ E as shown in table 1.

Table 1: Location wise GPS readings of selected farmers' fields

Field No.	Location	GPS reading	
		Latitude	Longitude
1	Bhendala	N 21^0 19' 843"	E 79^0 34' 487"
2		N 21^0 19' 833"	E 79^0 34' 482"
3		N 21^0 19' 835"	E 79^0 34' 483"
4		N 21^0 19' 845"	E 79^0 34' 479"
5		N 21^0 19' 829"	E 79^0 34' 475"
6	Mangli (Chande)	N 21^0 19' 937"	E 79^0 35' 142"
7		N 21^0 19' 925"	E 79^0 35' 149"
8		N 21^0 19' 932"	E 79^0 35' 138"
9		N 21^0 19' 947"	E 79^0 35' 156"
10		N 21^0 19' 939"	E 79^0 35' 149"
11	Batnor	N 21^0 13' 969"	E 79^0 23' 774"
12		N 21^0 13' 973"	E 79^0 23' 778"
13		N 21^0 13' 978"	E 79^0 23' 769"
14		N 21^0 13' 971"	E 79^0 23' 776"
15		N 21^0 13' 975"	E 79^0 23' 769"
16	Tarsa	N 21^0 13' 819"	E 79^0 27' 099"
17		N 21^0 13' 816"	E 79^0 27' 095"
18		N 21^0 13' 812"	E 79^0 27' 091"
19		N 21^0 13' 810"	E 79^0 27' 101"
20		N 21^0 13' 813"	E 79^0 27' 098"
21	Nimkheda	N 21^0 14' 058"	E 79^0 25' 517"
22		N 21^0 14' 056"	E 79^0 25' 519"
23		N 21^0 14' 059"	E 79^0 25' 512"
24		N 21^0 14' 051"	E 79^0 25' 521"
25		N 21^0 14' 061"	E 79^0 25' 517"

The visits to 25 farmers field were done, discussed with them about selection of his field for the study and overall informed him about the importance of study. Two samples were collected from each field after harvest of paddy. Sampling was done at surface (0-15 cm) and sub-surface (15-30 cm) depth having common management practices. The samples were processed and analyzed in the laboratories of Soil Science and Agricultural Chemistry section, College of Agriculture, Nagpur during 2018-2019. The soil samples were analyzed for different forms of K viz., water-soluble K was determined by using saturation paste extract method. (Pratt, 1982), exchangeable potassium was determined by extracting with 1 N NH_4OAc solution as outlined by Piper, 1966. The non-exchangeable K was estimated by boiling 1N HNO_3 method as outlined by Pratt, 1982. Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Jackson, 1973) [6]. The lattice potassium was computed as difference between total potassium and the sum of water-soluble, exchangeable and non-exchangeable K fractions (Ranganathan and Satyanarayana, 1980) [12]. Simple correlations were worked out between different forms of potassium by standard statistical method by (Gomez and Gomez, 1983) [4].

Results and Discussion

Status of different forms of potassium

The different forms of potassium are quite important to know the potassium status of the soil. As such potassium is not rapidly available to plants but it is an important reservoir of slowly available K, if released gradually to more available forms. About 1 to 10 per cent of total K is present in non-exchangeable form which is slowly available because of its fixation by soil colloids. The data related to forms and distribution of potassium in surface and sub-surface depths is presented in table 2.

Water-soluble potassium

The water-soluble potassium in selected soils of paddy growing areas of Nagpur district varied from 5.10 to 8.10 mg kg^{-1} with a mean of 6.75 mg kg^{-1} in surface depth. The sub-surface water-soluble K content varied from 3.90 to 7.70 mg kg^{-1} with a mean of 6.21 mg kg^{-1}. The soils recorded more water-soluble K at surface as well as sub-surface depths due to the fact that black soils have greater moisture retention capacity and nutrient holding capacity than red soils and also organic matter content was relatively higher in these soils (Sharma et al., 2009) [13].

Exchangeable potassium

The exchangeable potassium content of soils ranged from 139.76 to 217.25 mg kg^{-1} in surface layer and in sub-surface layer it varied from 120.84 to 207.29 mg kg^{-1}. The mean value of exchangeable K was 183.93 and 167.22 mg kg^{-1} in surface and sub-surface layers, respectively. In both the soil depths, surface samples recorded high available potassium compared to sub-surface. The mean exchangeable potassium of soils was high, it may be due to fact that black soils are rich in organic matter content and in general, dominated by 2:1 type of clay minerals which offered more exchange sites for K. The results were in corroboration with that of Sharma et al., (2009) [13], Hebsur and Gali (2011) [5].

Non-exchangeable potassium

The lowest value of non-exchangeable K i.e. 673.13 mg kg^{-1} and 628.12 mg kg^{-1} was recorded in surface and sub-surface depth in Batnor whereas highest value i.e. 789.50 mg kg^{-1} and 778.00 mg kg^{-1} was observed in Tarsa location, respectively. The increase in non-exchangeable potassium at sub-surface may be attributed to adsorption and fixation of K removed from surface through leaching. The similar findings were obtained by Kundu et al., (2014) [9] and Divya et al., (2016) [3].

Lattice potassium

The lattice K content of soil ranged from 5316.40 mg kg^{-1} to 7324.64 mg kg^{-1} in surface layer and in sub-surface layer it varied from 6013.73 mg kg^{-1} to 7241.60 mg kg^{-1}. Based on degree of weathering and soil type the surface and sub-surface lattice K content might have been varied among the samples. The results corroborated with the findings of Divya et al., (2016) [3].

Total potassium

The total potassium in selected soils of paddy growing areas of Nagpur district varied from 6250 to 8322 mg kg^{-1} with a mean of 7517.60 mg kg^{-1} in surface depth. The sub-surface total K content varied from 6900 to 8140 mg kg^{-1} with a mean of 7605.28 mg kg^{-1}. This value of total potassium is slightly higher than the range 1900-5500 mg kg^{-1} reported by Deshmukh et al., (1991) [2]. It may be because of the rich K-bearing minerals in their lattice structure (Sharma et al., 2009) [13]. Depending on clay mineralogy, lattice K content and organic matter content, the total K content might have been varied in surface and sub-surface layers. The results were in comparison with those of research findings of Jagmohan and Grewal (2014) and Divya et al., (2016) [3].

Table 2: Distribution of forms of soil potassium

Sr No.	Depth (cm)	Potassium fractionation status in soil					
		Av. K (mg kg^{-1})	Ws K (mg kg^{-1})	Ex. K (mg kg^{-1})	Non-Ex. K (mg kg^{-1})	Lattice K (mg kg^{-1})	Total K (mg kg^{-1})
	Bhendala						
1	0-15	173.25	7.4	165.85	729.02	6342.72	7245.00
	15-30	164.97	7.3	157.67	697.54	6392.49	7255.00
2	0-15	222.38	7.1	215.27	746.52	6884.10	7853.00
	15-30	214.19	6.9	207.29	718.83	7008.98	7942.00
3	0-15	206.78	6.2	200.28	752.40	6101.12	7060.00
	15-30	200.21	5.8	194.41	720.09	6829.70	7750.00
4	0-15	178.01	6.3	171.31	691.02	6511.37	7380.00
	15-30	162.05	5.9	156.15	676.94	6573.01	7412.00
5	0-15	194.01	7.6	186.42	695.58	6530.40	7420.00
	15-30	190.03	7.1	182.93	693.96	7066.01	7950.00
	S mean	194.89	6.92	187.83	722.91	6473.95	7391.60
	SS mean	186.29	6.60	179.69	701.47	6774.04	7661.80
	Mangli (Chande)						
6	0-15	155.08	6.5	148.58	695.25	6281.67	7132.00
	15-30	126.64	5.8	120.84	686.32	6241.04	7054.00
7	0-15	191.51	5.3	185.21	736.00	7248.49	8175.00
	15-30	175.16	4.8	170.36	726.50	6383.34	7285.00
8	0-15	190.78	6.8	183.98	729.80	6591.42	7512.00
	15-30	164.47	6.2	158.27	679.50	6566.03	7410.00
9	0-15	183.69	7.4	176.29	744.50	6602.80	7531.00
	15-30	170.90	7.0	163.90	727.50	7241.60	8140.00
10	0-15	144.86	5.1	139.76	758.00	6222.14	7125.00
	15-30	140.89	3.9	136.99	714.50	6119.61	6975.00
	S mean	173.18	6.22	166.76	732.71	6589.30	7495.00
	SS mean	155.61	5.54	150.07	706.86	6510.32	7372.80
	Batnor						
11	0-15	188.86	6.5	182.36	716.9	7747.20	8153.00
	15-30	163.71	4.8	158.91	691.33	7162.96	8018.00
12	0-15	150.22	5.7	144.52	686.32	6113.50	6950.00
	15-30	139.83	5.7	134.13	665.77	7019.40	7825.00
13	0-15	152.16	7.4	144.76	743.47	7227.37	8123.00
	15-30	144.51	6.3	138.21	730.76	7224.73	8100.00
14	0-15	157.19	6.7	150.49	695.07	7062.74	7915.00
	15-30	139.87	5.9	133.97	628.12	6932.01	7700.00
15	0-15	196.76	6.8	189.96	673.13	6980.11	7850.00
	15-30	188.42	6.2	182.22	656.50	6905.08	7750.00
	S mean	169.03	6.62	162.42	702.98	7026.19	7798.20
	SS mean	155.27	5.78	149.49	674.50	7048.84	7878.60
	Tarsa						
16	0-15	168.07	6.7	161.37	681.67	6400.25	7250.00
	15-30	158.79	6.7	152.09	647.50	6905.71	7712.00
17	0-15	207.86	7.4	200.46	789.50	7324.64	8322.00
	15-30	189.81	7.0	182.81	778.00	7017.19	7985.00
18	0-15	194.98	7.2	187.77	694.38	6985.64	7875.00
	15-30	171.99	6.9	165.09	691.55	6886.46	7750.00
19	0-15	224.55	7.3	217.25	744.50	7149.95	8119.00
	15-30	194.47	6.4	188.07	731.50	6186.03	7112.00
20	0-15	218.92	7.3	211.61	701.31	6199.77	7120.00
	15-30	179.91	6.7	173.21	690.00	7137.09	8007.00
	S mean	202.87	7.18	195.69	722.27	6812.05	7737.20
	SS mean	178.99	6.74	172.25	707.71	6826.49	7713.20
	Nimkheda						
21	0-15	221.31	7.1	214.21	758.08	6962.60	7942.00
	15-30	193.45	6.3	187.15	691.07	6815.48	7700.00
22	0-15	211.76	5.4	206.36	721.84	5316.39	6250.00
	15-30	196.70	4.9	191.80	698.36	6604.94	7500.00
23	0-15	210.09	6.2	203.89	751.02	6092.88	7054.00
	15-30	182.45	5.8	176.65	703.82	6013.73	6900.00
24	0-15	212.52	8.1	204.42	781.00	6356.48	7350.00
	15-30	187.11	7.7	179.41	737.50	6475.39	7400.00
25	0-15	213.25	7.4	205.85	752.50	6268.24	7234.00
	15-30	195.16	7.3	187.86	692.50	6612.34	7500.00
	S mean	213.79	6.84	206.95	752.89	6199.32	7166.00
	SS mean	190.97	6.40	184.57	704.65	6504.38	7400.00
	Overall S Range	144.86-224.55	5.1-8.1	139.76-217.25	673.13-789.50	5316.40-7324.64	6250.00-8322.00
	Overall SS Range	126.64-214.19	3.9-7.7	120.84-207.29	628.12-778.00	6013.73-7241.60	6900.00-8140.00
	Overall S Mean	190.75	6.75	183.93	726.75	6600.16	7517.60
	Overall SS Mean	173.43	6.21	167.22	699.03	6732.81	7605.28

Yield of paddy under different soils of Nagpur district

Crop yield is a measurement of the amount of agricultural production harvested per unit land area. The yield data depicted in table 3 was collected from the farmers at the time of harvesting of paddy. The yield of paddy was recorded between 25.57 to 43.87 q ha^{-1} in location of villages of Mauda tahsil of Nagpur district under various paddy growing practices.

Table 3: Yield of paddy of selected farmers field

Location	Field No.	Yield (q ha^{-1})
Bhendala	1	31.35
	2	41.09
	3	35.47
	4	32.54
	5	35.98
Mangli (Chande)	6	29.37
	7	37.40
	8	43.12
	9	40.65
	10	25.57
Batnor	11	37.36
	12	29.89
	13	37.43
	14	33.98
	15	37.45
Tarsa	16	32.57
	17	36.20
	18	37.28
	19	43.87
	20	41.65
Nimkheda	21	36.45
	22	35.11
	23	34.98
	24	39.87
	25	38.94

Correlation studies

Correlation between forms of potassium and yield of paddy

Correlation matrix showing the relationship between yield of paddy (q ha^{-1}) and forms of potassium (mg kg^{-1}) is presented in table 4. Correlation was found out between seven variables namely (i) Yield of rice as dependable variable and (ii) Available K (iii) Water-soluble K (iv) Exchangeable K (v) Non-exchangeable K (vi) Lattice K and (vii) Total K as independent variable. Different K fractions were positively and significantly correlated with yield of paddy and each other indicating dynamic equilibrium among various fractions of K and yield of paddy. The result indicates that, the higher degree of correlation was noted among available K and yield of paddy (r=0.707**) followed by exchangeable K and yield of paddy (r=0.697**), water-soluble K and yield of paddy (r=0.553**) at 1 % level of significance and total K and yield of paddy (r=0.388*) at 5% level of significance.

Table 4: Correlation between forms of potassium and yield of paddy

K fractions	Paddy yield
Available K	0.707**
Water-soluble K	0.553**
Exchangeable K	0.697**
Non-exchangeable K	0.249
Lattice K	0.340
Total K	0.388*

** Significant at 1% level (0.496)
*Significant at 5% level (0.388)

Inter-relationship amongst the different forms of potassium

The coefficient of correlation between forms of potassium in surface soil (Table 5a) indicates that, available K and exchangeable K were strongly positively correlated (r=0.999**) is surface as well as sub-surface soil depth. Behera et al., observed the similar results i.e. irrespective of soil series and depth, available K and exchangeable K were positively correlated (r=1.00). Available K was also significantly and positively correlated with non-exchangeable K (r=0.395*) at 5% level of significance. Lattice K also showed positive and significant coefficient of correlation with total K (r=0.996**) at 1% level. The exchangeable K also showed positive and significant correlation with non-exchangeable K (r=0.393*) at 5% level. Similar results were also observed by Sparks and Huang (1985) [14], they reported that, positive and significant correlation among various K fraction indicating dynamic equilibrium. In case of different forms of potassium in sub-surface soil (Table 5b), available K showed positive and significant correlation with exchangeable K (r=0.999**) at 1% level of significance and non-exchangeable K (r=0.390*) at 5% level of significance. Exchangeable K showed positive and significant correlation with non-exchangeable K (r=0.390*) at 5% level of significance. Lattice K also showed positive and highly significant coefficient of correlation with total K (r=0.992**) at 1% level. Kaskar *et al*., (2001) [8] found that, there was highly significant positive relationship amongst different fractions of K in soil indicating existence of equilibrium between these forms. Similar results with different soil type were also reported by several researchers (Chand and Swami, 2000; Kaskar *et al*., 2001; Sharma *et al*., 2009) [1, 8, 13].

Table 5(a): Inter-relationship amongst the different forms of potassium in surface soil (0-15 cm)

	Av.-K	Ws-K	Ex-K	Non-Ex.-K	Lattice K	Total K
Av.-K	-					
Ws-K	0.349	-				
Ex-K	0.999**	0.326	-			
Non-Ex.-K	0.395*	0.187	0.393*	-		
Lattice K	0.014	0.330	0.001	0.094	-	
Total K	0.089	0.356	0.077	0.177	0.996**	-

** Significant at 1% level (0.496)
*Significant at 5% level (0.388

Table 5(b): Inter-relationship amongst the different forms of potassium in sub-surface soil (15-30 cm)

	Av.-K	Ws-K	Ex-K	Non-Ex.-K	Lattice K	Total K
Av.-K	-					
Ws-K	0.359	-				
Ex-K	0.999**	0.323	-			
Non-Ex.-K	0.390*	0.135	0.390*	-		
Lattice K	0.069	0.293	0.058	-0.093	-	
Total K	0.165	0.325	0.154	0.018	0.992**	-

** Significant at 1% level (0.496)
*Significant at 5% level (0.388)

Conclusions

The result of the present investigation on forms of soil potassium under different soils of paddy growing areas of Nagpur district suggests that, the contribution of different K fractions at surface and sub-surface soil depth was in order of lattice K> non-exchangeable K> available K> exchangeable K> water-soluble K. The significant and positive relationships between forms of K and yield of paddy indicated that, there existed equilibrium between these forms and depletion of one is instantly replenished by one or more of the other forms of

K. Thus, findings of the present investigation indicate that, the application of balanced potassic fertilizers help in improving K reserves of the soil and crop yields. The significant and positive relationship amongst forms of potassium showed existence of dynamic equilibrium among the different forms of K.

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