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Forms and Distribution of Potassium and Their Relationships to Different Characteristics of the Soil in the Soils of Pipari Village, District Khargone of Western Madhya Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Forms and distribution of potassium were examined in 150 soil samples taken from Pipari village, K halgone (MP) district. Surface (0-15 cm) soil samples were collected from 150 parcels of land in Pipari village. The concentration range of water soluble potassium, exchangeable potassium, available potassium, non-exchangeable potassium, lattice potassium and total potassium in soil is 3.82-35.8, 95.1-371.92, 108.35-379.20, 164.0-388.8, 8599.8-15865.32, 9066.2-16249.12 mg kg^{-1}. For all potassium forms, EC showed negative correlation. The pH showed highly negative correlation with water soluble potassium (r= -0.111**), exchangeable potassium (r= -0.45**),

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available potassium (r= -0.060**) and positive correlation with lattice potassium (r= 0.034*) and total potassium (r= 0.033*). Organic carbon was positively correlated with all potassium forms except water-soluble and non-exchangeable potassium (r = -0.034 *). CaCO3 has a positive correlation with water soluble potassium (r = 0.046**), lattice potassium (r = 0.090**) and total potassium (r = 0.084**) and total potassium (r= 0.084**) and highly negative correlation with exchangeable potassium (r= -0.147**), available potassium (r= -0.130**) and non-exchangeable potassium (r= -0.060**). Available nitrogen showed highly positive correlation with lattice potassium (r= 0.063**) and total potassium (r=0.062**). Available phosphorus showed negative correlation with exchangeable potassium (r= -0.046**) and available potassium (r= -0.046**) and positive correlation with lattice potassium (r= 0.090**) and total potassium (r= 0.087**). Highly positive correlation noticed between different forms of potassium except lattice potassium (r= - 0.113**) and total potassium (r= - 0.095**).

Keywords: Potassium; soil; correlation; lattice.

1. INTRODUCTION

Potassium is the seventh most abundant element and fourth most abundant mineral nutrient in the lithosphere. Among the important K bearing minerals that are found in soil are feldspars and micas as primary and illites and transitional clay as secondary minerals. Soil K-minerals such as feldspars, illites and micas are present in abundant amounts in some soils. Potassium (K), which occurs in soil in four forms and is essential for plant growth, e.g., water soluble K is directly absorbed by plants; exchangeable K is held by clay particle negative charges and is available to plants; fixed K is trapped between layers of expanding lattice clays; and lattice K is an essential component of primary K-bearing minerals. When investigating how crops respond to potassium. The forms of soil K in the order of their availability to plants and microbes are solution > exchangeable > fixed (non exchangeable) >mineral (Raghad Mouhamad et al. 2016).

The study area of Pipari Village of Khargone district belongs to Nimar Valley agro-climatic zone (X) M.P. and having medium to deep black soils. These soils are dark grey-brown to dark greyish brown colour with black shades (Tamgadge et al. 1999). Due to variation in topography and cropping sequence in this zone, various forms of K may change and affects its availability in soil. Knowledge of quantitative magnitude of different K forms in soils and interrelationship among them is important for the assessment of long term availability of K in soils.

2. MATERIALS AND METHODS

Surface (0-15 cm) soil samples were collected from 150 locations belonging to farmer's fields of the village Pipari, Tehsil & District Khargone M.P., and their geographical position was recorded with the help of GPS. The collected soil samples were processed using following standard procedures and analyzed for pH (1:2.5), electric conductivity (EC, 1:2:5), organic carbon (OC) [1,2], calciumcarbonate [3], available nitrogen (alkaline permanganate; Subbiah and Asija [4]), available phosphorus [5].

Water soluble potassium was estimated in 1:2 soil water suspension; Available potassium was determined by using 1 neutral normal ammonium acetate in solution using flame photometer as described Hanway and Heidal [6]; Exchangeable potassium was calculated by subtracting water soluble K from available K by [7]; 1N boiling HNO_3 extractable potassium was estimated by using flame photometer in 1: 10, soil: acid suspension boiled for 10 minutes as described by Black (1965). The results were expressed in mg kg^{-1}; Total potassium was estimated by using flame photometer. In this digested soil sample with hydrofluoric (48%) and perchloric acid (70-72%) in platinum crucible by the method outlined by Black [8]. The results were expressed in mg kg^{-1} and lattice potassium was calculated by subtracting water soluble K, exchangeable K and Non-exchangeable K from Total K. The statistical analysis to understand correlation among different forms of potassium and with soil properties was done as suggested by Panse and Sukhatme [9-11].

3. RESULTS AND DISCUSSION

3.1 Physico-Chemical Properties of Soil

The pH values of soil samples were found in the range of 7.0-8.5 under different fields with the mean value of 7.74 (Table 1). Electrical

conductivity (EC) status of collected soil samples was found in the range of 0.42-1.07 on average value of 0.65 (dSm^{-1}). Maximum value of soil EC (1.07) was observed in soil collect from the 4th field whereas minimum value (0.42) was noted in 131th field (Table 1). It is evident that 94.667% soil sample belongs to low status and 5.333% soil sample shows medium status of electrical conductivity. Soil organic carbon status was found in the range of 0.32-0.76% under different fields with the mean value of 0.53 (Table 1). Available Nitrogen status was found in the range of 147-276 kg ha^{-1} under different fields with the mean value of 212.78 kg ha^{-1}. Maximum value of available nitrogen (276 kg ha^{-1}) in the soils was observed in 128th field whereas minimum available nitrogen (147 kg ha^{-1}) was noted in 126th field (Table 1). Available phosphorous (P) status of soil samples was found in the range of 5.6-16.00 kg ha^{-1} with mean value of 10.61 kg ha^{-1}(Table 1). Calcium Carbonate status of collected Soil samples was found in the range of 2.14 - 5.95% under different fields with the mean value of 4.46% (Table 1).

3.2 Distribution of Different Forms of Potassium

The data on distribution of different forms of potassium in the profiles from different cropping sequences are presented in Table 2. The relationship between different forms of potassium and physico-chemical properties is presented in Table 3.

3.3 Water Soluble K (mg kg^{-1})

Statusof soil water soluble K in Pipari village of district Khargone (Table 2.) was found in the range of 3.82-35.80 mg kg^{-1} under different fields with the mean of 16.98 mg kg^{-1}. Maximum value of soil water soluble K (35.80 mg kg^{-1}) was observed in 100th field and The minimum value of water soluble K in soil (3.82 mg kg^{-1}) was noticed in 5th field. Results on the same line with different soil types have also been reported by Dixit et al. (1993) and Yadav et al. (2009).This form represented 7.97, 7.38, 6.71, 0.15 and 0.14% of exchangeable, available, non-exchangeable, lattice and total K respectively.

3.4 Exchangeable K (mg kg^{-1})

Exchangeable K status of surface soil samples collected from Pipari village of district Khargone (Table 2) was found in the range of 95.10-371.92 mg kg^{-1} on average value of 212.87 mg kg^{-1}. Maximum value of soil exchangeable K (371.92 mg kg^{-1}) was observed in soil collected from the 27th field where as minimum value (95.10 mg kg^{-1}) was noted in 38th field.Exchangeable K status of soil samples was found in the range of 95.1-371.92 mg kg^{-1} on average value of 212.87 mg kg^{-1} (Table 2), contributed 1.80% of total K. Pharande and Sonar (1996) also reported the similar findings related to exchangeable K and total K.

3.5 Available K (mg kg^{-1})

Available K status of soil samples collected from Pipari village of district Khargone (Table 2.) was found in the range of 108.35-379.20 mg kg^{-1} with the mean value of 229.85 mg kg^{-1}. Maximum value of soil available K (379.20 mg kg^{-1}) was observed in soil collected from the 27th field whereas, minimum value (108.35 mg kg^{-1}) was noted in 7th field. Available K status of soil was found in the range of 108.35-379.20 mg kg^{-1} with the mean value of 229.85 mg kg^{-1} (Table 2). This form contributes 1.94% of total K in soil.

3.6 Non-Exchangeable K (mg kg^{-1})

Non-exchangeable K status of surface soil samples collected from Pipari village of district Khargone (Table 2) was found in the range of 164.00-388.80 mg kg^{-1} with the mean value of 253.17 mg kg^{-1}. Maximum value of soil non-exchangeable K (388.80 mg kg^{-1}) was observed in soil collected from the 13th field whereas minimum value (164.00 mg kg^{-1}) was noted in 121th field. Non-exchangeable K status of soil samples was found in the range of 164.0-388.80 mg kg^{-1} with the mean value of 253.17 mg kg^{-1}, (Table 2) contributed 2.14% towards total K.

3.7 Lattice K (mg kg^{-1})

Status of surface soil Lattice K in Pipari village of district Khargone (Table 2) was found in the range of 8599.80 - 15865.32 mg kg^{-1} under different fields with the mean of 11379.84 mg kg^{-1}. Maximum value of soil lattice K (15865.32 mg kg^{-1}) was observed in 8th field whereas, minimum value of soil lattice K (8599.80 mg kg^{-1}) were noticed in 39th field. Status of soil Lattice K was found in the range of 8599.80-15865.32 mg kg^{-1} under different fields with the mean of 11379.84 mg kg^{-1} (Table 2) contributed 95.35% of total K.

3.8 Total K (mg kg^{-1})

Total K status of soil samples collected from Pipari village of district Khargone (Table 2) was found in the range of 9066.20-16249.12 mg kg^{-1}

with the mean value of 11863.76 mg kg^{-1}. Maximum value of soil Total K (16249.12 mg kg^{-1}) was observed in soil collected from the 8th field whereas, minimum value (9066.20 mg kg^{-1}) was noted in 39th field.

Total K status of soil samples was found in the range of 9066.20-16249.12 mg kg^{-1} with the mean value of 11863.76 mg kg^{-1} (Table 2).

3.9 Correlation between Soil Properties and Forms of Potassium

3.9.1 Soil pH

The results (Table 3) indicate that, in soil the soil pH showed negative relationship water soluble potassium, exchangeable K and available K the coefficient of correlation of pH with water soluble

Table 1. Physio-Chemical characteristics of the soils of Pipari Village of Khargone District

Sample No.	pH (1:2)	EC (dSm^{-1})	OC (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	$CaCo_3$ (%)
1	8.01	0.66	0.48	196	9.60	3.09
2	7.96	0.69	0.48	196	8.00	4.23
3	7.90	1.00	0.44	188	9.60	4.32
4	8.05	1.07	0.36	164	8.00	3.68
5	8.03	0.68	0.64	247	11.20	5.39
6	7.94	0.74	0.52	204	9.60	2.46
7	7.88	0.76	0.60	235	13.60	3.98
8	8.03	0.74	0.56	218	11.20	4.90
9	7.92	0.81	0.56	218	9.60	4.31
10	7.94	0.75	0.44	188	8.00	4.85
11	7.90	0.69	0.60	235	13.60	3.40
12	7.84	0.76	0.48	196	11.20	3.60
13	7.89	0.71	0.40	180	8.00	3.15
14	7.82	0.72	0.52	204	8.00	3.45
15	7.84	0.78	0.64	247	11.20	5.95
16	7.87	0.71	0.56	220	11.20	4.45
17	7.85	0.75	0.60	235	13.60	4.05
18	7.91	0.76	0.52	204	9.60	3.65
19	7.86	0.63	0.60	235	13.60	3.95
20	7.84	0.71	0.42	184	11.20	5.20
21	7.89	0.78	0.64	247	13.60	4.82
22	7.83	0.80	0.60	235	16.00	4.50
23	7.62	0.85	0.48	196	9.60	4.62
24	7.51	0.78	0.52	204	11.20	3.90
24	8.20	0.69	0.56	220	11.20	5.34
26	7.93	0.62	0.60	235	13.60	5.05
27	8.03	0.60	0.56	218	11.20	4.16
28	7.99	0.69	0.60	235	9.60	5.85
29	8.03	0.70	0.52	204	11.20	4.95
30	8.02	0.59	0.40	180	8.00	5.52
31	7.94	0.56	0.56	218	13.60	5.33
32	8.50	0.76	0.48	196	11.20	5.33
33	8.10	1.04	0.52	204	9.60	5.00
34	8.01	0.64	0.56	218	11.20	5.29
35	7.00	0.62	0.52	204	9.60	5.03
36	7.45	0.58	0.60	235	13.60	5.89
37	7.63	0.63	0.44	188	8.00	3.16
38	7.69	0.56	0.64	247	13.60	5.50
39	7.69	0.62	0.52	204	11.20	5.66
40	7.88	0.57	0.56	220	13.60	5.18
41	7.79	0.68	0.60	235	15.60	5.85
42	7.70	0.60	0.48	196	9.60	4.65
43	7.72	0.49	0.52	204	11.20	5.30

Sample No.	pH (1:2)	EC (dSm^{-1})	OC (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	$CaCo_3$ (%)
44	7.65	0.56	0.60	235	13.60	3.99
45	7.63	0.62	0.48	196	8.00	4.12
46	7.65	0.54	0.56	220	13.60	5.69
47	7.64	0.67	0.44	188	11.20	3.75
48	7.60	0.66	0.56	220	9.60	2.35
49	7.63	0.64	0.52	204	8.00	5.36
50	7.61	0.64	0.52	204	8.00	4.54
51	7.73	0.68	0.36	164	5.60	2.43
52	7.69	0.71	0.56	218	11.20	4.56
53	7.70	0.64	0.64	247	13.60	4.68
54	7.64	0.73	0.52	204	9.60	5.12
55	7.71	0.63	0.44	188	8.00	5.14
56	8.10	0.74	0.52	204	9.60	4.89
57	7.73	0.55	0.48	196	8.00	3.54
58	7.68	0.71	0.52	204	8.00	3.65
59	7.64	0.76	0.56	220	11.20	2.14
60	7.58	0.61	0.48	196	9.60	5.87
61	7.69	0.68	0.56	220	11.20	4.31
62	7.65	0.50	0.60	235	13.60	4.96
63	7.60	0.61	0.44	188	8.00	4.37
64	7.64	0.72	0.40	180	9.60	5.87
65	8.07	0.75	0.60	235	11.20	5.23
66	7.73	0.61	0.56	220	13.60	4.32
67	7.66	0.63	0.52	204	9.60	4.67
68	7.71	0.59	0.56	220	13.60	3.85
69	7.60	0.68	0.48	196	8.00	4.58
70	7.58	0.62	0.52	204	9.60	4.37
71	7.62	0.56	0.40	180	8.00	3.48
72	7.63	0.74	0.44	188	9.60	4.39
73	7.69	0.61	0.64	247	13.60	4.59
74	7.55	0.73	0.52	204	9.60	4.39
75	7.64	0.61	0.56	220	11.20	4.87
76	7.69	0.67	0.48	196	8.00	5.23
77	7.70	0.68	0.60	235	13.60	5.54
78	8.10	0.63	0.56	220	11.20	4.86
79	7.75	0.75	0.44	188	9.60	4.39
80	7.81	0.69	0.52	204	11.20	3.84
81	7.69	0.68	0.60	235	13.60	3.48
82	7.63	0.72	0.64	247	15.60	5.14
83	7.65	0.57	0.52	204	8.00	2.84
84	7.69	0.64	0.56	220	9.60	5.32
85	7.78	0.81	0.48	196	8.00	5.41
86	7.81	0.74	0.60	235	13.60	4.46
87	7.90	0.67	0.68	259	15.60	4.68
88	7.84	0.62	0.60	235	13.60	4.39
89	7.83	0.61	0.52	204	8.00	4.91
90	7.62	0.75	0.56	220	9.60	3.25
91	7.94.	0.79	0.44	188	8.00	2.19
92	7.85	0.64	0.48	196	8.00	5.57
93	7.72	0.61	0.40	180	9.60	4.26
94	7.79	0.72	0.60	235	11.20	4.63
95	7.63	0.68	0.52	204	9.60	4.12
96	7.83	0.67	0.64	247	13.60	5.24
97	7.65	0.58	0.56	220	11.20	4.69
98	7.94	0.81	0.52	204	9.60	4.17

Sample No.	pH (1:2)	EC (dSm^{-1})	OC (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	$CaCo_3$ (%)
99	7.81	0.63	0.4	196	9.60	5.18
100	7.51	0.75	0.52	204	9.60	2.15
101	7.74	0.52	0.52	204	8.00	5.38
102	7.70	0.70	0.60	235	13.60	5.16
103	7.73	0.62	0.48	196	8.00	4.69
104	7.77	0.59	0.56	218	9.60	4.81
105	7.72	0.63	0.64	247	11.20	3.67
106	7.80	0.65	0.48	196	9.60	3.98
107	7.71	0.66	0.56	220	13.60	5.15
108	7.79	0.64	0.44	188	8.00	4.16
109	7.73	0.59	0.52	204	9.60	4.67
110	7.65	0.62	0.40	186	8.00	2.16
111	7.69	0.65	0.48	196	9.60	5.17
112	7.69	0.56	0.60	235	13.60	4.38
113	7.73	0.62	0.52	204	8.00	4.18
114	7.79	0.55	0.56	220	9.60	4.67
115	7.62	0.63	0.44	188	8.00	4.28
116	7.66	0.57	0.52	204	9.60	3.97
117	7.89	0.59	0.48	196	8.00	3.54
118	7.70	0.60	0.56	220	11.20	5.61
119	7.68	0.69	0.64	247	13.60	5.31
120	7.67	0.63	0.60	235	15.60	5.83
121	7.72	0.60	0.52	204	8.00	4.37
122	7.71	0.61	0.48	196	9.60	4.92
123	7.75	0.59	0.56	218	11.20	4.85
124	7.86	0.68	0.40	180	8.00	3.59
125	7.69	0.67	0.52	204	9.60	4.65
126	7.56	0.63	0.32	147	5.60	3.18
127	7.60	0.62	0.44	188	8.00	2.69
128	7.31	0.59	0.76	276	13.60	3.98
129	7.48	0.68	0.68	259	15.60	5.47
130	7.64	0.52	0.60	235	11.20	3.47
131	7.59	0.42	0.64	247	13.60	5.08
132	7.52	0.61	0.56	220	11.20	3.98
133	7.72	0.45	0.64	247	9.60	4.25
134	7.65	0.53	0.52	204	9.60	4.83
135	7.68	0.55	0.56	218	11.20	4.67
136	7.67	0.60	0.48	196	8.00	4.15
137	7.60	0.58	0.60	235	13.60	5.76
138	7.65	0.52	0.64	247	15.60	2.86
139	7.60	0.63	0.56	218	9.60	3.43
140	7.79	0.59	0.52	204	8.00	4.28
141	7.69	0.65	0.67	259	13.60	3.97
142	7.63	0.68	0.64	247	11.20	4.16
143	7.59	0.51	0.40	180	8.00	4.75
144	7.64	0.63	0.44	188	9.60	4.63
145	7.53	0.67	0.52	204	9.60	4.63
146	7.66	0.68	0.56	218	11.20	5.37
147	7.62	0.57	0.64	247	13.60	5.19
148	7.69	0.53	0.48	196	8.00	4.61
149	7.51	0.65	0.60	235	11.20	4.38
150	7.65	0.62	0.52	204	8.00	4.51
Range	**7.0-8.5**	**0.42-1.07**	**0.32-0.76**	**147-276**	**5.6-16.00**	**2.14-5.95**
Mean	**7.74**	**0.65**	**0.53**	**212.78**	**10.61**	**4.46**

Table 2. Status of different forms of potassium (mg kg^{-1}) in soils of Pipari village of district Khargone

Sample No.	W.S.K (mg kg^{-1})	Ex. K (mg kg^{-1})	Avail. K (mg kg^{-1})	Non-ex. K (mg kg^{-1})	Lattice K (mg kg^{-1})	Total K (mg kg^{-1})
1	13.30	212.10	225.40	196.00	12826.81	13248.21
2	12.40	287.00	299.40	364.40	9192.65	9856.45
3	19.30	181.50	200.80	279.20	9778.39	10258.39
4	4.55	217.55	222.10	226.80	9403.22	9852.12
5	3.82	205.58	209.40	212.80	9928.92	10351.12
6	16.50	236.90	253.40	285.20	10040.88	10579.48
7	35.50	181.60	217.10	327.60	11812.49	12357.19
8	19.30	182.10	201.40	182.40	15865.32	16249.12
9	4.45	110.89	115.34	226.00	11114.70	11456.04
10	29.80	145.70	175.50	295.20	10022.62	10493.32
11	13.70	211.50	225.20	228.40	13831.08	14284.68
12	18.20	216.20	234.40	273.20	12150.58	12658.18
13	17.30	222.90	240.20	388.80	12620.37	13249.37
14	4.38	178.02	182.40	323.80	9751.18	10257.38
15	5.21	159.79	165.00	222.80	10310.47	10698.27
16	6.21	248.79	255.00	175.60	9866.55	10297.15
17	5.23	202.07	207.30	193.20	9869.33	10269.83
18	14.90	300.10	315.00	250.00	12024.91	12589.91
19	13.80	108.00	121.80	252.40	14873.08	15247.28
20	18.20	138.20	156.40	326.80	12989.44	13472.64
21	28.30	179.50	207.80	365.20	11925.23	12498.23
22	9.33	123.07	132.40	228.80	14320.06	14681.26
23	4.00	270.80	274.80	175.20	8696.56	9146.56
24	13.20	128.80	142.00	229.20	12783.42	13154.62
24	17.30	141.70	159.00	276.40	12251.88	12687.28
26	28.90	177.50	206.40	212.80	13235.04	13654.24
27	7.28	371.92	379.20	171.20	9699.46	10249.86
28	12.20	182.20	194.40	290.40	13866.35	14351.15
29	18.40	144.00	162.40	232.80	12186.03	12581.23
30	15.70	215.50	231.20	226.80	12786.02	13244.02
31	16.30	194.10	210.40	286.00	9758.63	10255.03

Sample No.	W.S.K (mg kg^{-1})	Ex. K (mg kg^{-1})	Avail. K (mg kg^{-1})	Non-ex. K (mg kg^{-1})	Lattice K (mg kg^{-1})	Total K (mg kg^{-1})
32	5.23	144.17	149.40	225.20	11050.92	11425.52
33	15.40	200.20	215.60	169.20	8700.43	9085.23
34	23.70	206.30	230.00	327.60	13010.61	13568.21
34	29.80	103.56	133.36	268.40	10492.36	10894.12
36	8.35	112.05	120.40	210.40	13154.23	13485.03
37	5.83	230.77	236.60	249.20	9768.43	10254.23
38	17.40	95.10	112.50	223.20	10222.50	10558.20
39	29.50	182.90	212.40	254.00	8599.80	9066.20
40	28.80	219.60	248.40	170.80	10129.10	10548.30
41	23.60	191.20	214.80	210.00	12360.85	12785.65
42	15.50	108.70	124.20	259.20	12093.83	12477.23
43	9.42	183.78	193.20	284.80	9776.02	10254.02
44	5.24	198.16	203.40	372.40	9276.82	9852.62
45	4.53	203.87	208.40	327.20	10869.70	11405.30
46	8.23	228.97	237.20	212.40	12126.66	12576.26
47	7.24	143.11	150.35	197.20	10130.95	10478.50
48	19.20	149.60	168.80	251.20	11434.32	11854.32
49	5.83	166.47	172.30	232.40	10243.53	10648.23
50	8.25	197.55	205.80	214.80	10026.43	10447.03
51	3.84	141.76	145.60	196.20	9514.43	9856.23
52	6.23	162.09	168.32	224.80	14198.38	14591.50
53	4.92	119.28	124.20	249.20	12098.22	12471.62
54	13.20	95.15	108.35	196.80	14223.95	14529.10
55	8.24	142.01	150.25	212.80	9868.07	10231.12
56	9.23	284.07	293.30	244.80	9308.40	9846.50
57	8.63	166.57	175.20	316.40	10986.60	11478.20
58	24.80	199.52	224.32	241.20	14386.78	14852.30
59	6.83	247.17	254.00	208.40	10787.63	11250.03
60	22.80	227.42	250.22	171.20	13809.70	14231.12
61	28.30	203.90	232.20	250.00	10858.00	11340.20
62	9.62	200.58	210.20	312.00	9726.10	10248.30
63	26.90	166.30	193.20	193.20	9465.90	9852.30
64	16.30	118.60	134.90	215.20	14402.10	14752.20

Sample No.	W.S.K (mg kg^{-1})	Ex. K (mg kg^{-1})	Avail. K (mg kg^{-1})	Non-ex. K (mg kg^{-1})	Lattice K (mg kg^{-1})	Total K (mg kg^{-1})
65	5.27	156.83	162.10	267.20	11042.20	11471.50
66	18.40	133.70	152.10	311.60	9767.90	10231.60
67	25.93	267.32	293.25	327.20	11420.85	12041.30
68	6.32	224.08	230.40	360.4.0	12342.63	12573.03
69	35.80	169.70	205.50	225.20	13036.60	13467.30
70	22.40	192.40	214.80	199.20	14371.26	14785.26
71	19.30	123.50	142.80	265.20	13845.20	14253.20
72	13.80	198.55	212.35	287.20	11978.75	12478.30
73	8.24	216.86	225.10	322.80	14237.30	14785.20
74	18.30	235.20	253.50	233.20	11995.60	12482.30
75	12.40	127.70	140.10	301.20	10083.30	10524.60
76	18.20	157.92	176.12	333.60	13693.30	14203.02
77	32.70	179.64	212.34	287.60	9745.36	10245.30
78	24.80	168.63	193.43	250.80	11410.18	11854.41
79	13.76	191.04	204.80	248.00	9199.22	9652.02
80	22.30	276.00	298.30	215.20	10733.80	11247.30
81	14.56	149.84	164.40	195.20	14425.60	14785.20
82	15.32	138.98	154.30	198.80	9892.10	10245.20
83	27.30	147.05	174.35	323.40	11549.63	12047.38
84	22.40	275.93	298.33	289.20	9065.09	9652.62
85	25.20	167.95	193.15	215.20	12076.95	12485.30
86	23.40	209.94	233.34	192.40	10152.86	10578.60
87	16.30	234.02	250.32	255.60	11508.18	12014.10
88	25.60	243.72	269.32	232.80	9721.40	10223.52
89	19.40	135.93	155.33	190.00	11439.69	11785.02
90	8.64	160.47	169.11	252.80	9832.29	10254.20
91	8.62	224.68	233.30	312.40	9932.92	10478.62
92	23.80	124.40	148.20	232.20	10071.90	10452.30
93	13.76	111.93	125.69	202.80	9192.81	9521.30
94	8.33	208.20	216.53	195.60	14413.99	14826.12
95	26.40	300.90	327.30	253.20	9664.80	10245.30
96	8.63	328.07	336.70	297.20	10890.30	11524.20
97	13.80	304.50	318.30	197.20	9830.12	10345.62

Sample No.	W.S.K (mg kg^{-1})	Ex. K (mg kg^{-1})	Avail. K (mg kg^{-1})	Non-ex. K (mg kg^{-1})	Lattice K (mg kg^{-1})	Total K (mg kg^{-1})
98	28.30	244.10	272.40	360.40	11401.80	12034.60
99	6.82	278.68	285.50	355.60	13612.11	14253.21
100	35.80	279.60	315.40	325.20	9604.70	10245.30
101	22.50	300.30	322.80	195.20	9338.62	9856.62
102	25.60	291.30	316.90	231.30	10712.10	11260.30
103	16.40	280.00	296.40	257.20	14266.71	14820.31
104	12.36	273.94	286.30	303.2	13930.53	14520.03
105	22.34	290.76	313.10	227.20	12006.00	12546.30
106	6.83	250.87	257.70	306.80	11889.12	12453.62
107	26.60	309.50	336.10	298.80	12986.40	13621.30
108	26.50	286.10	312.60	355.20	11383.50	12051.30
109	28.20	290.30	318.50	213.20	9919.51	10451.21
110	31.30	237.10	268.40	186.80	9997.40	10452.60
111	22.40	226.10	248.50	258.80	12697.08	13204.38
112	24.60	226.20	250.80	361.20	10009.65	10621.65
113	16.80	233.20	250.00	226.00	11086.30	11562.30
114	27.20	214.50	241.70	243.20	11560.40	12045.30
115	35.60	296.40	332.00	261.20	9652.10	10245.30
116	28.30	264.20	292.50	225.20	11585.60	12103.30
117	26.50	210.30	236.80	191.20	11759.03	12187.03
118	27.40	278.00	305.40	299.20	9937.70	10542.30
119	34.80	210.80	245.60	320.00	11837.60	12403.20
120	18.30	306.60	324.90	355.6	11775.74	12456.24
121	23.60	303.50	327.10	164.00	9754.11	10245.21
122	25.50	300.30	325.80	234.00	9582.40	10142.20
123	28.40	279.60	308.00	277.20	13671.40	14256.60
124	8.63	267.17	275.80	342.40	11835.42	12453.62
125	6.82	292.88	299.70	211.6	14067.00	14578.30
126	12.50	309.30	321.80	175.6	11955.80	12453.20
127	26.20	310.20	336.40	302.8	10902.82	11542.02
128	15.25	251.55	266.80	281.2	9710.30	10258.30
129	18.23	303.37	321.60	275.2	9648.50	10245.30
130	16.23	255.37	271.60	261.61	11621.09	12154.30

Sample No.	W.S.K (mg kg^{-1})	Ex. K (mg kg^{-1})	Avail. K (mg kg^{-1})	Non-ex. K (mg kg^{-1})	Lattice K (mg kg^{-1})	Total K (mg kg^{-1})
131	18.24	240.76	259.00	178.2	11020.10	11457.30
132	5.26	259.04	264.30	241.60	9739.42	10245.32
133	28.30	206.20	234.50	203.60	12816.20	13254.30
134	14.66	232.24	246.90	232.00	9752.52	10231.42
135	7.22	222.78	230.00	190.80	9433.82	9854.62
136	8.93	228.27	237.20	257.20	11959.20	12453.60
137	6.22	268.38	274.60	284.00	13964.50	14523.10
138	13.82	285.18	299.00	295.60	13605.61	14200.21
139	25.40	299.90	325.30	194.40	11820.60	12340.30
140	14.66	326.44	341.10	334.20	13577.80	14253.10
141	12.92	212.98	225.90	256.60	10169.85	10652.35
142	13.27	227.33	240.60	194.80	9211.90	9647.30
143	16.46	231.34	247.80	285.20	11920.52	12453.52
144	19.35	214.55	233.90	331.60	10913.14	11478.64
145	18.66	232.84	251.50	240.40	11965.74	12457.64
146	6.35	213.85	220.20	272.40	11958.04	12450.64
147	25.22	203.38	228.60	175.60	13883.20	14287.40
148	34.60	189.30	223.90	209.20	12777.51	13210.61
149	5.20	199.90	205.10	226.80	11599.30	12031.20
150	12.35	183.25	195.60	307.30	9742.40	10245.30
Range	**3.82-35.8**	**95.1-371.92**	**108.35-379.20**	**164.0-388.8**	**8599.8-15865.32**	**9066.2-16249.12**
Mean	**16.98**	**212.87**	**229.85**	**253.17**	**11379.84**	**11863.76**

potassium (r= -0.111**) exchangeable K (r= -0.045**), available K (r= -0.060**) were significant at 1% level of significance whereas lattice K (r= 0.034*) and total K (r= 0.033*) were significant at 5% level, non-exchangeable K (r= 0.017).

pH showed significant and negative correlation with water soluble K and exchangeable K in soil (Table 3).

3.9.2 Electrical Conductivity (EC)

Electrical conductivity (EC) of soil showed negative relationship with all the forms of potassium (Table 3). In soil the coefficient of correlation of electrical conductivity with water soluble K (r= -0.136**),), available K (r= -0.162**), exchangeable K (r= -0.145**), lattice K (r= -0.080**) and total K (r=-0.089**), significant at 1% level of significance and non-exchangeable K (r= -0.022).

Electrical conductivity showed a significant and negative correlation with all forms of K in soils (Table 3). It seems that soluble salts of potassium may contribute to EC.

3.9.3 Organic Carbon (OC)

The organic carbon (OC) content of samples showed positive relationship with exchangeable K, available K, lattice K and total K (Table 3). The water soluble K (r= -0.007) and Non-exchangeable K (r= -0.034*) showed negative relationship with OC. lattice K (r=0.046**) and total K (r= 0.045**) were significant at 1% level of significance whereas exchangeable K (r= 0.032*), available K (r= 0.030*), Non-exchangeable K (r= -0.034*) were significant at 5% level of significance.

3.9.4 Available nitrogen

The results (Table 3) indicate that in soil, the coefficient of correlation between available nitrogen content and water soluble potassium (r= -0.022) and non-exchangeable potassium (r= -0.008) were showed negative relation and non significant, whereas positive relationship with exchangeable K (r=0.016), Available K (0.012), Lattice K (0.063**), total K (r= 0.084**). Coefficient of correlation Nitrogen with Lattice K (r= 0.063**), total K (r= 0.084**) were significant at 1% level of significance.

3.9.5 Available phosphorous

In general available phosphorous content of the soil showed positive relationship with water soluble K (r= 0.030*) non-exchangeable K (r= 0.022) Lattice K (r= 0.090**), total K (r= 0.087**) and negative relationship with exchangeable K (r= -0.046**), Available K (r= -0.046**) (Table 3). Coefficient of correlation of available phosphorous with Lattice K (r= 0.090**), total K (r= 0.087**), exchangeable K (r= -0.046**), Available K (r= -0.046**) were significant at 1% level of significance whereas water soluble K(r=0.030*) were significant at 5% level of significance.

3.9.6 Calcium carbonate ($CaCO_3$)

The results (Table 3) indicate that in soil the calcium carbonate content showed positive relationship with water soluble K (r= 0.046**), Lattice K (r= 0.090**),total K (r= 0.087**). And negative relation with exchangeable K (r= -0.147**), Available K (r= -0.130**), non-exchangeable K (r= -0.060). All forms of K were significant at 1% level of significance.

Table 3. Coefficient of correlation (r) between forms of potassium and soil properties in soil

	W.S.K	Ex.K	Avail.K	Non-ex.K	Lattice K	Total K
pH	-0.111**	-0.045**	-0.060**	0.017	0.034*	0.033*
EC	-0.136**	-0.146**	-0.162**	-0.022	-0.080**	-0.089**
OC	-0.007	0.032*	0.030*	-0.034*	0.046**	0.045**
$CaCO_3$	0.046**	-0.147**	-0.130**	-0.060**	0.090**	0.084**
Avail.N	-0.022	0.016	0.012	-0.008	0.063**	0.062**
Avail.P	0.030*	-0.046**	-0.046**	0.022	0.090**	0.087**
Sand	0.049**	-0.184**	-0.172**	0.022	0.037*	0.034*
Silt	0.131**	0.129**	0.144**	0.050**	0.010	0.020
Clay	-0.138**	0.016	-0.005	-0.090**	-0.033*	-0.039*

Note. Table value for correlation coefficient at 5% (0.026) and 1% (0.045)

4. CONCLUSION

Soils of Pipari village of district Khargone were slightly alkaline in reaction and safe limit of EC. Most of the fields were low in organic carbon and available nitrogen content. Low to medium status of available phosphorous and low to high status of calcium carbonate content were observed in soils under different fields of Pipari village of district Khargone. More than half of soil samples were in medium range of water soluble K, exchangeable K and non-exchangeable K content. Electrical conductivity in soil showed highly significant negative correlation with all forms of K.

Soil test crop response studies may be conducted according to potassium present in Pipari village of district Khargone soil. The similar studies may be repeated for the other major nutrients also.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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