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Distribution of different forms of potassium in mustard growing regions of Northern Madhya Pradesh

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Abstract
One hundred fifty GPS based surface soil sample of mustard growing fields were analysed for different physico-chemical properties and different forms of potassium (i.e. water soluble, exchangeable, non exchangeable, mineral and total. Soils were neutral to slightly alkaline in nature with having normal electrical conductivity and calcium carbonate content. Organic carbon was found in the range of 0.180 to 0.640 per cent with average value of 0.441 percent. The amount of water soluble, exchangeable and non-exchangeable-K in different villages of Gwalior district; ranged from 7.2 – 26.4, 115.2 – 330.2 and 290.4 – 965.4 mg kg^{-1} with the mean value of 15.1,230.5 and 548.4 mg kg^{-1} respectively. These forms contributed 0.102, 1.55 and 3.70% towards total-K. Whereas, Lattice and total-K found in the range of1.072-1.729 and 1.127-1.859% with the mean value of 1.403 and 1.482% respectively. Lattice – K contributed maximum (94.67%) towards total-K. organic carbon and clay content of the soils of mustard growing fields shows positive relationship with all the forms of potassium, whereas, sand and soil pH show negative relationship. A highly significantly and positively relationship were observed between different forms of K.

Keywords: Soil physical properties, exchangeable K, Non-exchangeable K, total K and correlation

1. Introduction
Potassium is a major constitute of the earth crust contained more in igneous rocks than in sedimentary rocks. it comprise on an average of 2.6% of the earth crust making it the seventh most abundant element and fourth most abundant mineral nutrient in lithosphere. More than 98% of the total potassium reserve in soil and exist in inorganic combinations which can further be classified as water soluble K, exchangeable –K, non exchangeable –K and lattice-K. Water soluble and exchangeable together constitutes the plant available K. The different forms of soil potassium are in dynamic equilibrium and any depletion in a given K form is likely to shift equilibrium in the direction to replenish it. Major portion of soil K exists as part of mineral structure and in fixed or non-exchangeable form with a small fraction as water soluble and exchangeable K in soil and high correlations among different forms of potassium in some Indian soils (Mishra *et al.*, 1993) [6]. Under intensive cultivation, readily available or exchangeable K is removed by crops. However, this is followed by release of K from non-exchangeable form. The knowledge regarding the different forms of K in soil is important for an understanding of the potential K supplying power of the soil to crops. With this background, the present study was undertaken to generate information on the distribution of different forms of K in soils of mustard growing regions of northern Madhya Pradesh and their relationship with soil properties.

2. Method and material
Under present study, 150 GPS based surface soil samples were collected from mustard growing regions of northern Madhya Pradesh comprises Gwalior, Morena and Bhind district where mustard was grown as preceding crop. The soil samples were analyzed for pH and electrical conductivity using standard methods suggested by Jackson (1973) [4], soil organic carbon by Walkley-Black (1934) [15] and $CaCO_3$ by Piper (1950) [10] and particle size distribution by hydrometer method (Bouyoucous, 1962) [1]. Water soluble K was determined in the soil extracted with water (1:5: soil: water); available K by extracting the soil with NH_4OAc and non-exchangeable K by extracting the soil with boiling 1N HNO_3

(Wood and De Turk, 1941) [17] and then subtracting the available fraction. Exchangeable K was calculated by subtracting water soluble form from available K. Total K was determined by extracting soil with H_2SO_4, $HClO_4$ and HF mixture in platinum crucible at 220-225°C (Jackson, 1973)[4], and lattice-K was calculated from the difference between total K and the sum of NH_4OAc-K and non-exchangeable K (Wiklander, 1954) [16]. Potassium in all the extracts was estimated through flame photometer. Correlations between different forms of K and soil properties were worked out by the procedure described by Panse and Sukhatme (1950) [9].

3. Results and discussion

3.1 Physico-chemical properties of soil

In the selected area of different district, sand, silt and clay per cent varied from 45.6 – 71.4, 5.0 – 30.9and 14.2 - 33.5 with the mean value of 58.4, 16.8 and 24.6, respectively (Table-1). Soil pH of studied fields was found in the range of 7.02 - 8.30 under with the average value of 7.65. The pH value appeared to be influenced by parent material, rainfall and topography of the study area. The higher pH might be due to the increase in accumulation of exchangeable sodium and calcium carbonate (Thangaswamy*et. al*. 2005) [14]. Electrical Conductivityof studied area of mustard growing fields was found in the range of 0.11 - 0.95 with the average value of 0.56dSm^{-1}, it showed a considerable variation with variation in topography of soil. On the basis of limit suggested by Muhr *et al.* (1963) [7], all samples were (EC < 1.0 dSm^{-1}) in the range of normal category of salt content, the soils were found to have soluble salt concentration in safer limit for satisfactory plant growth, similar findings were reported Singh *et al*. (2013)[13]. The organic carbon content in the soils of different districts was low (<0.5%). It ranged from 0.180 to 0.640% with average value of 0.441%. The low organic carbon content in soils samples under investigation may be due to its oxidation under prolonged higher summer temperature and high cropping intensity. Similar results were mentioned in coarse textured soils by Yadav and Meena (2009) [18].

Calcium carbonateof selected fields was found in the range of 0.50 – 5.00 per cent under different fields with the average value of 2.17 percent (Table-2). This clearly indicates that the most of the soils under present study was normal in nature in respect of calcium carbonate content.

3.2 Different forms of potassium

3.2.1 Water soluble - K

Status of water soluble- K ranged from 4.18 – 22.70 mg kg^{-1} under different districts with an average value of 11.35 mg kg^{-1} and contributes only 0.086 per cent of total-K(Table-3). The sand fraction of soils was negatively and significantly correlated with water soluble K. This may be due to less content of potassium bearing minerals in sand fractions or due to the fact that the potassium in soil is utilized by crop more easily and is alsosubjected to erosion losses. (Singh *et al*. 2013) [13].

3.2.2 Exchangeable - K

Exchangeable K content found in the range of 62.5 – 326.2 mg kg^{-1} with an average value of 152.4 mg kg^{-1}which accounted for 1.16% of total-K. Kaskar *et al.* (2001) [5] also reported that exchangeable K contributed same line towards total K. The variation in exchangeable potassium content among the soil samples may be attributed to differential release of potassium from non-exchangeable and lattice potassium as well as variation in labile pool due to potassium fertilization. The values of correlation coefficient of exchangeable K with soil properties (Table-3) showed that exchangeable K was significantly and positively correlated with EC (r= 0.234**) and organic carbon (r=0.336**). Which might be due to the fact that with increase in organic matter in soils, the clay-humus complex become more active thereby providing more exchange sites and access to K. These results are in agreement with the findings of Dhakad *et al.* (2017) [2]. The sand fraction was significantly but negatively correlated with exchangeable potassium this may be due to less content of potassium bearing minerals in sand fractions. Sharma *et al*. (2009) [12] and Saini and Grewal (2014) [11] also observed similar type observation in their studies.

3.2.3 Non exchangeable - K

Status of non exchangeable - K in mustard growing regions was found in the range of 444.0 – 1987.2 mg kg^{-1} with an average value of 972.2 mg kg^{-1} and contributing to 7.40% of total-K. Correlation study of non-exchangeable-K with soil properties showed that it was significantly and positively correlated with organic carbon (r=0.258*) and clay (r=0.338**) content where as negatively correlated with pH (r=-0.232*). Kaskar *et al.* (2001) [5], Sharma *et al.* (2009) [12] and Dhakad *et al*. (2017) [2] also reported similar results with different soil type.

3.2.4 Lattice - K

Value of Lattice- K under studied area of three district ranged from 0.626 – 1.760 per cent with an average value of 1.216 per centwhich accounts more than 90 per cent (92.61%) of the total –K.Kaskar *et al.* (2001) [5] and Padole and Mahajan (2003) [8], also reported that lattice K contributed same line towards total- K. lattice-K was significantly and positively correlated with clay (r=0.306**).

3.2.5 Total- K

Status of total- K was noticed in the range of 0.736 – 1.922 per cent under with an average value of 1.313 per cent.The total-K was significantly and positively correlated with clay (r=0.452*) content where as negatively correlated with $CaCO_3$ (r = - 0.248*). These relationships confirmed that the finer fractions of the soils are in primary sources of potassium in the soils of study area. The results also point out that the light textured soils would be depleted easily than heavy textured for native potassium. Therefore, continuous monitoring of soil potassium status is essential in these types of soils. Sharma *et al.* (2009) [12] and Dhakad *et al.* (2017) [2] also observed positive correlation between total K and organic carbon and clay content.

3.3 Inter-relationship amongst different forms of potassium

3.3.1 Water soluble K

Highly significant and positive correlation was found between Water soluble K and other forms of potassium data was correlated with different fractions of K and observed that it was highly and significantly correlated with exchangeable potassium (r=0.760**), non-exchangeable potassium (r=0.412**), Lattice potassium (r=0.316**) and total potassium (r=0.441**). Positive and Significant relationship between water soluble K and exchangeable K and as well as in 1N HNO_3- K indicates the existence of dynamic equilibrium between these forms of K. Similar relationship were also reported by Sharma *et al.* (2009) [12] and Dhakad *et al.* (2017) [2].

3.3.2 Exchangeable K
Exchangeable K was highly and significantly correlated with other forms of potassium i.e. non-exchangeable potassium (r=0.806**), Lattice potassium (r=0.472**) and total potassium (r=0.422**). The present findings are in similar line as that of Gangopadhyay *et al*. (2005) [3].

3.3.3 Non exchangeable K (1N HNO_3 –K)
The non-exchangeable K was found to be positive and significantly correlated to lattice potassium (r=0.383**) and total potassium (r=0.494**). This means that whenever fixed potassium was released, changed to available forms, there will be a simultaneous release of potassium from structural forms. This relationship indicates that these soils contain significant amount of potash-bearing minerals which might have materially contributed to its larger K reserve. Similar relationship was also reported by Gangopadhyay *et al*. (2005) [3].

3.3.4 Lattice- K
The Lattice-K was found to be positive and significantly correlated with total potassium (r=0.992**). A highly significant (1% level) and positive correlation was also found between lattice K and totalK. These relationships indicated that there existed equilibrium between these forms of potassium and depletion of one is instantly replenished by one or more of the other forms of potassium (K).

Table 1: Mechanical Composition of soils of mustard growing fields

S. No	Name of district	Sand (%)		Silt (%)		Clay (%)	
		Range	Mean	Range	Mean	Range	Mean
1	Bhind (50*)	45.6–70.2	59.7	8.0–28.0	16.4	14.2–32.4	23.9
2	Gwalior (50)	47.2-65.6	56.8	5.0–30.9	17.9	18.5–33.5	25.3
3	Morena (50)	50.8–71.4	58.6	8.4–25.2	16.1	15.8–28.6	24.6
As a whole region		45.6–71.4	58.4	5.0–30.9	16.8	14.2–33.5	24.6

Parenthesis indicate the number of samples

Table 2: Physic-chemical properties of soils of mustard growing fields

S. No	Name of district	Soil pH (1:2)		Electrical conductivity (dSm^{-1})		Organic carbon (%)		Calcium carbonate (%)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Bhind	7.02 - 8.23	7.58	0.67 – 0.95	0.83	0.330 – 0.624	0.497	0.50 – 4.00	2.00
2	Gwalior	7.20 –8.30	7.73	0.25 – 0.77	0.47	0.256 – 0.622	0.466	0.50 – 3.50	2.08
3	Morena	7.30 –8.10	7.66	0.11 – 0.75	0.37	0.180 – 0.640	0.361	0.50 – 5.00	2.42
As a whole region		7.02 – 8.30	7.65	0. 11 –0.95	0.56	0.180 – 0.640	0.441	0.50 – 5.00	2.17

Table 3: Distribution of different forms of potassium in soils of mustard growing fields

S. No	Name of district	Water soluble–K (mg kg^{-1})		exchangeable –K (mg kg^{-1})		Non-exchangeable–K (mg kg^{-1})		Lattice –K (%)		Total –K (%)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Bhind	5.24–21.80	11.86	62.5–326.2	170.7	444.0 – 1987.0	1149.0	0.812– 1.682	1.310	0.887–1.770	1.393
2	Gwalior	5.04–22.70	12.48	75.2–265.9	161.9	559.0 – 1612.7	926.2	0.636– 1.689	1.216	0.736–1.842	1.326
3	Morena	4.18–19.16	9.70	81.1–286.0	124.7	550.3 – 1542.2	841.5	0.720– 1.760	1.123	0.817–1.922	1.220
As a whole region		4.18–22.70	11.35	62.5–326.2	152.4	444.0– 1987.0	972.2	0.636– 1.760	1.216	0.736–1.922	1.313

Table 4: Correlation coefficient between soil properties and forms of potassium

Soil parameters	WS-K	Ex.-K	NEx-K	Lattice-K	Total-K
pH	-0.184	-0.261*	-0.232*	-0.088	-0.104
EC	0.109	0.234*	0.144	0.128	0.155
OC	0.321**	0.336**	0.258*	0.156	0.194
$CaCO_3$	-0.083	-0.128	-0.136	-0.142	-0.248*
Sand	-0.214*	-0.238*	-0.202	-0.135	-0.144
Silt	-0.056	-0.158	-0.142	-0.058	-0.047
Clay	0.112	0.124	0.338**	0.306**	0.452**

Table 5: Correlation matrix of different forms of potassium

	WS-K	Ex.-K	NEx-K	Lattice-K	Total-K
WS-K	-	0.760**	0.412**	0.316**	0.411**
Ex.-K		-	0.806**	0.472**	0.422**
NEx-K			-	0.383**	0.494**
Lattice-K				-	0.992**
Total-K					-

4. Conclusions
The texture of the soils of mustard growing field's varied from sandy clay loam to clay loam. Soils were neutral to slightly alkaline in nature with having normal electrical conductivity and calcium carbonate content. Most of the samples (>75) of these three districts showed low category of organic carbon status (< 0.5%) in soil. The amount of water soluble, exchangeable and non-exchangeable-K ranged from 4.18 – 22.70, 62.5 – 326.2 and 444.0 – 1987.0 mg kg^{-1} with the mean value of 11.35,152.4 and 972.2 mg kg^{-1} and contributed 0.086, 1.16 and 7.40% towards total-K.A highly significantly and positively relationship were observed between different forms of K, These relationships indicate that there existed equilibrium between these forms of K and depletion of one is instantly replenished by one or more of the other forms of K.

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