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Hemlata Dhakad
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Shashi S Yadav
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Shweta Jamra
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Vinay Arya
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Kalpana Sharma
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Dharmendra Gaur
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Correspondence
Hemlata Dhakad
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, MP, India

Status and Distribution of Different Forms of Potassium in Soils of Gwalior District (M.P.)

Hemlata Dhakad, Shashi S Yadav, Shweta Jamra, Vinay Arya, Kalpana Sharma and Dharmendra Gaur

Abstract
The study was carried out during 2015-16 in Gwalior district (M.P.) having 120 GPS based surface soil samples (0-15 cm) collected from twenty three villages of four blocks (Dabra, Bhitarwar, Ghatigoan and Morar) of Gwalior district. The samples were prepared and analyzed for physico-chemical properties and different forms of potassium. The average shares of lattice potassium, non-exchangeable, exchangeable and water soluble potassium in the 'total' potassium were more than 90% (94.67%), 3.70%, 1.55% and 0.102% respectively. The results showed that the average values for water soluble-K, exchangeable-K, non-exchangeable-K, lattice-K and total K were: 15.1, 230.5, 548.4 mg /kg, 1.403% and 1.482%, respectively. Soils were neutral to slight alkaline with normal EC and $CaCO_3$, having texture sandy clay loam to clay loam. The Correlation of different forms of potassium was positively correlated with OC, EC, and clay content. Similarly highly significant and positive relationship was 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 constituent of the earth crust contained more in igneous rocks than the sedimentary rocks. Potassium 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 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. More than 98% of the total potassium reserve in soils and exists in inorganic combinations which can further be characterized as: water soluble K, exchangeable K, non-exchangeable K and lattice K. Exchangeable potassium, which is held by the negative charges on exchange site of clay and organic matter. the amount of water soluble potassium is too low to meet the requirement of K by crops, while exchangeable K is often large enough to satisfy the requirement of one crop, but too small to meet the needs of several crops (Sparks and Huang, 1985) [8]. Knowledge of different forms of potassium in soil together with their distribution is great relevance in assessing the long-term availability of potassium to crops and in formulating a sound basis of fertilizer recommendation. There are equilibrium and kinetic reactions between these forms that affect the level of soluble potassium at any particular time and thus, the amount of readily available potassium for plants. There is a paucity of information on the status of different forms of potassium in different blocks of Gwalior district (M.P.). With this view, the present study was planned to know the relationship of different forms of potassium with soil properties and relationship amongst different forms of potassium.

2. Method and material

For the present investigation, 120 GPS based (Latitude $26^0 00'02.19"$- $26^0 59'58.39"$ and longitude $78^0 01'40.11.4"$- $78^0 24'10.70"$) soil samples each from surface (0-15cm) were collected from four blocks of Gwalior district. At each location soil was collected from four places, mixed thoroughly and reduces to get a representative sample by quartering. The soil samples were collected, air dried ground to pass through a 2 mm sieve. The soil samples were analyzed for pH and electrical conductivity using standard methods suggested by Jackson (1973) [5], soil organic carbon by Walkley-Black (1934) [11] and $CaCO_3$ by Piper (1950) [7]. The percentage of different sizes that is sand, silt and clay was determined by mechanical analysis of soil, (Representive soil samples were analyzed by Bouyoucos Hydrometer method

(Bouyoucos, 1951) [2]. Total potassium was extracted by digestion with a mixture of HF (hydrofluoric acid) 48%, H_2SO_4 97% and concentrated $HClO_4$ (per chloric). Water soluble potassium was determined by shaking the soil with distilled water in 1:5 ratio, Black (1965) [1]. Exchangeable potassium was extracted by 1N ammonium acetate solution (in 1:5 soil extract ratio), Non-exchangeable potassium was extracted by 1N HNO_3, Exchangeable and non-exchangeable–K was determined as per procedure advocated by Black (1965) [1]. Mineral potassium was calculated by the formula that was suggested by Martin and Sparks in 1983.

Mineral K = Total K – (Ex.-K + Non Ex.-K)

Correlations between different forms of K and soil properties were worked out by the procedure described by Panse and Sukhatme (1950) [6].

3. Result

3.1 Physico-chemical properties of soil

The physico-chemical characteristics of the soil samples are shown in Table 1. The results indicate that, the EC of the soil ranged from 0.24 to 0.66 dSm.$^{-1}$A majority of the soils was non calcareous in nature. The pH values ranged between from 7.10 to 8.70, indicating that the soils are neutral to slightly alkaline in reaction. The organic carbon content in soil ranged from 0.16 to 0.66% with average value of 0.43%. 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. The Calcium carbonate content in soil samples ranged from 0.50-4.50. The texture of the soils ranged from sandy clay loamy to clay loam.

Table 1: Physico-chemical properties and texture of soil

Soils	pH (1:2)	EC (dSm^{-1}) (1:2)	OC (%)	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)
Dabra	7.10-8.50	0.31-0.62	0.35-0.66	0.50-3.50	50.8-67.6	8.1-26.3	16.3-31.3
Bhitarwar	7.20-8.20	0.24-0.62	0.36-0.52	0.50-3.50	47.6-64.7	4.9-30.8	18.5-33.5
Ghatigoan	7.10-8.30	0.29-0.66	0.16-0.64	0.50-4.50	50.8-67.6	13.2-28.0	18.4-30.3
Morar	7.10-8.70	0.28-0.62	0.34-0.46	0.50-3.00	52.4-64.4	9.3-25.0	18.4-28.4
As a whole district	7.10-8.70	0.24-0.66	0.16-0.66	0.50-4.50	47.6-67.6	4.9-30.8	16.3-33.5

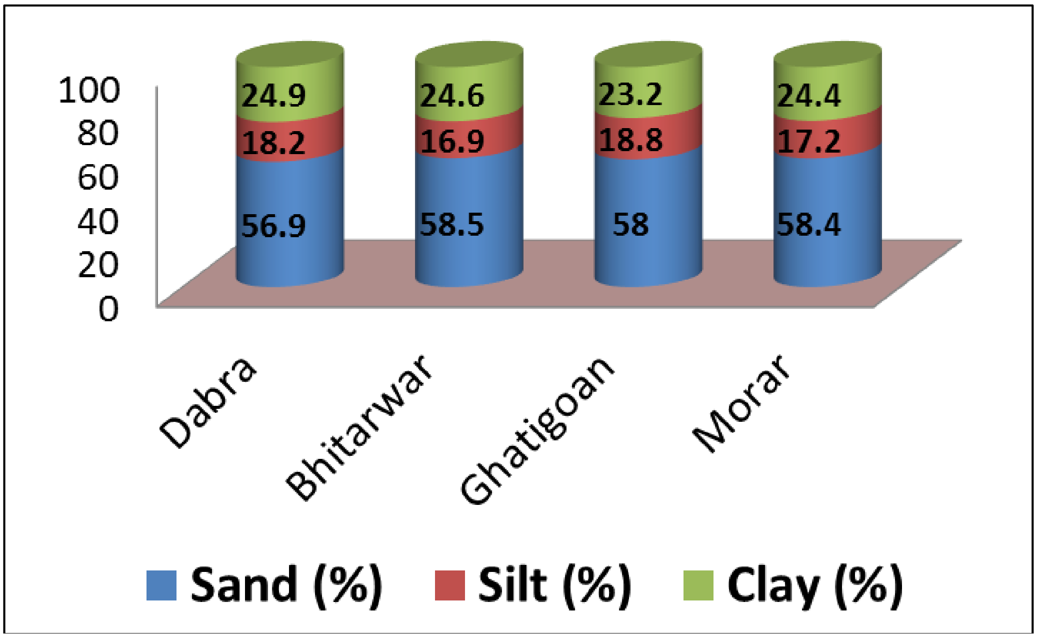

Fig 1: Mechanical Composition of the soils of Gwalior district

3.2 Content of different potassium forms

The content of different potassium forms in the studied soil samples are displayed in Table 2.

Table 2: Distribution of different forms of K in different soil samples of Gwalior

Soils	WS-K (mg kg^{-1})	Ex.-K (mg kg^{-1})	Non-Ex.-K (mg kg^{-1})	Lattice-K (%)	Total-K (%)
Dabra	8.0-26.4 (15.9)	115.2-320.0 (230.4)	372.2-965.4 (532.1)	1.159-1.729 (1.411)	1.233-1.859 (1.488)
Bhitarwar	7.2-21.2 (13.0)	158.5-330.2 (251.5)	365.0-879.0 (623.9)	1.072-1.554 (1.400)	1.127-1.665 (1.489)
Ghatigoan	10.3-25.8 (16.4)	173.2-326.2 (229.4)	290.4-796.5 (541.3)	1.254-1.605 (1.421)	1.302-1.720 (1.499)
Morar	12.1-22.7 (15.3)	176.9-265.9 (210.7)	356.2-652.2 (496.5)	1.251-1.562 (1.381)	1.317-1.648 (1.453)
As a whole district	7.2-26.4 (15.1)	115.2-330.2 (230.5)	290.4-965.4 (548.4)	1.072-1.729 (1.403)	1.127-1.859 (1.482)

- Note: WS-K= Water Soluble K; Ex-K= Exchangeable K; Non.-Ex-K= Non-exchangeable K
- Figures in parentheses represent the mean values

Table 3: correlation coefficient between forms of potassium and soil properties

Soil properties/ Forms of K	pH	EC	OC	$CaCO_3$	Sand	Silt	Clay
WS-K	-0.054	0.388**	0.243*	-0.225*	-0.279**	-0.063	0.424**
Ex-K	-0.288**	0.444**	0.357**	-0.456**	-0.348**	-0.158	0.629**
Non-Ex-K	-0.259**	0.266**	0.246*	-0.300**	-0.161	-0.155	0.406**
Lattice-K	-0.052	0.261**	0.150	-0.274**	-0.145	-0.031	0.201*
Total-K	-0.089	0.281**	0.167	-0.295**	-0.162	-0.033	0.245*

*Significant at 5%, **Significant at 1% levels

Table 4: Correlation matrix between different forms of potassium

Forms of K	WS-K	Ex.-K	Non-Ex-K	Lattice-K	Total-K
WS-K	-	0.583**	0.367**	0.342**	0.371**
Ex.-K		-	0.668**	0.415**	0.481**
NEx-K			-	0.639**	0.706**
Lattice-K				-	0.995**
Total-K					-

3.3 Water soluble K
water soluble potassium (H_2O-K) in the studied soil samples ranged between from 7.2 – 26.4 mg kg^{-1} under different blocks with an average value of 15.1 mg $kg^{-1}$and contributed only 0.102% of total-K. Maximum average value of water soluble K (16.4 mg kg^{-1}) was observed in Ghatigoan block whereas minimum value (13.0 mg kg^{-1}) was found in Bhitarwar block of Gwalior district. Correlation study (Table 3) of different forms with soil properties showed that water soluble potassium was significantly and positively correlated with EC (r= 0.388**), organic carbon (r=0.243*), and clay (r=0.424**) content whereas negatively correlated with pH (r=-0.054), silt (-0.063) and sand (r=-0.279**). It is interesting to note that the sand fraction was negatively and significantly correlated with all forms of potassium. This may be due to less content of potassium bearing minerals in sand fractions. Water soluble K data was correlated with different fractions of K (Table 4) and observed that it was highly and significantly correlated with exchangeable potassium (r=0.583**), non-exchangeable potassium (r=0.367**), lattice potassium (0.342**) and total potassium (r=0.371**). Similar results were also reported by Das *et al.* (2000) [3]. The better correlation of these forms of potassium with other forms indicates that the water soluble potassium was governed by the other forms of potassium like nonexchangeable and total potassium.

3.4 Exchangeable-K
The content of exchangeable potassium as shown in Table 2 ranged between 115.2 – 330.2 mg kg^{-1} under different blocks with an average value of 230.5 mg kg^{-1} which accounted for 1.55% of total-K. Maximum average value of exchangeable-K (251.5 mg kg^{-1}) was observed in Bhitarwar block whereas minimum value (210.7 mg kg^{-1}) was found in Morar block of Gwalior district. The high values of exchangeable potassium in soil of Bhitarwar block may be due to high content of clay fraction with the presence of vermiculite and mica-vermiculite minerals. The values of correlation coefficient of exchangeable K with soil properties showed that exchangeable K was significantly and positively correlated with EC (r= 0.444**), organic carbon (r=0.357**), and clay (r=0.629**) content whereas negatively correlated with pH (r=-0.288**), $CaCO_3$ (-0.456**), sand (r=-0.348**) and silt (-0.158). Das *et al.* (2000) [3] also observed similar type observation in their studies. Exchangeable K was highly and significantly correlated with other forms of potassium (Table 3) i.e. water soluble potassium (r=0.583**), nonexchangeable potassium (r=0.668**), lattice potassium (0.415**) and total potassium (r=0.481**). The present findings are in similar line as that of Saini and Grewal (2014) [13].

3.5 Non-exchangeable-K
Acid (HNO_3) extractable potassium, which is used as an index of non-exchangeable potassium and represents the supplying power of potassium for long-term cropping are shown in Table 2. The values of this form showed a wide variation and ranging from 290.4 – 965.4 mg kg^{-1} under different blocks with an average value of 548.4 mg kg^{-1} and contributed to 3.70% of total-K. Maximum average value of non-exchangeable - K (623.9 mg kg^{-1}) was observed in Bhitarwar block whereas minimum value (496.5 mg kg^{-1}) was found in Morar block of Gwalior district. Non-exchangeable-K is generally considered slowly released and available potassium to the plant under stress situations. Correlation study (Table 3) of non-exchangeable-K with soil properties showed that it was significantly and positively correlated with EC (r=0.266**), organic carbon (r=0.246*) and clay (r=0.406**) content whereas negatively correlated with pH (r=-0.259**), $CaCO_3$ (-0.300**), sand (r=-0.161) and silt (-0.155) Sharma *et al.* (2009) [10] also observed similar type of correlation in their soils. The clay fraction was positively correlated with all forms of potassium. This may be due to high content of potassium bearing minerals in clay fraction. The non-exchangeable K was found to be positive and significantly correlated to water soluble potassium (r=0.367**), exchangeable potassium (r=0.668**), lattice potassium (0.639**) and total potassium (r=0.706**). This means that whenever fixed potassium was released, changed to available forms, there will be a simultaneous release of potassium from structural forms.

3.6 Lattice potassium
The values of mineral potassium showed a wide variation in the studied soil samples, ranging from 1.072 – 1.729% under different blocks with an average value of 1.403% which accounts more than 90% of the total –K. Maximum average value of lattice- K (1.421%) was observed in Ghatigoan block whereas minimum value (1.381%) found in Morar block of Gwalior district (Table 2). The content of this K-form depends on soil type, type of primary and secondary minerals and the degree of weathering (Sharpley, 1987) [9]. The lower values of percentage of mineral-K of total-K indicate a relatively high degree of weathering of K-bearing minerals and vice versa.

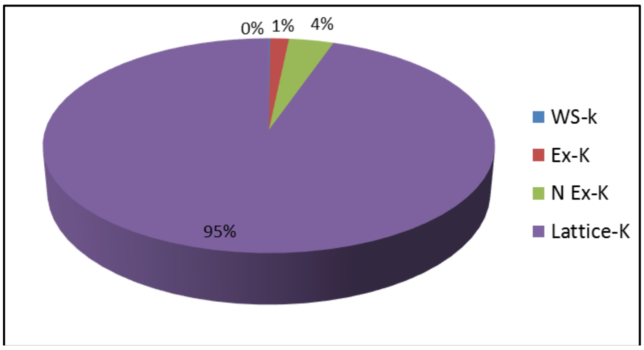

Fig 1: Contribution of different forms of potassium in total –K

3.7 Total-K

The values of total potassium in the studied soil samples showed a very wide variation. 1.127 – 1.859% under different blocks with an average value of 1.482% (Table 2). Maximum average value of total-K (1.499%) was observed in Ghatigoan block whereas minimum value (1.453%) found in Morar block of Gwalior district. The content of total potassium depends on the type of parent material, type of primary and secondary minerals and type of soil fraction. The total-K was significantly and positively correlated with EC (r=0.281**), clay (r=0.245*) and non-significantly correlated with organic carbon (r=0.167) content whereas negatively correlated with pH (r=-0.089), $CaCO_3$ (-0.295**), sand (r=-0.162) and silt (-0.033). These relationships confirmed that the finer fractions of the soils are in primary sources of potassium in the soils of Gwalior (MP). 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. Similar results were also reported by Dinagaran *et al*. (2006) [4]. Total-K showed a highly positive and significant correlation with other forms i.e. water soluble potassium (r=0.371**), exchangeable potassium (r=0.481**), nonexchangeable potassium (r=0.706**) and lattice potassium (0.995**). The above relationship confirmed that availability of exchangeable, nonexchangeable and total potassium could significantly determine potentially available potassium in these soils. Similar results were obtained by Yadav *et al*. in Vertisols of Madhya Pradesh.

4. Conclusion

The texture of the soils of Gwalior district 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. Organic carbon was found in the range of 0.16-0.66% under different villages with the average value of 0.43%. Most of the villages of Gwalior district showed low category of organic carbon status (<0.5%). 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 of 1.072-1.729 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. In general, organic carbon and clay content of the soils of Gwalior district shows positive relationship with all the forms of potassium, whereas, sand and soil pH show negative relationship. A highly significant and positive 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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