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Sonu Kori
College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India

SK Singh
Scientist K.V.K. RVSKVV, Gwalior, Madhya Pradesh, India

Rahul Morya
College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India

Sulekha Keshri
College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India

Hemlata Dhakad
College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India

BK Rajput
College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India

Correspondence
Sonu Kori
College of agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India

Status and distribution of different forms of potassium in soils of Ashoknagar district (M.P.)

Sonu Kori, SK Singh, Rahul Morya, Hemlata Dhakad, Sulekha Keshri and BK Rajput

Abstract
The study was conducted during 2016-17 at Ashoknagar district (M.P.) having 150 GPS based surface soil samples (0-15 cm) collected from five blocks (namely; Mungaoli, Chanderi, Ishagarh, Ashoknagar and sadora) of Ashok Nagar 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%, 4.0%, 1.0% and 0.4% respectively. The results showed that the average values for water soluble-K, exchangeable-K, non-exchangeable-K, lattice-K and total K were: 17.6, 161.1, 614.8 mg /kg, 1.334% and 1.409%, respectively. Highly significant and positive relationship was observed between different forms of K.

Keywords: Water soluble K, Exchangeable K and Non-exchangeable K

Introduction
Potassium (K) plays a particularly crucial role in a number of physiological processes vital to growth, yield, quality, and stress resistance of all crops. K constitutes about 2.1–2.3% of the earth's crust and thus is the seventh or eighth most abundant element (Wedepohl, 1995) [17]. The availability of K differs greatly with soil type and is affected by physico-chemical properties of the soil. Based on the degree of availability to crops, soil potassium can be classified into four forms i.e. soil solution K, exchangeable K, non-exchangeable K and mineral K (Darunsontaya *et al*., 2012) [4]. The primary source of potassium absorbed by plant roots is that which is present in soil solution. The concentration of the readily available K forms are relatively small at any time and do not provide a good indication long term ability of soils to supply K to plants (Jibrin, 2010) [7]. Exchangeable potassium, which is held by the negative charges on soil clay and organic matter exchange sites, soil solution and exchangeable potassium are in equilibrium and collectively known as the readily available potassium pool (Shaikh *et al*., 2007) [11]. Fixed –K which is trapped between layers of expanding lattice clays and lattice –K, an integral part of primary K bearing minerals (Tisdale *et al*. 1985) [15]. Because of continuous removal of potassium by crop uptake and leaching in sandy soil, the static equilibrium among different K fractions in soil is probably never obtained. There is a continuous but slow transfer of potassium in the primary minerals to the exchangeable and slowly available forms. It is thus imperative to have precise information on all these forms for an appraisal of K supplying power of a particular soil. The three forms of soil potassium are unavailable, slowly available or fixed, and readily available or exchangeable potassium. Plant cannot use the potassium in these insoluble forms over long period. 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.

Method and Material
For the present investigation, 150 GPS based (24°34′48″ N and 77°43′48″E with average elevation of 507 meters (1640 ft.) above sea level) surface soil samples (0-15cm) were collected from five blocks (namely- Mungaoli, Chanderi, Isagarh, Ashoknagar and Sadora) of Ashoknagar 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. 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 were worked out by the procedure described by Panse and Sukhatme (1954).

Result

Content of different potassium forms

The content of different potassium forms in the studied soil samples are displayed in Table 1 and 2.

Table 1: Distribution of water soluble and exchangeable-K in different soil samples of Ashoknanar

Soils	WS-K (mg kg^{-1})		Ex.-K (mg kg^{-1})	
	Range	Mean	Range	Mean
Mungaoli (30)	9.5 – 25.5	15.9	102.0 – 177.0	152.5
Chanderi (30)	12.0 – 26.8	13.0	122.5 – 202.25	166.2
Isagarh (30)	11.5 – 26.3	16.4	127.2 – 211.0	172.1
Ashoknanar (30)	9.4 – 23.6	15.3	101.5 – 187.0	154.5
Sadora(30)	10.0-26.1	17.1	107.5-205.0	160.0
As a whole district	9.4 – 26.8	17.6	101.2 – 205.0	161.1

Note: WS-K= Water Soluble K; Ex-K= Exchangeable K; Non.-Ex-K= Non-exchangeable K

Water Soluble K: water soluble potassium (H_2O-K) in the studied soil samples ranged between from 9.4 – 26.8 mg kg^{-1} under different blocks with an average value of 17.6 mg kg^{-1}and contributed only 0.4 % of total-K. Maximum average value of water soluble K (17.1 mg kg^{-1}) was observed in Sadora block whereas minimum value (13.0 mg kg^{-1}) was found in Chanderi block of Ashoknanar district. Exchangeable-K: The content of exchangeable potassium as shown in Table 1 ranged between 101.2 – 205.0 mg kg^{-1} under different blocks with an average value of 161.1mg kg^{-1} which accounted for 1.0 % of total-K. Maximum average value of exchangeable- K (172.1mg kg^{-1}) was observed in Isagarh block whereas minimum value (152.5 mg kg^{-1}) was found in Mungaoli block of Ashoknanar district.

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 was presented in Table 2. The values of this form showed a wide variation and ranging from 300.0 – 950.0 mg kg^{-1} under different blocks with an average value of 614.8 mg kg^{-1} and contributed to 4.0 % of total-K. Maximum average value of non-exchangeable - K (691.1mg kg^{-1}) was observed in Isagarh block whereas minimum value (564.8 mg kg^{-1}) was found in Mungaoli block of Ashoknanar district. Non-exchangeable-K is generally considered slowly released and available potassium to the plant under stress situations.

Table 2: Distribution of Non- Exchangeable, Lattice and Total-K in different soil samples of Ashoknanar

Soils	Non-Ex. K (mg kg^{-1})		Lattice-K (%)		Total-K (%)	
	Range	Mean	Range	Mean	Range	Mean
Mungaoli (30)	315.1 – 860.2	564.8	1.012 – 1.546	1.342	1.010 – 1.620	1.389
Chanderi (30)	340.0 – 940.3	623.9	1.018 – 1.677	1.290	1.020 – 1.740	1.361
Isagarh (30)	350.4 – 940.0	691.1	1.019 – 1.754	1.430	1.102 – 1.820	1.520
Ashoknanar (30)	300.0 – 850.2	570.7	1.082 – 1.529	1.244	1.107– 1.594	1.352
Sadora(30)	300.1-950.0	601.1	1.042-1.582	1.362	1.134-1.650	1.424
As a whole district	300.0 – 950.0	614.8	1.012 – 1.754	1.334	1.010 – 1.820	1.409

Lattice Potassium

The values of mineral potassium showed a wide variation in the studied soil samples, ranging from 1.012 – 1.754 % under different blocks with an average value of 1.334 % which accounts more than 90% of the total –K. Maximum average value of lattice- K (1.430 %) was observed in Isagarh block whereas minimum value (1.244 %) found in Ashoknanar block of Ashoknanar 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) [13]. 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.

Total-K: The values of total potassium in the studied soil samples showed a very wide variation. 1.010 – 1.820 % under different blocks with an average value of 1.409 % (Table 2). Maximum average value of total-K (1.520 %) was observed in Isagarh block whereas minimum value (1.352 %) found in Ashoknanar block of Ashoknanar district. The content of total potassium depends on the type of parent material, type of primary and secondary minerals and type of soil fraction.

Correlation matrix of different forms of potassium

Water soluble K: Water soluble K was correlated with different fractions of K (Table 3) and observed that it was highly and significantly correlated with exchangeable potassium (r=0.557**), non-exchangeable potassium (r=0.363**), lattice potassium (0.442**) and total potassium (r=0.471**). Similar results were also reported by Das *et al.* (2000). 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 non-exchangeable and total potassium.

Exchangeable K: Ex-K was highly and significantly correlated with other forms of potassium (Table 3) i.e. water soluble potassium (r=0.557**), non-exchangeable potassium

(r=0.868**), lattice potassium (0.605**) and total potassium (r=0.681**). The present findings are in similar line as that of Saini and Grewal (2014) [10].

Non-exchangeable K: Non-Ex K was found to be positive and significantly correlated to water soluble potassium (r=0.363**), exchangeable potassium (r=0.868**), lattice potassium (0.569**) and total potassium (r=0.566**). This means that whenever fixed potassium was released, changed to available forms, there will be a simultaneous release of potassium from structural forms.

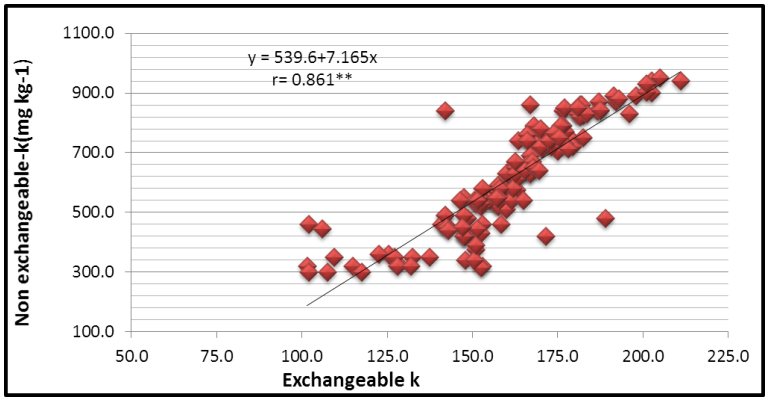

Fig 1: Relationship between exchangeable and non-exchangeable-K

Total-K: Toal K Showed a highly positive and significant correlation with other forms i.e. water soluble potassium (r=0.471**), exchangeable potassium (r=0.681**), non-exchangeable potassium (r=0.566**) and lattice potassium (0.983**). The above relationship confirmed that availability of exchangeable, non-exchangeable and total potassium could significantly determine potentially available potassium in these soils. Similar results were obtained by Yadav *et al.* (1999) [18] in Vertisols of Madhya Pradesh.

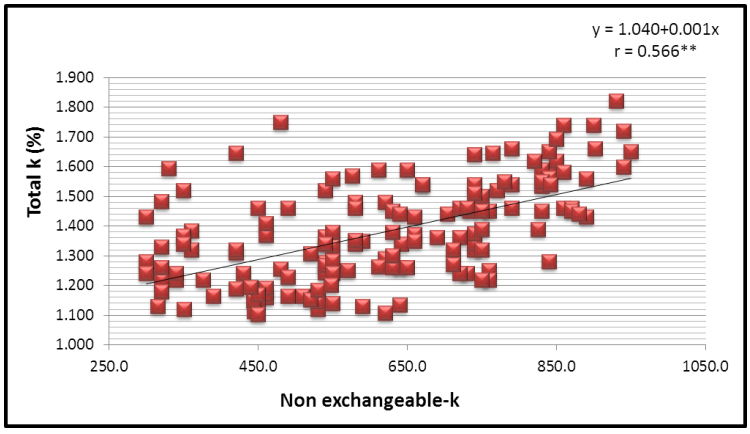

Fig 2: Relationship between non exchangeable-K and Total-K

Table 3: Correlation matrix of different forms of potassium

	WS-K	Ex.-K	N Ex-K	Lattice-K	Total-K
WS-K	-	0.557**	0.363**	0.442**	0.471**
Ex.-K		-	0.868**	0.605**	0.681**
NEx-K			-	0.569**	0.566**
Lattice-K				-	0.983**
Total-K					-

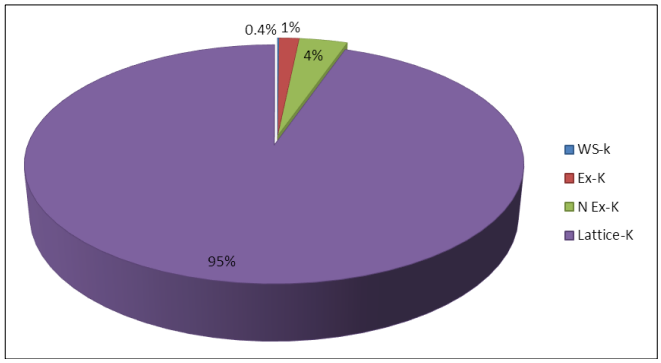

Fig 3: Contribution of different forms of potassium in total –K

Conclusion

The amount of water soluble, exchangeable and non-exchangeable-K in different villages of Ashoknanar district, ranged from 9.4 – 26.8, 101.2 – 205.0 and 300.0 – 950.0 mg kg^{-1} with the mean value of 17.6, 161.1 and 614.8 mg kg^{-1} respectively. These forms contributed 0.4, 1.0 and 4.0 % towards total-K, Whereas Lattice and total-K found in the range of 1.012 – 1.754 and 1.010 – 1.820 % with the mean value of 1.334 and 1.409 % respectively. Lattice-K contributed maximum (95 %) towards total-K. 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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