Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 10 Issue 4 April 2026

Research Article

Potassium Fractions Study in Surface Soils of Ballia District

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DOI: 10.31080/ASAG.2026.10.1553

Received: April 07, 2026

Published: April 15, 2026

Abstract

A fractionation study for potassium was conducted in surface soil of Ballia district, U.P. by collection of surface soil samples by prepared composite soil samples from five village of 17 blocks and analyses K fraction- NH_4OAc extractable K, water soluble K, exchangeable K, non-exchangeable K, fixed K or lattice K, total K, 0.01 M $CaCl_2$ extractable K, HNO_3 soluble K, 1M NaCl extractable K, Mehlich-III extractable K, EDTA extractable K (mg/kg) in the laboratory of Agricultural Chemistry and Soil Science, Department of Shri Murali Manohar Town P.G. College, Ballia. Most of the soils were light textured soils from 17 different blocks of Azamgarh district were collected and analyzed for surface soil potassium fractions. The soils were neutral to slight alkaline in nature. The distribution of different forms of potassium fraction was NH_4OAc extractable-K 27.36 to 138.02, water soluble K 45.36 to 102.54, exchangeable K 22.58 to 75.38), non-exchangeable K (189.35 to 492.36), fixed K or lattice K (45.67 to 91.54), total K (732.58 to 941.02), 0.01 M $CaCl_2$ extractable K (117.57 to 157.58), HNO_3 soluble K (66.05 to 126.89), 1M NaCl extractable K (104.87 to 131.58), Mehlich-III extractable K (104.93 to 139.75) and EDTA extractable K (88.35 to 123.58) in different surface soils respectively. Among the different fraction of K total-K, non-exchangeable K, 0.01 M $CaCl_2$ extractable K, Mehlich-III extractable K, 1M NaCl extractable K, Available K, EDTA extractable K were observed in greater concentration while of Exchangeable K, HNO_3 soluble K, Water soluble, Fixed K or lattice K were observed comparatively in small concentration.

Keywords: Potassium Fractions; Surface Soil; Extractants; Different Blocks

Introduction

It has been established that K is a quality nutrient element for plants and act as a traffic police man of chemical reaction in plants. It's playing an important role in increasing the production and improving the quality of crops and vegetables. Soil potassium is found in different forms viz. solution, exchangeable, non-exchangeable, mineral and total K. There are many 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 (Sparks, 2001). Potassium is found in soils in various forms and combination; in soil it is difficult to ascertain because of its interaction with various intrinsic and extrinsic properties of soil. The direction of rate of reactions determines the rate of applied K and release of non-exchangeable K (Singh., *et al.* 2004). A number of extractants have been used from time to time to assess quantitatively the available

K. In soils, potassium exists in different forms viz. water soluble, exchangeable, non-exchangeable and lattice potassium. The water soluble and exchangeable together constitutes the plant available potassium. Plants take up K from soil solution which is readily replenished by soil exchangeable K. Some non-exchangeable K can be come exchangeable when solution and exchangeable K are depleted by plant removal, leaching, or exchange reactions with other cations. Distribution of K among these forms are also occurs as K added in soil as fertilizer, manure, or crop residues. It has long been recognized that wetting-drying and freezing-thawing cycles influence transformations of K between non-exchangeable, exchangeable and solution phases. It is known that potassium content in Indian soils varies from 0.5 % to 3.00% [8] keeping in view on the above facts the present study initiated on different fraction of K in soil.

Materials and Methods

The experimental area Ballia district was lies between the parallels of 26° 4' 19.4412'' N latitude and 83° 11' 8.3544'' E longitude and 59 -64 meter above the sea elevation and mean annual rain fall ranges from 940-1100 mm.

Soil sampling

Soil samples were collected from a depth of 0-15 cm, were obtained from the farmer's fields across various village of Ballia district, Bairia, Bansdih, Belhari, Beruarwari, Chilkahar, Dubhad, Garwar, Hanumanganj, Maniyar, Murali chhapra, Nagara, Navanagar, Pandah, Rasara, Revati, Sear, Sohaon in the Ballia district. The samples were air-dried, ground using a wooden mortar, sieved through a 2 mm mesh, and subsequently stored in polythene bags for further analysis.

Determination of various forms of potassium in the soil samples

The various potassium fractions such as Water-soluble K, Exchangeable K, Non-exchangeable K, Total K, Fixed K or lattice K, HNO_3 soluble K, 1M NaCl extractable K, Mehlich-III extractable K, Mehlich-III extractable K, EDTA extractable K and 0.01 M $CaCl_2$ extractable K. Water soluble (mg kg^{-1}) -Water soluble method described by Rouse and Bertramson (1949), Exchangeable K (mg kg^{-1})-The exchangeable K was determined by neutral normal NH_4OAc described by Jackson (1973). Non-exchangeable K (mg kg^{-1}) -Non-exchangeable K was determined by the extraction of soil with boiling 1M HNO_3 (Jackson (1976), Total K (mg/kg)-Total potassium was estimated as per the method suggested by Pratt (1951). Fixed K or lattice K(mg/kg). HNO_3 soluble K (mg/kg) - Nitric acid described by Wood and Deturk (1940). 1M NaCl extractable K-Sodium chloride method described by Scott., *et al.* (1960). Mehlich-III extractable K-Mehlich-III method described Mehlich, A (1984). EDTA extractable K-EDTA method described by Haynes and Swift (1983). 0.01 M $CaCl_2$ extractable K-Calcium chloride method described by Woodruff and McIntosh (1960).

Results and Discussion

The various fractions of potassium such as Water-soluble K, Exchangeable K, Non-exchangeable K, Total K, Fixed K or lattice K, HNO_3 soluble K, 1M NaCl extractable K, Mehlich-III extractable K, Mehlich-III extractable K, 0.01 M $CaCl_2$ extractable K and EDTA extractable K is presented in table-1.

Name of Blocks	NH_4OAc (mg/kg)	Water Soluble K (mg/kg)	Exchangeable K (mg/kg)	Non-Exchangeable Potassium (mg/kg)	Fixed K or lattice Potassium (mg/kg)	Total Potassium (mg/kg)
Bairia	105.39	75.33	29.75	270.58	52.33	732.58
Bansdih	102.54	86.33	41.35	259.57	52.38	895.54
Belhari	124.98	94.06	38.75	351.29	79.75	937.21
Beruarwari	128.05	84.29	75.29	449.35	58.36	941.02
Chilkahar	96.35	102.54	56.12	189.35	61.08	766.58
Dubhad	135.05	48.36	49.37	492.36	75.36	835.84
Garwar	128.46	75.05	48.58	478.02	51.87	815.47
Hanumanganj	98.02	69.87	75.38	243.07	86.31	866.54
Maniyar	104.38	45.36	22.58	275.68	64.13	735.20

Murali chhapra	89.31	75.39	42.57	287.36	58.37	768.25
Nagara	87.36	86.57	45.75	255.29	75.47	898.36
Navanagar	135.02	87.28	38.42	351.08	91.54	936.51
Pandaha	128.04	79.15	75.21	469.08	64.81	931.05
Rasara	104.37	15.37	39.54	199.34	49.68	794.12
Revati	123.05	45.28	29.05	489.08	67.43	835.12
Sear	138.02	78.57	46.35	475.38	45.67	822.58
Sohaon	98.47	65.15	67.02	253.05	66.35	859.22
Mean	113.34	71.40	48.29	340.52	64.75	845.36

Table 1: Amount of Potassium fractions in surface soils of Ballia district.

NH_4OAc extractable K (mg/kg)

The NH_4OAc extractable K value (table-1) in soil varied from 27.36 to 138.02 mg/kg. The available potassium in surface soil samples from different blocks of Ballia disrict was in Bairia 105.39 mg/kg mg/kg, Bansdih 102.54 mg/kg, Belhari 124.98 mg/kg, Beruarwari 128.05 mg/kg, Chilkahar 96.35 mg/kg, Dubhad 135.05 mg/kg, Garwar 128.46 mg/kg, Hanumanganj 98.02 mg/kg, Maniyar 104.38 mg/kg, Murali chhapra 89.31 mg/kg, Nagara 87.36 mg/kg, Navanagar 135.02 mg/kg, Pandah 128.04 mg/kg, Rasara 104.37 kg ha^{-1} mg/kg, Revati 123.05 mg/kg, Sear 138.02 mg/kg, Sohaon 98.47 mg/kg respectively. The average value of NH_4OAc extractable K of Ballia district was 113.34 kg ha^{-1}. NH_4OAc extractable K in the surface soils (0–15 cm) of Ballia districts (part of the Indo-Gangetic Alluvial Plain) generally ranges from low to medium. The spatial variation, showing increasing or decreasing trends across different blocks, might be due to combination of natural soil properties (mineralogy, texture) and, more significantly, intensive and human agricultural practices [13].

Water soluble (mg kg^{-1})

The water-soluble K (table-1) was ranged between 45.36 to 102.54 mg/kg. The content was in Bairia block 75.33 mg/kg, Bansdih 86.33 mg/kg, Belhari 94.06 mg/kg, Beruarwari 84.29 mg/kg, Chilkahar 102.54 mg/kg, Dubhad 48.36 mg/kg, Garwar 75.05 mg/kg, Hanumanganj 69.87 mg/kg, Maniyar 45.36 mg/kg, Murali Chhapra 75.39 mg/kg, Nagara 86.57 mg/kg, Navanagar 87.28 mg/kg, Pandah 79.15 mg/kg, Rasara 85.37 mg/kg, Revati 75.28 mg/kg, Sear 78.57 mg/kg, Sohaon 65.15 mg/kg respectively. The average value of water-soluble K of Ballia district was 71.40 mg/kg. Surface soil in Azamgarh district exhibits variable Water-Soluble Potassium, mostly influenced by fertilizer application, clay content, and cropping intensity. Increases often occur in top soil due to crop residues and added fertilizers, while decreases result from high crop uptake, leaching, and low soil organic carbon [13].

Exchangeable K (mg kg^{-1})

The Exchangeable K (table-1) in surface soil was ranged from 22.58 to 75.38 mg/kg. The content was in Bairia block 29.75 mg/kg, Bansdih 14.35 mg/kg, Belhari 38.75 mg/kg, Beruarwari 75.29 mg/kg, Chilkahar 56.12 mg/kg, Dubhad 49.37 mg/kg, Garwar 48.58 mg/kg, Hanumanganj 75.38 mg/kg, Maniyar 22.58 mg/kg, Murali chhapra 42.57 mg/kg, Nagara, 45.75 mg/kg Navanagar 38.42 mg/kg, Pandah 75.21, Rasara 39.54 mg/kg, Revati 29.05 mg/kg, Sear 46.35 mg/kg, Sohaon 67.02 mg/kg respectively. The average value of exchangeable K of Garwar block was 48.29 mg/kg. In the surface soils (0-15 cm) of Ballia district, water-soluble potassium is generally higher due to nutrient recycling, organic matter accumulation, and fertilizer application, but varies based on cropping intensity, clay content, and weathering. It decreases in deeper profiles due to lower root density and decreased organic matter, with concentrations typically in the range [13].

Non-exchangeable K (mg kg-1)

The Non-exchangeable K value (table-1) in soil varied from 189.35 to 492.36 mg/kg. The content was showed in Bairia block 270.58 mg/kg, Bansdih 259.57 mg/kg, Belhari 351.29 mg ha^{-1}, Beruarwari 449.35 mg/kg, Chilkahar 189.35 mg/kg, Dubhad 492.36 mg/kg, Garwar 478.02 mg/kg, Hanumanganj 243.07 mg/kg, Maniyar 275.68 mg/kg, Murali chhapra 287.36 mg/kg, Nagara 255.29 mg/kg, Navanagar 351.08 mg/kg, Pandah 469.08 mg/kg, Rasara 199.34 mg/kg, Revati 489.08 mg/kg, Sear 475.38 mg/kg, Sohaon 253.05 mg/kg, respectively. The average value of

non-exchangeable K of Ballia district was 340.52 mg/kg. In the alluvial soils of the Ballia districts of eastern Uttar Pradesh, the non-exchangeable Potassium acts as a crucial long-term reserve, generally falling in the medium to high range. It was of potassium is tapped between layers of clay minerals (primarily elite) and slowly released to replace exchangeable K depleted by plant uptake. The fluctuation (increasing or decreasing) of content might be due to dynamic equilibrium between potassium pools, driven by farming practices and soil properties. The similar finding has been given by [1].

Fixed K or lattice K (mg/kg)

The fixed K or lattice K was observed in table-1 in which soil varied from 45.67 to 91.54 mg/kg. The fixed K or lattice K in surface soil samples from different blocks of Ballia disrict was in Bairia 52.33 mg ha^{-1}, Bansdih 52.38 mg/kg, Belhari 79.75 mg/kg, Beruarwari 58.36 mg/kg, Chilkahar 61.08 mg/kg, Dubhad 75.36 mg/kg, Garwar 51.36, Hanumanganj 86.36 mg/kg, Maniyar 64.13 mg/kg, Murali chhapra 58.37 mg/kg, Nagara 75.47 mg/kg, Navanagar 91.54 mg/kg, Pandah 64.81 mg/kg, Rasara 49.68 mg/kg, Revati 67.43 Sear 45.67 mg/kg, Sohaon 66.35 mg/kg, respectively. The average value of fixed K of Ballia district was 64.75 mg/kg. Therefore, Ballia potassium exists in various fractions (water-soluble, exchangeable, non-exchangeable, and fixed/lattice). These soils are mostly Inceptisols, which generally contain high amounts of mica/illite, providing significant reservoirs of non-exchangeable and lattice K. However, these fractions change depending on agricultural practices and soil characteristics [13].

Total K (mg/kg)

The total K value (table-1) is ranging between 732.58 to 941.02 mg/kg. The total-K in surface soil samples from different blocks of Ballia disrict was in Bairia block 732.58 mg/kg, Bansdih 895.54 mg/kg, Belhari 937.21 mg/kg, Beruarwari 941.02 mg/kg, Chilkahar 766.58, Dubhad 835.84 mg/kg, Garwar 815.47 mg/kg, Hanumanganj 866.54 mg/kg, Maniyar 735.20 mg/kg, Murali chhapra 768.25 mg/kg, Nagara 898.36 mg/kg, Navanagar 936.51 mg/kg, Pandah 931.05 mg/kg, Rasara 794.12 mg/kg, Revati 835.12 mg/kg, Sear 822.58 mg/kg, Sohaon 859.22 mg/kg, respectively. The average value of total K was 845.36 mg/kg. Total Potassium in the surface soils (0–15 cm) of Ballia districts (part of the Indo-Gangetic Plains) generally ranges from low to high depending on the specific block, with most soils being alluvial and rich in K-bearing minerals like elite and mica. The variation (increase/decrease) in total K and its fractions (water-soluble, exchangeable, non-exchangeable) might be due to intensive cropping, clay content, and fertilizer management. The similar finding has been given by [1].

0.01 M $CaCl_2$ extractable K (mg/kg)

The 0.01 M $CaCl_2$ extractable-K content (table-2) was ranged from 117.57 to 157.58 mg/kg. The 0.01 M $CaCl_2$ extractable-K in surface soil samples from different blocks of Ballia disrict was in Bairia block 117.57 mg/kg, Bansdih 157.58 mg/kg, Belhari 135.33 mg/kg, Beruarwari 128.57 mg/kg, Chilkahar 128.37, Dubhad 119.08, Garwar 133.57, Hanumanganj 127.48 mg/kg, Maniyar 123.81 mg/kg, Murali chhapra 129.87 mg/kg, Nagara 149.37 mg/kg, Navanagar 135.15 mg/kg, Pandah 122.34 mg/kg, Rasara 117.84 mg/kg, Revati 125.10 mg/kg, Sear 125.10 mg/kg, Sohaon 122.08 mg/kg, respectively. The average value of 0.01 M $CaCl_2$ extractable potassium of Ballia district was 128.97 mg/kg. In the alluvial soils of Ballia districts in Eastern Uttar Pradesh, extractable potassium (representing the readily available soil solution K) generally decreases with depth but varies significantly across different blocks and locations. The surface soil was typically showed the highest amount of available potassium. Based on findings from regional studies, the trends are driven by the following factors [13].

Name of Blocks	0.01 M $CaCl_2$ extractable Potassium (mg/kg)	HNO_3 soluble Potassium (mg/kg)	1M NaCl extractable Potassium (mg/kg)	Mehlich III extractable Potassium (mg/kg)	EDTA extractable Potassium (mg/kg)
Bairia	117.57	75.68	122.39	112.38	105.18
Bansdih	157.58	96.14	111.54	124.05	96.58
Belhari	135.33	88.67	125.39	124.58	111.25
Beruarwari	128.57	86.02	131.58	115.38	104.89
Chilkahar	128.37	126.89	115.57	135.24	111.35
Dubhad	119.08	97.25	120.59	131.02	115.36

Garwar	133.57	75.16	127.35	119.58	123.58
Hanumanganj	127.48	66.58	116.35	122.85	96.34
Maniyar	123.81	68.64	129.38	105.38	105.36
Murali chhapra	129.87	87.87	104.87	104.93	107.98
Nagara	149.37	96.05	119.36	117.28	98.39
Navanagar	135.15	78.47	124.03	128.64	120.58
Pandaha	122.34	95.42	127.06	125.98	115.36
Rasara	117.84	125.77	122.54	120.58	110.54
Revati	119.38	102.68	109.65	139.75	107.42
Sear	125.10	86.37	128.14	115.74	119.58
Sohaon	122.08	66.05	115.68	118.56	88.35
Mean	128.97	89.39	120.67	121.28	108.12

Table 2: Amount of different forms of potassium in surface soils of Azamgarh district.

HNO_3 soluble K (mg/kg)

The HNO_3 soluble K content (table-2) of soils of Ballia was ranged from 65.05 to 126.89 mg/kg. The content was in Bairia block 75.68 mg/kg, Bansdih 96.14 mg/kg, Belhari 88.67 mg/kg, Beruarwari 86.02 mg/kg, Chilkahar 126.89 mg/kg, Dubhad 97.25 mg/kg, Garwar 75.16 mg/kg, Hanumanganj 66.58 mg/kg, Maniyar 68.64 mg/kg, Murali chhapra 87.87 mg/kg, Nagara 96.05 mg/kg, Navanagar 78.47 mg/kg, Pandah 95.42 mg/kg, Rasara 125.77 mg/kg, Revati 102.68 mg/kg, Sear 86.37 mg/kg, Sohaon 66.05 mg/kg, respectively. The average value of HNO_3 soluble potassium of Ballia district was 89.39 mg/kg. Therefore, the soils of Azamgarh soluble potassium were dominated by alluvial soil (Khadar and Bangar), soluble K shows both increasing and decreasing trends in surface soil (0-15 cm) due to dynamic equilibria, farming practices, and soil characteristics [13].

1M NaCl extractable K (mg/kg)

The 1M NaCl extractable K content (table-2) in soils varied from 104.87 to 131.58 mg/kg. The Bairia block 122.39 mg/kg, Bansdih 111.54 mg/kg, Belhari 125.39 mg/kg, Beruarwari 131.58 mg/kg, Chilkahar 115.57 mg/kg, Dubhad 120.59 mg/kg, Garwar 127.35 mg/kg, Hanumanganj 116.35 mg/kg, Maniyar 129.38 mg/kg, Murali chhapra 104.87 mg/kg, Nagara 119.36 mg/kg, Navanagar 124.03 mg/kg, Pandah 127.06 mg/kg, Rasara 122.54 mg/kg, Revati 109.65 mg/kg, Sear 128.14 mg/kg, Sohaon 115.68 mg/kg, respectively. The average value of available potassium of Ballia district was 120.67 mg/kg. The alluvial soils of Azamgarh districts (eastern Uttar Pradesh) 1 M NaCl extractable potassium had typically highest in the surface (0-15 cm) layer and decreases with depth. The concentration ranges generally from 95.0 to 160.0 mg/kg or higher depending on the block and management practices [13].

Mehlich III extractable K (mg/kg)

The Mehlich III extractable K content (table-2) in soils was ranged varied from 104.93 to 139.75 mg/kg. The Mahlich-III extractable potassium value of composite soil samples of block was in Bairia block 112.38 mg/kg, Bansdih 124.05 mg/kg, Belhari 124.58 mg/kg, Beruarwari 115.38 mg/kg, Chilkahar 135.24 mg/kg, Dubhad 131.02 mg/kg, Garwar119.58 mg/kg, Hanumanganj 122.85 mg/kg, Maniyar 105.38 mg/kg, Murali chhapra 104.93 mg/kg, Nagara 117.28 mg/kg, Navanagar 128.64 mg/kg, Pandah 125.98 mg/kg, Rasara 120.58 mg/kg, Revati 139.75 mg/kg, Sear 115.74 mg/kg, Sohaon 118.56 mg/kg, respectively. The average value of all block samples was 121.28 mg/kg. Surface soils in the Ballia districts (Eastern Uttar Pradesh) generally exhibit moderate to high levels of available potassium might be due to their recent alluvial nature and the presence of elite clay minerals. However, Mehlich-III extractable potassium shows significant spatial variation (increasing/decreasing trends) across different blocks, driven by agricultural intensity, soil type, and management practices.

EDTA extractable K (mg/kg)

The EDTA extractable K content (table-2) is ranged 88.35 to 123.58 mg/kg. The Bairia 105.18 mg/kg, Bansdih 96.58 mg/kg,

Belhari 111.25 mg/kg, Beruarwari 104.89 mg/kg, Chilkahar 111.35 mg/kg, Dubhad 115.36 mg/kg, Garwar 123.58 mg/kg, Hanumanganj 96.34 mg/kg, Maniyar 105.36 mg/kg, Murali chhapra 107.98 mg/kg, Nagara 98.39 mg/kg, Navanagar 120.58 mg/kg, Pandah 115.36 mg/kg, Rasara 110.54 mg/kg, Revati 107.42 mg/kg, Sear 119.58 mg/kg, Sohaon 88.35 mg/kg, respectively. The average value of all block samples was 108.12 mg/kg. The potassium fractions in Eastern Uttar Pradesh, Ballia had influenced by intensive cropping, soil texture, and organic carbon content. EDTA-extractable potassium represents a fraction of plant-available K that is often held on exchange sites or easily released from, typically reflecting exchangeable K or a part of the non-exchangeable pool.

Conclusions

The potassium (K) fractions in the surface soils (0–15 cm) of the Ballia district, Uttar Pradesh, consistently indicate a medium to high status of available potassium. The soils are predominantly alluvial, and the potassium content generally decreases with increasing depth, reflecting a greater accumulation of organic matter and more intense weathering of K-bearing minerals in the surface layers. The surface soils generally contain a considerable, often high, amount of available potassium, frequently categorized in the medium-to-high range, suitable for intensive rice-wheat cropping systems.

Acknowledgement

Authors are thankful to the principal of the college for provided the facility during the research work.

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