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Forms of Potassium in Soil and their Relationship with Soil Properties- A Review

Harpreet Kaur*

Department of Soil Science, College of Agriculture, Punjab Agricultural University, India

**Corresponding author*

ABSTRACT

Potassium (K) is vital to many plant processes and the knowledge about different forms and availability of potassium is must while studying the response of crops to K. Because Potassium supply to crop plants is a complex phenomenon involving relationships among various K fractions in soil. Potassium is available in the soil in different forms and amount *viz.*, water soluble K, exchangeable K, fixed K and mineral K. Plants utilize not only the readily available K but also the non-exchangeable and mineral K during the crop growth. The potassium availability to plants is determined by the rate of change in the dynamic equilibrium between different forms of K in the soil which in turn is controlled by the mineral make up, rate of weathering and exchange properties of the soil. The distribution of different forms of K in soils is related to a number of soil properties such as soil minerals, particle size distribution, organic matter and pH. The relationship between K forms and soil properties can be used to predict K availability in soil.

Keywords

Exchangeable K, Forms of K, Non exchangeable K, Total K and Water soluble K

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Introduction

There are four different forms of potassium in soils. These forms are water soluble, exchangeable, non exchangeable and mineral form of potassium in soils. These forms are not homogeneously distributed in soils but all these forms are in dynamic equilibrium with each other. The potassium dynamics in soil based on the magnitude of equilibrium among various forms of potassium and generally controlled by the physicochemical properties of soil. The amount of these fractions in soil depends on degree of weathering, parent material, K gains through manures and fertilizers and losses due to erosion, leaching and crop removal. However in the soil, the amounts of non-exchangeable and total fraction are high as compared to water soluble and exchangeable fraction. About 98% of total K which forms the bulk of soil potassium generally having primary (micas and feldspars) and secondary (illite group) clay minerals as unavailable forms. Water soluble and exchangeable K represents as readily available to plants, whereas non-exchangeable form of K regarded as slowly available form. Therefore, soil solution and exchangeable forms of K are usually readily available to plants. To confirm the availability of potassium in plants, it is required to determine the content of different forms of K in soil. The availability of K to plants is affected by the equilibrium, which is controlled by the rate of weathering of the minerals, complex mineralogical factors and exchange properties of the soil.

Water soluble K

Potassium present in soil solution as soluble cation is termed as water soluble K which is readily absorbed by the plants and relatively unbound by cation exchange forces and invariably subject to leaching losses in relation to soil properties (Ramamoorthy and Velayutham, 1976). Appreciable quantities of potassium is likely to occur when applying water soluble K fertilizers and from irrigation water of high K content or soils contain high mixed soluble salts. In intensively cultivated soils of India, the water soluble K content is 0.2 per cent of the total K in surface soils indicating almost negligible contribution to the total potassium of soils. (Tandon and Sekhon, 1998) and it ranged from 4 to 125.6 mg kg^{-1} in the soils of India. Generally surface soils had relatively high water soluble K than the subsurface soils. The possible reason for this could be an upward translocation of K by capillary rise (Sharma *et al.*, 2009) and also could be due to vegetation, release of labile K from organic residues and addition of farmyard manure (Ranganathan and Satyanarayana, 1980). The water soluble K is positively correlated with clay and silt and negatively correlated with sand (Basumatary and Bordoloi, 1992). Hence soils contain high amount of clay content has more the water soluble K. In addition Srinivasarao and Takkar (1997) also stated that soils with larger amounts of clay showed greater amounts of water soluble and ammonium acetate extractable K in both the rhizosphere as well as non rhizosphere. The negative relationship between water-soluble K and sand content with greater amount of water-soluble K being present in heavy textured soils (Darunsontaya *et al.*, 2012). Jatav and Sud (2006) observed that water-soluble K was significantly correlated with organic carbon.

Exchangeable K

The exchangeable potassium is the form of K held in the solid phase of soil, on clay and organic matter in the soil matrix, by electrostatic forces and easily moves into the soil solution as this form can be readily exchanged by other cations and also is readily available to plants. Exchangeable potassium is not homogeneously distributed on soil colloids (Mengel and Haeder, 1973). It constitutes approximately 90 per cent of the available form of potassium. Exchangeable K contribution towards total K is less than 2 per cent (Schroeder, 1974). The exchangeable K is important in replenishing soil solution potassium which is removed by cropping or lost by leaching. Baruah *et al.*, (1991) revealed that exchangeable K is closely correlated with pH, CEC, OC, CaCO3 and clay content. Singh *et al.*, (1985) observed that the finer particles contained higher amount of exchangeable potassium as compared with coarse fractions because ammonium acetate K was positively correlated with per cent clay and silt and negatively with sand. But Srinivasarao *et al.*, (2007) found that lower levels of exchangeable K were found in Inceptisols and Aridisols despite of greater content of K-rich mica in these soils attributes to lesser mobility of K from illite clay structure to the exchange complex because these minerals typically have a restrictive interlayer space which is selective for K ions, resulting in its low desorption (Sparks and Huang, 1985; Sparks 1987). In neutral and slightly alkaline soils, the Ca^{2+} ion is the dominating ion which causes the opening of clay mineral structure and promotes the release of lattice K. The exchangeable K used for making fertilizer recommendation to the crops as it could give a better indication of the potential K supplying power of a soil (Sharpley, 1989).The higher amount of exchangeable K content was found in the surface soils than the subsurface soils attributed to the addition of K through manures, fertilizers and plant residues (Sharma *et al.,* 2009). Guzel *et al.,* (2006) indicated that exchangeable K was significantly and positively correlated to organic matter and clay content, indicating that as the amount and surface area of exchange complex increases the exchangeable K increases. Ngwe *et al.,* (2012) found that there was significant and positive correlation between exchangeable K and organic matter.

Non-exchangeable K

Non-exchangeable K differs from mineral K because it is not bonded within the crystal structures of soil mineral particles. Generally, it is held at inter-lattice positions and this form is not exchangeable by NH4OAc (Ramamoorthy and Velayutham, 1976). The non exchangeable form of K is present largely within clay minerals and become available to plants with relatively difficulty. However it is in equilibrium with available forms and consequently acts as an important reservoir of slowly available K (Perkins, 1973). The rate and amount of non exchangeable K governs the inherent K status of a soil. Dhillon *et al.,* (1985) revealed that the pattern of non-exchangeable K at different depths and found that it was higher in sub-surface soils compared to the surface soils. This might be due to release of fixed K to compensate the removal of water-soluble K and exchangeable K by plants. The higher amount of non-exchangeable K fraction in sub-surface layers is related to per cent clay and silt which could easily fix the potassium particularly in the soils rich in illitic clay minerals (Sharma *et al.,* 2009). The per cent utilization of fixed K decreased as the level of added K increased to rice crop (Ramanathan, 1978; Nagarajan, 1980).In the soils of north-west India, fixed K is the principal source for supplying K to plants (Pasricha, 2002). The net release of non-exchangeable K which is mainly interlayer K of clay mineral depends on the low concentration of potassium in soil (Martin and Sparks, 1983). The contribution of non exchangeable K to crops was relatively more in untreated plots than those receiving fertilizers K and there was close relationship between K in crops and non exchangeable K released from the soil (Ganeshamurthy and Biswas, 1985). The non exchangeable K is significantly correlated with per cent silt and clay of soil and its amount in the soil depends on the types and quantities of clay minerals, particle-size distribution, and removal of K from minerals (Das *et al.,* 1993).

A significant and positive correlation of non-exchangeable K was found with the sand content of soils. Dixit *et al.,* (1993) found that among the different soil separates, sand fraction was negatively correlated with non-exchangeable Baruah and Nath, (1992) and Pal and Mokhopadhyay, (1992) revealed that non-exchangeable K was significantly correlated with silt and clay content of soil. Basumatary and Bordoloi, (1992) reported that non-exchangeable potassium showed a positive correlation with clay, organic carbon content and CEC. This might be due to the fact that with an increase in organic matter in soils, the clay-humus complex becomes more active thereby, providing more exchange sites and access to potassium.

Lattice K

It is fraction of K that gets fixed in lattice space of the 2:1 clay minerals. The lattice K constitutes from 93.60 to 94.95 per cent of the total K in different soils. The percent contribution of lattice K towards total K for surface soil was ranged from 94.78 to 95.27 with a mean value of 94.92. However, in case of subsurface soil such contribution of lattice K towards total K was ranged from 94.66 to 95.21 per cent, with a mean value of 94.84 per cent (Kundu *et al.,* 2014). The lattice K is diffirent from mineral K because it is not bonded covalently within the crystal structure of soil mineral particle but held between adjacent tetrahedral layers of dioctahedral and trioctahedral wedge zones of weathered micas and vermiculite (Sparks, 1987). The large amount of lattice K indicates that the soils are rich in K-bearing minerals (Mukhopadhyay and Datta, 2001). The availability of lattice K to plants depends on weathering, environmental conditions and soil texture (Grewal and Kanwar, 1973). The release and fixation of the lattice K is mainly depends on the soil reaction, type of clay minerals and type of cation etc. Fairly high content of lattice K indicates that these soils have been developed from mica-rich parent material and much of potassium is present in the mica-lattice (Mishra *et al.,* 1993).

Mineral K

Most of the total K in soils is in the form of mineral K in a fixed or non-exchangeable form, mainly as K-bearing primary minerals such as biotite, muscovite and feldspar. Most of the mineral K was present as K feldspar in the sand fractions. In general more than 90 per cent of the total K in the soils is found in mineral form as structural K (Pasricha, 2002). Sharma *et al.,* (2009) also opined the dominance of this form over the other forms of K because the per cent contribution of mineral K to total K in soils was more than 90 per cent. They further revealed that the highest amount of mineral K was found in sub-surface soils than the surface soils. This may be because of the intense weathering of K minerals at the surface than the subsurface. Sharpley (1989) revealed that mineral K was a function of clay content of soil (r^2 of 0.66 to 0.90). Sidhu and Dhillon (1985) found that biotite, muscovite, microcline and orthoclase are the K bearing minerals present in sand fractions. Micas, orthoclase and microcline occurred in silt, while illite was found in clay fractions.

Total potassium

The total potassium in soil occurs as structural component of soil minerals and is unavailable to plants. The content of total potassium depends on the type of soil fraction, type of primary and secondary and type of parent material (Dhakad *et al.,* 2017). Ahmed and Walia, (1999) revealed that the total K was found more in sub-surface soils than the surface soils. Clay mineralogy is a key factor affecting dynamics of K in the soils (Ghiri and Abtahi, 2011). Total K has highly significant and positive correlation with clay (r = 0.83*) fraction showing that most of the Total-K is derived from interlayer of clay structure and increase total-K with finess of soils (Das *et al.,* 1997). Ghosh and Mukhopadhyay (1996) also revealed that the total K has highly positive and significant correlation with silt and clay fraction of soil indicating that substantial quantities of K bearing minerals are present in silt and clay fractions of the soils under investigation. Sharma *et al.,* (2006) found that total potassium was high in clay soil which shows that among the various particle-size fractions, clay is a principal host of K in these soils. Total potassium was positively correlated with CEC in soils while water soluble was negatively correlated with CEC and clay content in the soil. They also reported significant positive correlation between pH and total potassium and highly significant negative relationship of total potassium with clay, which is attributed mainly to a higher proportion of potassium rich minerals in silt fractions and feldspars are known to occur mainly in 2 to 50 µ fractions (Koria *et al.*, 1989). Adhikari and Ghosh, (1991) observed an increase in total potassium content of different size fractions with increase in particle size.

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