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Chemistry of potassium availability in soil

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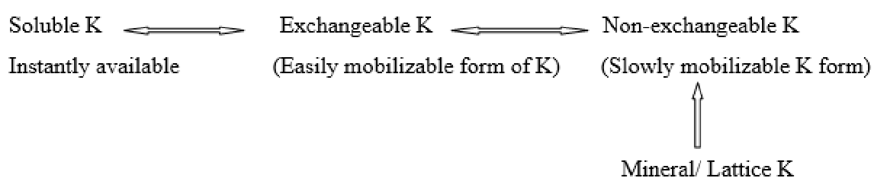
Abstract
Importance of nutrients for plants growth and for food production is unavoidable. These are one of the most important factor which limits growth and production. Many soils being rich in primary nutrients are still considered deficient in available form of nutrients and have to supply with external sources of nutrients. It is also evident in many soils that after external source application, nutrients get fixed in soil very quickly and this all occur because of reaction or chemistry happening in soil. Potassium (K) is one the most important primary nutrient element and its uptake is similar to uptake quantity of nitrogen but it has to face negligence problem and can be understand as earlier Indian soil was in medium to high potassium status and due to negligence of importance of K and its application in soil, K deficiency is now emerging in many regions of Indian soil. This issue discusses the importance of K and chemistry behind its availability and deficiency in soil.

Keywords: potassium, intensity-quantity relations, buffering capacity, available form

Introduction
Potassium (K) is the third most important essential nutrient element which limits the growth of plants. Potassium is the biggest in non-hydrated size (0.133 nm) with a large number (8 or 12) of oxygen atoms surrounding it in mineral structure, which indicates that the strength of K-O bond is relatively weak. As K has high polarity which is 0.088 nm^3, so it is preferred in ion-exchange reactions. Potassium has hydration energy of 142.5 kJ g^{-1} ion^{-1}, which indicates little ability to cause swelling (Sparks, 2002) [7]. A soil sample survey was done in 1968-74 and 4.5 million samples were analysed and resulted that Indian soil was 35% in high K content, in medium K and 20% in low K content (Ghosh and Hasan, 1976) [3]. Then, again in 1997-1999, 3.5 million soil samples were analysed for K content in Indian soil and it was reported that 21% districts were low, 51% districts were in medium and 28% districts were high in K status (Tandon, 2004) [9]. Availability or deficiency of K in different soil may have different factors such as nature of parent material (clay mineralogy), soil texture, high rainfall, intensive cropping, pH, liming, freezing& thawing, wetting & drying etc. But most important basic thing is chemistry or reaction which occurs in soil and which cause K to be in available form or fixed form. There are 4 forms of K which exist in soil and which are soil solution- K, Exchangeable –K, Non-exchangeable-K and Mineral/Lattice-K. Soil solution-K constitutes 0.1-0.2% of total K in soil and most readily available form of K. Exchangeable-K has 1-2% contribution to total K and soil solution & exchangeable-K constitute available form of K. 1-10% of total-K has contribution of non-exchangeable-K and maximum portion of total K in soil is contributed by mineral/lattice-K i.e., 90-98%. These all 4 forms are always in equilibrium.



When available K is taken up by plants from soil solution, a deficiency of K is caused in available-K and it is compensated by release of K from exchangeable portion. In the similar way, deficiency in exchangeable portion is compensated by release of K from non-exchangeable –K. Deficiency in non-exchangeable-K is then get rid out by mineral/lattice- K portion but release of K from lattice-K portion to non-exchangeable-K is a very slow process.

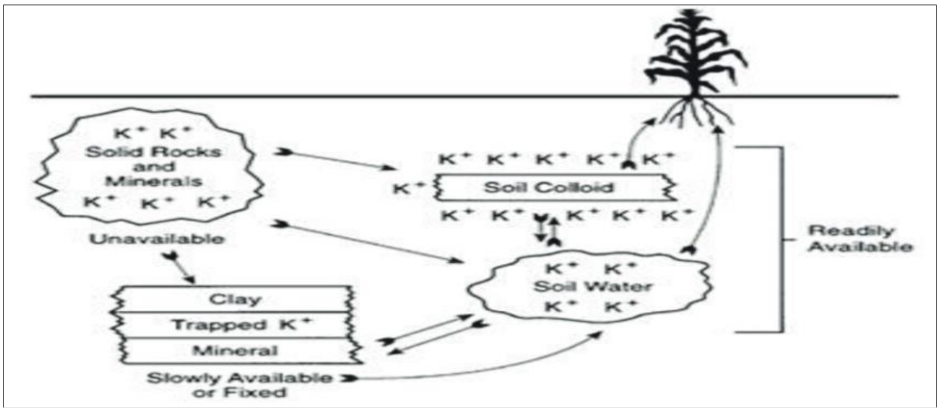


Fig 1: Relationship among unavailable, slowly available and readily available potassium in the soil-plant system (Rehm G. & Schmitt M., 2002).

How pool of K is maintained in soil is totally revealed by quantity-intensity relations of K. It is the intensity factor which is measure of immediately available form of K to be absorbed by plants i.e., soil solution –K. It is well known that absorption of K by plants is affected by presence of cations like Ca^{2+} and Mg^{2+} in soil solution. To show the availability of K and effect of presence of Ca^{2+} and Mg^{2+} on availability of K, potassium activity ratio (AR_K) is used to indicate the intensity factor:

$$AR_K = \frac{[K+]}{\sqrt{[Ca2+\ +Mg2+]}}$$

The quantity factor (Q) is a measure of the capacity of the soil to maintain the level of K in soil solution (I) over a long period or the duration of crop growth. The capacity is mainly due to the exchangeable K, although some non-exchangeable K is released to meet a considerable portion of the crop needs. The buffering capacity indicates how K level in the soil solution (I) varies with the amount of labile form of this element (capacity). In quantitative terms, the buffering capacity is expressed as the ratio $\Delta Q/\Delta I$. The wider the ratio of $\Delta Q/\Delta I$, more buffered is the soil and it very clearly depicted in figure 2.

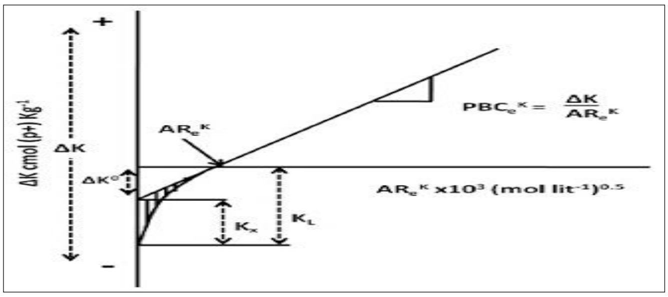


Fig 2: Quantity-intensity relationship of soil potassium. Source: Sarkar *et al.* (2014).

It is the parent material which often affects K availability much in soil and it is like that because of their K% content, weather ability and position of K in lattice. The micaceous clay minerals, e.g. illite contains 6-10% K_2O, muscovite contains 10.6% K_2O and biotite has 9.4% K_2O, but it is biotite which release K very easily due to its higher weatherabilty in comparison to others. There are various factors like tetrahedral rotation, degree of tetrahedral tilting, -OH group orientation, degree of K^+ depletion from the soil solution, hydronium ions (H_3O^+), complexing organic acids, inorganic cations etc. Which determine the release of K from micaceous minerals. Muscovite is unable to release K because of occurrence of tetrahedral rotation and deeper placement of K inside the mineral structure. Phenomenon of hysteresis affects the releases of K from illitic parent materials. Potassic feldspar is also rich of K but it does not release K in soil due to arrangement of K in whole lattice structure of feldspar.

Flooding or submergence increase K^+ in soil solution. On flooding Fe and Mn get converted into their reduced form i.e., Fe^{2+} and Mn^{2+} respectively and replace K+ from exchangeable sites. Continuous flooding and alternate drying and wetting increase K^+ content in soil solution. It has been also reported that availability of applied K decreases in submerged soils due to formation of Fe-K sparingly soluble complexes.

Conclusion

Potassium's importance and its role in plant growth are unavoidable. So, surety for its availability is much necessary to know. Vertisols have high potassium content but it also has potassium fixation capacity. A number of factors work on potassium availability in soil, which is the cause for release and fixation of potassium in soil. When potassic fertilizer is applied in soil, it may be leached, lost through run-off or soil surface erosion. It is also acted upon by microorganisms and root exudates of plants which enhance potassium availability and plant uptake.

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