ROLE OF CLAY MINERALS IN POTASSIUM AVAILABILITY OF BLACK SOILS IN INDIA

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Black soils are locally called regur or black cotton soils have been developed by the weathering of the Deccan lava. These soils spread mostly across interior Gujarat, Maharashtra, Karnataka and Madhya Pradesh on the Deccan lava plateau and the Malwa plateau. Geographically black soils are spread over 5.46 lakh sq.km i.e. 16.6% of the total geographical area of the country. These soils extends from 8ºº45' to 26º0'N latitudes and 68o0' to 83º45'E longitudes. These soils are dominated by smectite minerals and are generally rich in potassium and give an intuition of adequate K reserves for potassium supply to plants (Gurav et al. 2018a).

Potassium is an essential plant nutrient required in large amount for growth and development of plant. It is second only to nitrogen, when comes to nutrient needed by plant. It is commonly considered as the 'quality nutrient' because it affects the plant shape, size, color and taste. The major role of potassium is to regulate opening and closing of stomata which helps to maintain water and carbon dioxide uptake. It has an important role in the activation of many growth related enzymes in plants. It also provides resistance against the pest, diseases and stresses.

In India, so far there was a general consideration that black soils are rich in potassium and therefore its application was inessential. However, with time it is likely that in some soils deficiency of potassium could occur due to soil erosion, continuous cropping and leaching loss. This publication gives the information on potassium behaviour in black soils and role of clay minerals in potassium availability.

RELATION BETWEEN FORMS OF K AND CLAY MINERALOGY

The total potassium content in soils commonly over 20,000 ppm. Almost all soil potassium is in a mineral form, therefore, not available for plant growth. Plants can use only the potassium dissolved in the soil water and exchangeable potassium on the surface of soil particles. According to the availability of soil potassium it is classified into three forms; readily available or exchangeable, slowly available and unavailable (Bhonsle et al. 1992) (Fig. 1). The unavailable form (mineral K), contains approximately 90-98% of total soil K. The non-exchangeable potassium (slowly available) is trapped between the layers of clay minerals; plants can use very little of this K during a single growing season (Sparks 1987) (Fig. 1). Micas and vermiculites are the major sources of slowly available potassium in soils which are potassium rich 2:1 clay minerals. (Sparks, 1987). Mica (illite) clay minerals also fix K between their layers when they become dry, but do not release all of fixed K when wet. Depending on their weathering state potassium release from the interlayer of these minerals is very slow.

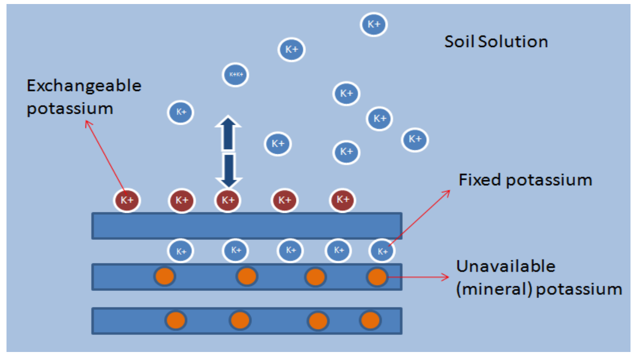

Figure 1 Forms of potassium in soil

The particle size and chemical composition of these minerals are the major factors which influenced on the release of K from clay minerals. The biotite is trioctahedral mica, which releases K more readily than dioctahedral one such as muscovite (Fanning et al. 1989) (Fig. 2). Several studies have been demonstrated the relationship between clay mineralogy composition and form of potassium (Surapaneni et al. 2002). The command in clay mineralogy is essential for understanding nutritional status and nutrient supplying power of soils. Potassium dynamics are influenced by the mineralogical composition of soils (Surapaneni et al. 2002). The relationship between potassium forms and clay mineralogy can be used in evaluating potential soil K fertility, prediction of clay cycling and plant uptake (Sharply 1989). Information on the exchangeable form (1N NH_4OAc) of potassium along with knowledge of clay mineralogical composition can provide understanding about the equilibrium and release of non-exchangeable K to plants and the need for K fertilizers (Bhonsle et al. 1992).

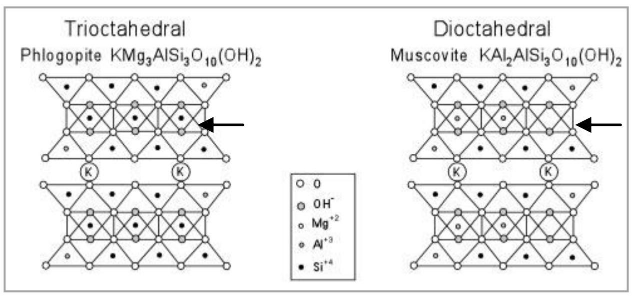

Figure 2 Structure of dioctahedral and trioctahedral micas

Soils with high 2:1 clay minerals such as vermiculite, micas, and high charge smectites contain a larger amount of HNO_3 extractable K than kaolinite and other siliceous minerals (Sharply 1989). Bhonsle et al. (1992) reported that smectitic soils had high levels of exchangeable K, mixed and illitic soils had medium level, and kaolinitic soils had low levels of exchangeable K (1N NH_4OAc). Determination of both exchangeable and non-exchangeable potassium give better indication of potential K supply power of soil (Sharply 1989).

ROLE OF MINERALS IN POTASSIUM AVAILABILITY

The major K bearing minerals in soils are potash feldspars and micas. Micas are more important than potash feldspars in supplying potassium to plant. Availability of K to plant is mostly related to the weathering of feldspars and micas in soil environment (Pal and Srinivasarao 2001). The contribution of feldspars is very little to the soil pool of K used by plant because the process of K release is very slow reaction in natural soil environment (Gurav et al. 2018b). In micas, a large unhydrated K ion is held in ditrigonal cavities of the basal plane of oxygen's of the tetrahedral sheets by electrostatic bonds. This keeps the layer collapsed (Pal and Srinivasarao 2001). Trioctahedral micas release their K more readily by weathering than dioctahedral micas (Mortland et al. 1957). Serratosa and Bradly (1958) observed that the proton of OH in trioctahedral micas is repelled equally by all the three octahedral cations, and lies on the normal to the basal plane, directed towards the interlayer space. In dioctahedral micas the proton is attracted to the vacant octahedral site and is displaced to one side of the normal. K in trioctahedral micas is repelled to a certain extent by the proton, and is therefore, in a less electronegative environment than K in dioctahedral micas. This result in dioctahedral mica is held more strongly than in trioctahedral micas.

The concentration of K in soil solution is most important factor that controls the rate of release of K from micas (Pal and Srinivasarao 2001). Pal et al. (2001) reported that experimental attempt to relate K release reaction of Indian soils without ascertaining the nature and composition of soil micas may not be adequate enough to establish a relationship between crop response to K fertilizers and nature of soil micas. Mica, hydrous mica and vermiculite have high adsorption/fixation properties (Pal et al. 2012). Whereas, smectites do not fix or adsorb K due to their low charge (Ray et al. 2003). Research work on the fundamental aspects of K release and adsorption/fixation in relation to the mineralogy of soils took momentum during 1985 to 2001 in India (Rao et al. 2001). It is well established the role of K bearing minerals in releasing K from their non-exchangeable fraction of Indian soils. Micas are prime K bearing minerals of major Indian soils that are mainly concentrated in their silt and clay fractions. Despite this favorable K mineral endowment, crop response to K fertilizers many of these soils have been anomalous (Pal et al. 2000). Both di- and trioctahedral micas are very common in these soils. Therefore, release of K from fine-grained micas is not similar because they are far from ideal in composition and structure (Pal and Srinivasarao 2001). The proposed relationships between potassium release and micas are based on results obtained from specimen micas and not from soil micas and thus they are speculative (Pal et al. 2012). The mica present in black soils is both muscovite and biotite minerals. Because the ratio of peak heights of 001 and 002 basal reflections is >1 suggests that muscovitic characteristic of mica but in reality it indicates the presence of both muscovite and biotite minerals (Pal et al. 2000). The ratio would have been very close to unity if muscovite minerals were present alone (Tan 1982). Pal et al. (2012) observed a significant positive correlation between cumulative K release from sand, silt and clay and their total K content, indicates that the K release is a function of total K content in micas and feldspars. He further observed a positive correlation between total K content in sand, silt, clay and soil and their mica content indicates that the predominant influence of mica to supply K to the plants gown in Vertisols. However, better correlations than those between K release of sand, silt, clay and soils and their biotite content provide undeniable evidence that the K release in soils is primarily controlled by biotite (Pal et al. 2012).

CONCLUSION

Potassium is a major element for plant growth and development. Clay minerals serve as both sources and sinks for this essential plant nutrient. The K^+ ions fixed in the interlayer of 2:1 clay mineral contribute to the plant K nutrition. Micas and vermiculites are the major sources of K reservoirs and have key role for K cycle in black soils. The mica present in black soil is both muscovite and biotite, however K release in soils is primarily controlled by biotite.

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