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Potassium dynamics in soil under long term regimes of organic and inorganic fertilizer application

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Abstract

Knowledge of different potassium fractions in soils is essential for potassium management to determine long term sustainability of a cropping system. It is generally believed that our soils are not deficient in available potassium due to dominance of illitic clay mineral, therefore farmers usually skip the application of potassium in many crops. But increased cropping intensity and introduction of hybrid varieties are resulting in a considerable drain of potassium reserves and crops are becoming responsive to potassium fertilizer application. This study was conducted to monitor the changes in different fractions of soil potassium viz. water soluble, exchangeable, non-exchangeable and total potassium. For this study two sites were selected from research area of Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad. In 1st long term study (since 1978) seven combinations of organic and inorganic sources were used. In 2nd study (since 1986) two sources of potassium were tested. Soil samples from these two studies were collected from 0-60 cm depth with interval of 15 cm. Results indicated that both soluble and exchangeable potassium concentration in soil decreased with depth at both sites. At 1st site range of soluble and exchangeable K was 2.5 to 10.5 mg kg^{-1} and 57 to 273 mg kg^{-1}, respectively, while in 2nd study water soluble and exchangeable K varied from 1.35 to 6.0 and 63 to 83 mg kg^{-1}. It is interesting to note that application of nitrogen through farm manure (FM) improved the soluble and exchangeable potassium in soil profile. Data revealed that in 1st long term study FM showed 209% and 127% increase in soluble K, while 43% and 33% increase in exchangeable K over NP and control at 0-15 cm depth. In case of 2nd long term study muriate of potash caused 18% and 5% increase in water soluble and exchangeable K over sulphate of potash, respectively, at 0-15 cm depth. There was no consistent trend of non-exchangeable and total potassium in soil profile and among various fertilizer application sources and combinations. The study concludes that no appreciable changes were observed in potassium pools of sandy clay loam and clay loam soils under long term fertilizer application. FM application improved potassium fraction as compared to inorganic sources.

Keywords: *K-dynamics, long term fertilization, farm manure, inorganic fertilizers*

Introduction

The issue of sustainable soil potassium management was partially ignored during the last few decades while the potential use of nitrogen and phosphorus was considered a more important aspect (Simonsson *et al.*, 2007). It is now established that because of heavy mining of nutrients from the soil under multiple cropping systems, the potassium status of soil is depleting rapidly. So, knowledge of various potassium pools in soil is essential for sustainable crop production. Long term studies are the basic platform for examination and quantification of cultivation based changes in agro-eco-systems and enables the evaluation of effects of continuous fertilizer application on different nutrient dynamics in soil (Merbach and Deubel, 2008). The potassium release rates from soil under long term cropping, fertilizer application and manuring helps to predict the fate of added K in soil as well as nature of K supply from soil to plant (Samra and Swarup, 2001). Several studies have shown that intensive cropping systems may cause heavy depletion of soil potassium under long term experiments (Dobermann *et al.*, 1996 a,b; Ali *et al.*, 1997; Gami *et al.*, 2001; Regmi *et al.*, 2002; Singh and Singh, 2002; Singh *et al.*, 2004). Potassium as a macronutrient is often taken up in large quantities by crops under intensive cropping and its uptake is in many crops almost equal to nitrogen (Marschner, 1995).

Agronomic data generated in the past often showed an erratic and inconsistent response to applied K under different agro-climatic conditions of Pakistan. Pakistani soils are derived either from alluvial or loess material. They have an abundance of potassium bearing minerals that are well supplied with accessible potassium (Tahir *et al.*, 2003). 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). The primary source of

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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). 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). The bio-available K pools contain only a minor fraction of the total soil potassium reserve (Haung, 2005). Soil fixed (non-exchangeable) K is an important contribution to plant K supply (Parkar *et al.,* 1989 a,b; Badraoui *et al.,* 1992; Mengel and Uhlenbecher, 1993). It is held as fixed ion in the lattice structure of clay minerals. The suitability of using non exchangeable K as a measure of plant available K remains controversial, especially when soils have different texture and clay mineralogy. 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 aim of this study was to evaluate the changes in various pools of potassium in sandy clay loam and clay loam soils after long term fertilizer application and different crop rotation.

Materials and Methods

The various pools of potassium in soil were measured from two sites of long term studies which are in progress at research area of Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences, Ayub Agriculture Research Institute, Faisalabad. In 1st long term study, effect of fertilizers use on soil health is being evaluated since 1978. In 2nd study two sources of potassium i.e. muriate of potash vs. sulphate of potash is being monitored since 1986. In 1st study seven treatments are being used viz. control, N, NP, NPK, FM, ½ FM+ ½ Urea and ½ NP on permanent layout. The cropping pattern of this study was wheat- maize fodder, wheat- cotton, sugarcane-wheat-toria, Maize fodder-wheat. While in 2nd study four treatments are being tested viz. control, NP, NP + K_2SO_4 and NP + KCl on permanent layout following the wheat-maize fodder and onion-potato crop rotation. From both sites soil samples were collected from four depths viz. 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm during 2010-2011. Samples were air dried and ground to pass through 2 mm sieve. These ground samples were subjected to detailed analysis for different K fractions i.e. water soluble, exchangeable, non-exchangeable/fixed and total K. The particle size distribution of the soils was determined using the Bouyouscos hydrometer method (Bouyouscos, 1962). Various fractions of potassium (water soluble, exchangeable, non exchangeable and total K) in same samples were measured by different methods. I) Exchangeable bases were extracted with a neutral salt 1.0 M NH_4OAC (Knudsen *et al.,* 1982). II) Water soluble K (H_2O-K) was extracted by shaking 2.5 g soil in 50 mL deionized water for 30 minutes. III) Non-exchangeable K was calculated by the soil with 1M HNO_3 (Martin and Sparks, 1983). Total K in the soil was estimated by digesting it with concentrated HF (Klesta and Bartz, 1996). Statistical analysis was done by using the MSTAT-C program.

Results and Discussion

Data pertaining to the changes in different forms of K in soils receiving different sources of plant nutrients are presented below.

Changes in water soluble K

Pooled data of water soluble K content after 36 and 26 years of cropping are shown in figure 1 and 2.

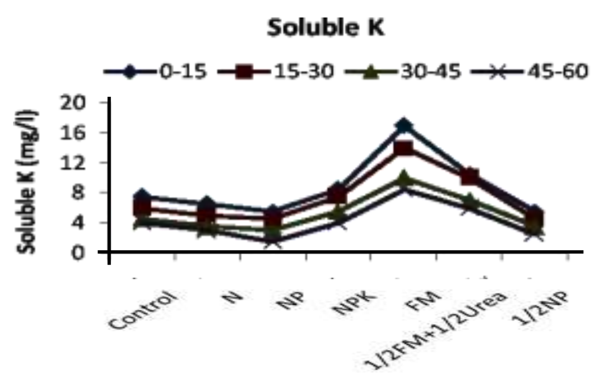

Figure 1: Soluble K status of sandy clay loam soil (after 36 years)

Appreciable changes in water soluble content were observed with sole and integrated use of organic sources in long term studies. In 1st site soluble K was in the order of FM > ½ FM + ½ Urea > NPK > Control > N > ½ NP > NP. In 2nd site the trend of water soluble K was KCl > K_2SO_4 > Control > NP. Mean water soluble content ranged from 2.5 mg L^{-1} to 10.5 mg L^{-1} in 1st site and 1.5 mg L^{-1} to 6.6 mg L^{-1} in 2nd site. Ganeshmurthy *et al.* (1985) reported no effect of continuous cultivation on the water soluble K content. Maximum increase in soluble K over control was found in FM plots after 36 years and in plots receiving KCl after 26 years. FM, ½ FM and NPK showed 127%, 40% and 13% soluble K increase, respectively, over control at 0-15 cm depth. While NP, ½ NP and N showed 67%, 67% and 61% decrease over control at the same depth. Similar trend was found in other three depths. Comparison of organic sources with inorganic sources revealed that inorganic sources like NPK, N, ½ NP, and NP showed 50%, 61%, 67% and 67% decrease, respectively, over FM (organic source). Bansal (2000) reported the variation in K release from K-reserves to soil solution within a soil type and it was attributed to the potassium status and mineral composition of soil. In both studies soil solution K decreased with increasing depth and maximum decrease was found in 45-60 cm.

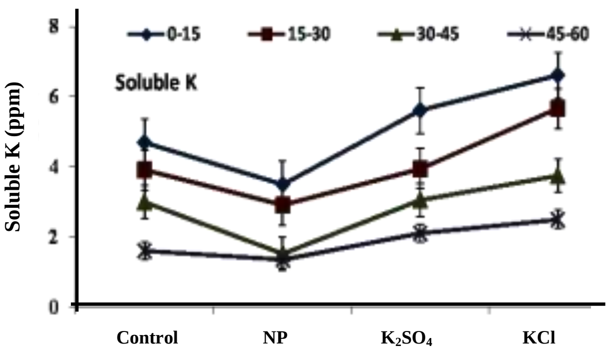

Figure 2: Soluble K status of clay loam soil (after 26 years)

Changes in exchangeable K

Pooled mean data of exchangeable-K content after 36 and 26 years of intensive cultivation are depicted in figure 3 and 4. It ranged from 105 mg L^{-1} to 237 mg L^{-1} at 1st site and 101 mg L^{-1} to140 mg L^{-1} at 2nd site. It was in order of FM > ½ FM + ½ Urea > NPK > Control > N > ½NP > NP and KCl > K_2SO_4 > Control >NP at two experimental sites. Upper depths of two sites gave maximum values of exchangeable K. Among all treatments applied to both sites FM and KCl had more values of exchangeable K. At 1st site NPK and FM showed 4% and 33% increase over control while NP, N and ½ NP gave 7%, 7% and 17% decrease, respectively, over control at 0-15 cm depth. It was estimated that NPK, N, ½ NP, and NP showed 22%, 30%, 37% and 30% decrease, respectively, over FM at upper depth. Similar trend was followed in all depths. At site 2, it was found that NP showed 9% decrease while K_2SO_4 and KCl gave 16% and 22% increase over control in upper soil depth (0-15 cm). KCl showed 5% increase over K_2SO_4 in exchangeable K content and trend was same in all depths. Variation in exchangeable K in different soils could be linked to the difference in clay content and parent material of the soil (Acquaye, 1973; Martin and Sparks, 1983). Sekhon *et al.* (1992) produced almost same results. Similar results were shown by Lal *et al.* (1990). They reported decline in exchangeable K status in plots which were receiving adequate NP but no K in a long term study.

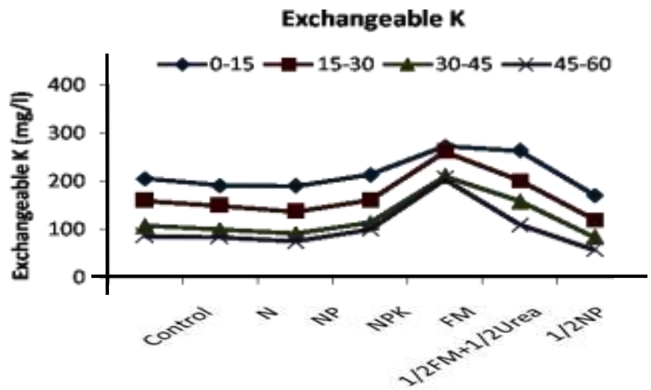

Figure 3: Exchangeable K status of Sandy Clay Loam soil (after 36 years)

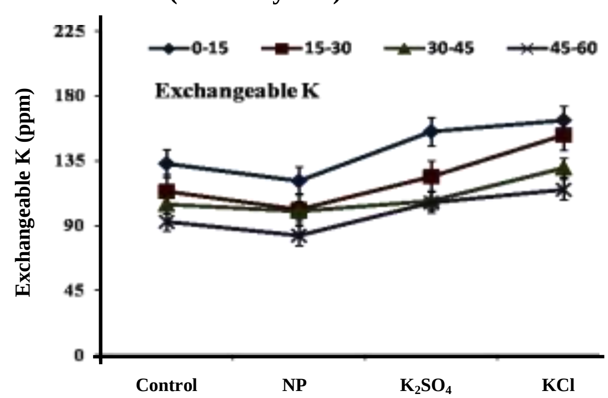

Figure 4: Exchangeable K status of clay loam soil (after 26 years)

Changes in non-exchangeable K

Figure 5 and 6 shows the status of non-exchangeable K of two long term experiments. Effect of continuous cropping and fertilization on the non-exchangeable K content was not marked. There was hardly any change observed in all the treatments applied on both sites. Tiwari and Nigam (1994) observed that on the whole non-exchangeable K content is linked with the clay and silt contents of the soil. More is the clay and silt contents, more is the non-exchangeable K in the soil. Many studies have demonstrated that non-exchangeable K is able to supply crops with a significant portion of K (Badraoui *et al.*, 1992; Mengel and Uhlenbecker 1993; Cox *et al.*, 1999).

The non-exchangeable K fraction is released when the level of soil solution and exchangeable K are decreased by plant uptake and leaching (Martin and Sparks, 1983). Several workers (Mengel, 1985; Mittal *et al.*, 1990; Singh and Singh, 2002) have reported that a significant portion of K (70–90%) required by the plants comes from the non-exchangeable pool in the absence of optimum K supply in many crops, thus showing the beneficial role of fixed K. Conversion of exchangeable and water soluble K into non-exchangeable form in a slow process but this equilibrium also plays an important role in K-nutrition of plants as it helps in maintaining the non-exchangeable K content of soils (Dhillon *et al.*, 1985). It is also reported that in many soils, with the passage of time, K applied to soil changes into non-exchangeable form (Kansal and Sekhon, 1976).

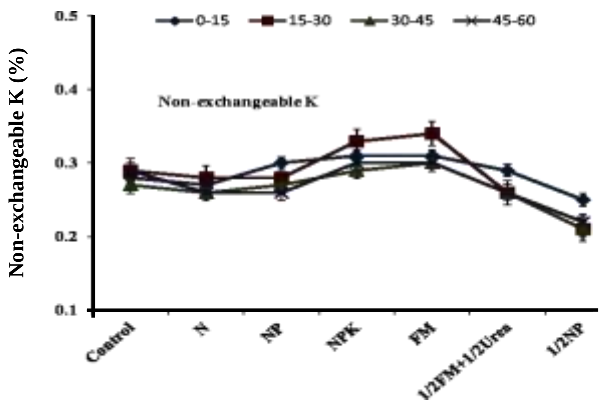

Figure 5: Non- exchangeable K status of sandy clay loam soil (after 36 years)

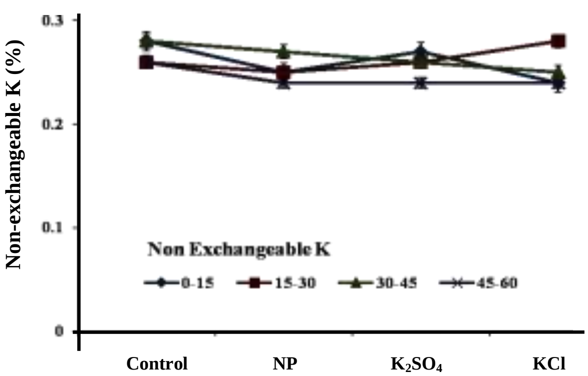

Figure 6: Non- exchangeable K status of clay loam soil (after 26 years)

Changes in total K content

Changes in total K content of two soils are shown in figure 7 and 8. The results did not indicate any change in the total K content of these soils with cropping and fertilizer application over a period of 36 and 26 years. Total K depends on the presence of K bearing primary and secondary minerals in the soil. Clay mineralogy is a key factor affecting dynamics of K in the soils (Ghiri and Abtahi, 2011). Soils differing in clay mineralogy may respond differently to K application (Akhtar and Dixon, 2013). Recently, it has been reported that the presence of specific clay minerals affect the K-fixing capacity and slow and fast release of K in different soils (Wakeel *et al.*, 2013). Smectite along with the mica is the reason for a soil having appreciable amount of total K. Only 1 - 2% of the total soil potassium is in a readily available form. Of this small percentage, 90% is weakly adorbed to colloidal surfaces on the outside of 2:1 clays, 1:1 clays and humus. Continuous crop production without K application may result in mica weathering particularly that of biotite into vermiculite and smectite and decomposition of feldspar structure over a longer period of time (Shaikh *et al.*, 2007).

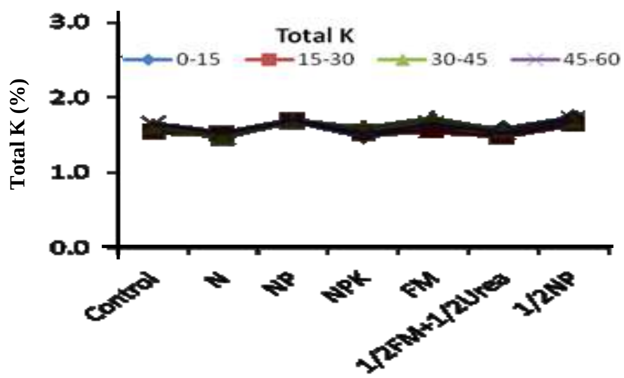

Figure 7: Total K status of sandy clay loam soil (after 36 years)

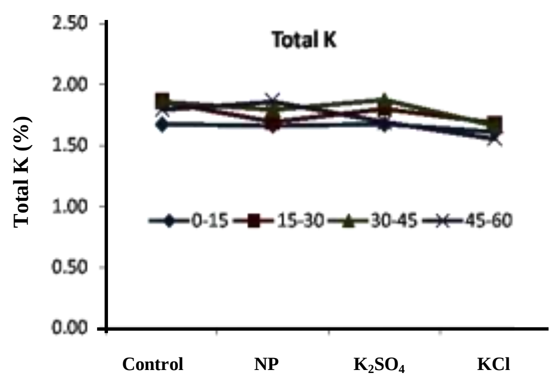

Figure 8: Total K status of clay loam soil (after 26 years

Conclusion

The results of two long- term field studies showed that potassium application improved the water soluble and exchangeable potassium of soil. Farm manure application improved potassium fraction in all depth. No considerable trend of non-exchangeable and total potassium in soil profile was found among various inorganic nutrient sources/combination over depth.

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