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STATUS OF K IN SOIL FOR PLANT GROWTH

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Abstract

Fertilizer is a vital input for food production and it should be used efficiently in order to minimize food production cost as well as to conserve natural resources. In developing countries crop yield are low either due to the lack of fertilizer or inefficient use of fertilizers. In Pakistan, the response of crop to applied K is unpredictable due to lack of refined critical level of soil K and this unpredictability is further intensified due to different adsorption characteristics of various soils for K. As fertilizer the fate of added K depends upon the initial level of soil K. The concentration of K in soil solution depend on the rapidity at which desorption of K can be occurred from the adsorption phase and the rate of removal by the plants, whereas adsorption equilibrium solution K level serve as a key of K availability. The response of crops to K considerably depends on the original status of the K, the status of initial soil K concentration must be considered before K fertilizer application. In the Indus plain of Pakistan, soils contain 2.65 to 3.55 % K. in the surveyed area of Pakistan more than half of the soils are categorized as Aridisols, under this situation crop response to K fertilizer are very unbalanced and intermittent because scientifically based critical soil K level did not exist.

Keywords: K, forms, application, response, factors, adsorption

Introduction

Pakistani soils are composed of mica, biotite, muscovite, orthoclase, microcline, vermiculite and smectite. Generally, mineral K is the only one which is slowly accessible to plant. However, the accessibility is reliant on the K level in the new form and the amount of weathering of mica and feldspars creating the mineral proportion of K (Sparks and Huang, 1985: Sparks, 1987). In the above 0.2 m of soil profile, total K contents in the soil range between $3x10^3$ to $1x10^5$ kg ha^{-1} about 98 % is present in the form of mineral, whereas 2 % is in the soil solution exchangeable forms. The importance of K to plant has been recognized mean while the exertion of Von Liebig that was presented in 1840 and has thus been studied extensively (Sparks, 1987 and Oborn *et al.*, 2005).

In Pakistan, most soils contain comparatively greater amount of K as component of fairly insoluble minerals, however only a small fraction is present in available form to plant. Most of soils have < 150 mg kg^{-1} of exchangeable K which is considered a perilous limit for soil K deficiency (Bajwa and Rehman, 1996). Presently K level in our soils are going to be depleted on day basis as it used by extensive cropping and cultivation of high yielding crop varieties. So far there is no natural source to replenish it in to the soil. However, due to its low levels in the soils negative effects on crop yield and quantity are seen in some parts of the country.

Although K content in Pakistani soils has traditionally been considered adequate for normal plat growth, however awareness has grown on the importance of K in crop production and need for K has been realized in Pakistan (Rashid and Rafique, 1998). Due to continuous cropping and cultivation of fertilizer responsive varieties with improved management practices are resulting in K mining. The use ok N and P fertilizer is very common but K is not being given due importance in nutrient management of different crops. Due to this reason use of potash as mineral fertilizer is very low in Pakistan and the ratio of nutrient fertilizer (N: P: K) is imbalanced.

Forms of K in soil

Potassium in soil is present in four forms. These four forms are solution form, exchangeable form, fixed (non-exchangeable) form and mineral form. The forms of soil K in order of their availability to plants and microbes are solution > exchangeable > fixed (non-exchangeable) > mineral (Sparks and Haung, 1985; Sparks, 1987; Sparks, 2000). Adoption of appropriate analytical techniques allows these four forms to be clearly defined, but in field distinct boundaries do not exist (Sharpley, 1990). As defined by an analytical procedure, the amount of K present in each form is determined by several soil factors including plant K uptake, the types and amount of clay, fertilizer addition, crop and leaching losses and the relative effectiveness of the K release/ fixation processes that operates in soil.

Solution K

It is the form of K that is directly taken up by the microbes and plants and also is the form most subjected to leaching in soil. The K content of which depends on depletion and replenishment from exchangeable and non-exchangeable K forms. The release of non-exchangeable K is also induced by the lower concentration of soil solution K (Hay *et al.,* 1976). Generally, level of soil solution K is low, unless recent amendments of K are made to the soil. The amount of K in the soil solution varies from 3 to 30 mg K L-1 for normal soils (Haby *et al.*, 1990). Levels of solution K are affected by kinetic reactions and the equilibrium that occur between the forms of soil K, the concentrations of divalent cations in solution and on the exchanger phase and the soil moisture content (Sparks and Huang, 1985; Sparks, 2000). The buffering capacity of clay mineral also affect the amount of soil solution K, weakly buffered allophonic clays do not maintain the soil solution K level whereas well-buffered vermiculites and micas maintain the level of solution K relatively unchanged (Parfit, 1992).

Exchangeable K

Exchangeable K is defined as the fraction of soil K that occupies sites on the soil colloid complex (Malavolta, 1985). The exchangeable K is held by different bond strength at the non-specific adsorption sites i.e. Edge and planer positions of clay minerals and at the negative charges created by the phenolic and carboxylic groups of humus colloids compared with pH dependent negative sites on clays. The quantity of K+ held by clay mineral at the exchange sites depends on thermodynamic as well as kinetic factors (Parfit, 1992). For K the affinity of the exchange sites is related to the concentration of K in relation to other exchangeable cation, mostly divalent ions present in the soil and the nature of the soil surface (Barber, 1984).

Non-exchangeable or fixed K

Non-exchangeable or fixed K varies from the mineral K in that it is not bounded within the crystal structures of soil mineral particles. Non-exchangeable K is held between adjacent tetrahedral layers of dioctahedral and trioctahedral vermiculites and micas, and the intergrade clay mineral such as chloritized vermiculite (Rich, 1972; Sparks and Huang, 1985; Sparks, 1987). Potassium becomes fixed because the binding forces between clay surfaces and K are greater than the hydration forces between individual K^+ ions, making K release slower due to physically trapped to varying degree (Sparks, 1987). Non-exchangeable K can also be found in wedge zones of weathered vermiculites and micas (Rich, 1964). Releases of non-exchangeable K to the exchangeable form occur when levels of exchangeable and soil solution K are decreased by leaching and/or crop removal and possibly by increase in microbial activity (Sparks *et al*, 1980; Sparks, 2000). Non-exchangeable K is moderately to sparingly available to plants (Mengel, 1985; Sparks and Huang, 1985; Sparks, 1987). The difference between structural and fixed K is that the release of structural K is irreversible whereas the release of fixed K is reversible. When the level of soil solution K^+ and exchangeable K^+ are decreased by leaching and/or by crop removal, the release of non-exchangeable K occurs (Doll and Lucas, 1973; Sparks *et al.*, 1980).

Structural K

Structural K is variously known as unweathered K, mineral K, native K, inert K or matrix K. It consists of the bulk of the total K in most soils (Metson, 1980) and its amount depends up on the composition of the stage of development of the soil and the present rock (Sparks and Huang, 1985). Structural K is mostly covalently bounded within the crystal structure of the K-bearing minerals such as micas (muscovite and biotite), feldspar (microcline and orthoclase), and volcanic glasses (Metson, 1968a).

K application and crop responses

Tandon and Sekhon (1988) suggested that soils with low available K (< 100 mg K kg^{-1} soil) are expected to readily response to K application. Bajwa and Rehman (1996) reported 100 mg K kg^{-1} soil as critical limit for K deficiency in Pakistan. K concentration of soil solution directly control the K-supply to the plant. The greatest uptake was expected during early stages of growth when all or most of the leaves were still expanding. Maximum weight of K in spring wheat was found at heading. In countries like Pakistan, the nutrient use is imbalanced, particularly for potash, which is requirement of Pakistani soils, as increasing cropping intensity is continuously exhausting the K reserves of soil. Some salient research work of different scientists regarding use of K fertilizers in Pakistani soils is reviewed here as follows. The term fertilizer efficiency is defined as the increase in yield of harvested portion of the crop per unit of fertilizer applied (Barber, 1977). Usually, K use efficiency (KUE) of various crops is known to be low and recovery in the year of application varies (Nisar, 1985). Saifullah *et al.* (2002) accompanied a field experiment to observe the wheat response to applied K fertilizer. Five treatments (0, 75, 150, 225, 300 kg K_2O ha^{-1}) were tested. The crop was irrigated with the tube well water and all cultural practices were kept uniform for each treatment. Thy conclude that 225 kg K_2O ha^{-1} of potash application significantly increase the 1000 grain weight, no. of tillers per plant, no. of grain per spike grain and straw yield. The highest harvest was recorded at 225 kg ha^{-1} of potash application. Increase in rate from 225 kg K_2O ha^{-1} decreased all the parameters studied. K application significantly affected uptake of N and P in straw as well as grain of wheat. K concentration increased by increasing rate of application of potash up to 225 kg K_2O ha^{-1}. Iqbal (2000) conducted a pot experiment and concluded that plant height, fresh weight and oven dry weight of wheat and maize plants were increased significantly over control with K application. It was also concluded that K uptake and its concentration in both maize and wheat plants significantly increased with increasing K rates. According to Jones (2003) K deficiency severely reduces maize yield. Low level of K results in low starch level and poor formation of cob and grain-fill in maize. Beringer (1980) showed that improved potassium nutrient enhanced grain development in the ear, i.e. upsurge in single grain weight and grain number per cob. It was also explained by Mussgnug *et al.* (2006) the potassium was the utmost yield-limiting macronutrient, and general application of potassium were necessary to make investment in the application of other mineral nutrient beneficial. Sofi *et al.* (2005) conducted an experiment to examine the influence of different N level (0, 120 and 160 kg ha^{-1}) and potassium fertilizer (0, 40 and 80 kg ha^{-1}) on the growth and yield of maize. The grain and stover yield were significantly increased with each addition in N and K up to 160 and 80 kg ha^{-1} respectively. The growth attributes (plant height, number of leaves per plant and dry weight) and yield attributes (length of cob, number of grain per cob, cob weight and 100 grain weight) showed the same trend. Karim *et al.* (2006) conducted an experiment to observe the effect of the rate and time of application of K fertilizer on maize. K was applied at 0, 50, 100 and 200 kg k_2O ha^{-1} in the form of K_2SO_4. The data revealed that with the application of K, number of grain per cob, grain and stover yield increased by 9.8, 4.5 and 36.9 % respectively over the application of N and P alone. N and P application without potash increased the grain yield and other yield component of maize crop significantly over no fertilizer application. Overall, the time of application of K had no effect on all the parameters. Ahmad *et al.* (2009) conducted a field experiment to observe the influence of potassium fertilizer on the eminence and maize yield on a calcareous sandy clay loam soil under semi-arid condition of district Faisalabad, Pakistan. K was applied at six rates of K i.e. 0, 25, 50, 75, 100 and 125 kg ha^{-1}. After eight weeks of emergence, crop was harvested and quality. Dry matter yield increased by 21 % over control. The K status of the soil was increased by 11 % due to K application. Ali *et al.* (2005) conducted a field experiment at Jatri Kohna, district Sheikhupura to evaluate the effects of foliar spray (1.5 % of K solution) of KCl, K_2SO_4 and KNO_3 on the yield of rice cv. 385. Foliar application of K_2SO_4 gave better paddy and straw yields, number of tillers, potassium content of paddy and straw than the other two sources of K. Potassium recovery (72.87 %) and agronomic efficiency (13.12 kg^{-1} of paddy kg^{-1} of fertilizer applied). Were also better in case of K_2SO_4 than other two sources: KNO_3 (44.87 % and 8.69 kg of paddy kg^{-1} of fertilizer applied) and KCl (22.40 % and 5.66 kg of paddy kg^{-1} of fertilizer applied). Awan *et al.* (2007) conducted an experiment to study the split application of recommended dosage of caustic potash effect on the rice yield and yield components at fields of farmer. In this examination a recommended dose of potash fertilizer (62.5 kg ha^{-1}) compared with that treatment were there no potash was applied. Maximum value of tillers per hill (26.81), grains per panicle (68.81), 1000 grains weight (22.00 g), paddy yield (4.73 t/ha) and lower limit percentage of sterile grains (6.39 %) were examined in treatment where split use of Potash received. The increased food grain yield of rice with spilt application of K was attributed to uninterrupted supply of K during crop growth period. Mitsios *et al.* (1994) evaluated Temkin, Freundlich and Langmuir equations for the K sorption. The pH of soil samples were ranged between 4.0 to 8.0. The effect of pH on the K adsorption was determined and the Temkin, Freundlich and Langmuir isotherms were transformed to pH dependent forms. The amount of K adsorption increased, as the pH and the initial concentration increased. The maximum amount adsorbed in a monolayer was determined with the help of Langmuir isotherm. It was important to note that the maximum amount of K adsorbed increased by increasing the pH. Hundal *et al.* (1998) evaluated the effect of temperature and back ground anion concentration of soil samples on adsorption-desorption kinetics of K in typical alluvial soil (Udic Ustochrepts, Tulewal loamy sand). It was concluded that with increasing temperature from 298 K to 313 K, cumulative K adsorption decreased and was more evident at lower depths. It could be due to more clay content, micaceous and vermiculitic clay minerals that increased K adsorption. Chloride being an anion natively present in soil caused relatively higher K adsorption compared to that of ClO^{4-} ions. K-exchange rates as calculated from first-order equation were higher with change from Cl^- to ClO^{4-} as background anion and with increase in temperature. Apparently desorption rate coefficient (kd) was 2-3 times lower than apparent adsorption rate coefficient (kd), but effect of increasing temperature was more conspicuous in desorption of K. Mehdi *et al.* (2001) conducted an experiment to calculate the K contents in the soils showing K deficiency symptoms in Hafizabad district. 98 plant and soil samples were collected from the fields showing K deficiency. Samples were analyzed for K contents. Low K content were observed in all 98 plant samples according to the critical limit while soil samples were tested medium in ammonium acetate (CH_3-CO-O-NH_4) extractable K. In same year K was applied @ 62.5 Kg ha^{-1} to rice crop showing K deficiency symptoms at 11 sites. The straw and paddy yields improved from 2.94 to 40.0 % and 4.17 to 36.20 % over control by the application of K, respectively. K concentration was also increased in both straw and paddy over control from 6.70 to 14.46 % and 18.75 to 36.59 % respectively. Total K uptakes by straw and paddy yields were also increased by applying K over control. Arif *et al.* (2010) conducted a pot experiment to study the response of rice genotypes to various level of K. The soil was air dried and was mixed with N, P and Zn fertilizers (applied @ 130, 70, and 12.5 kg ha-1 as urea, diammonium phosphate and ZnSO4 (33%) respectively. Three rice genotypes previously screened and categorized for their K use efficiency viz genotype 99509 (high K-use efficient), super basmati (medium K-use efficient) and IR-6 (low K-use efficient) were applied with different K rates (0, 30, 60, 90, and 120 kg ha-1). With K application significant improvement was observed in yield components and grain yield with different degree of efficacy. IR-6 (low K-use efficient) genotype responded poorly to application of K in term of grain yield. Moderate behavior was observed in super basmati (medium K-use efficient), while 99509 genotype (high K-us efficient) remained unaffected. In all three genotypes K @ 60 kg ha-1 was found optimum and application above 60 kg ha-1 had no positive impact on growth and yield. However using quadratic model, optimum K rate for maximum grain yield was found 62 kg ha-1 for genotype Super basmati and genotype 99505, and 70 kg ha-1 for IR-6. The results show that K-use efficient genotypes used K more efficiently. Ghiri *et al.* (2010) conducted an experiment to determine the different forms of K and their relation with clay mineralogy and other soil properties. Studied soils were divided in three groups on the base of illite percentage of clay fraction that were 20-35 %, 10-20 % and 0-10 % for group 1, 2 and 3, respectively. Except water soluble K all forms of K were high in group 1 followed by group 2 and 3. Significant correlation was observed between all forms of K, clay content, calcium carbonate content and CEC. Negative correlation was observed between different forms of K and calcium carbonate content in each group. These results show that estimation of water soluble, HNO3-extractable and mineral K content is possible from exchangeable K, calcium carbonate content, clay mineralogy and clay content. Sheng *et al.* (2004) conducted an experiment to study the effect of potassium application rates on plant K accumulation, grain quality and K use efficiency of japonica rice. When potassium fertilizer was applied as basal dressing, maximum K uptake of rice was at K2O application rate of 12.8 kg $667m^{-2}$ and excessive fertilization decreased K uptake, K absorption increased in grains with increase of K fertilizer application rate. Maximum uptake of potassium by rice was in the growth season from elongation stage to heading stage. Excessive fertilization and non-fertilization enhanced the proportion of plant K uptake before stage of elongation, but reduce the effective panicles. With one time application of K fertilizer a basal dressing, highest grain yield and quality occurred at level of 1: 0.8 of N: K2O ratio, which significantly increased the K physiological and agronomy efficiency, setting percentage and percentage of ear bearing tiller. Also at this level low amylose level and low chalkiness degree was found. Compare to one time application of K fertilizer as basal dressing, fertilization as panicle fertilizer caused increased in plant K uptake and proportion from elongation stage to heading stage, setting percentage, number of filled grains and gel consistency. Moreover, K fertilization as panicle fertilizer significantly decreased amylose content and chalkiness degree, resulting in high grain yield and quality. Du *et al.* (2004) conducted a study to investigate some factors controlling the adsorption of K onto two soils (Ariake clay and Akaboku). Multi-salts solution containing KCl, NaCl and CaCl2 and the solution having KCl salt were selected as synthetic leachates in the experiment. For both soils the potassium adsorption depends upon solid/solution ratio but in case of Ariake clay soil the results were more significant as compare to Akaboku soil. The K+ adsorption decreased with the increased ratio of soild/solution. The soils were equilibrating before the preordained time of standard batch-type tests and the Freundlich isotherm equation was used to determine the relationship between adsorbed and equilibrium concentration. In case of KCl solution conditions, both soils were adsorbed larger amount of K+ relative to multi-salt conditions. Hannan *et al.* (2012) Different soils have different adsorption capacity due to which an individual critical level of K is in sufficient for different textured soils as well as verity of crops. In a country, fertilizer recommendations for a specific region required prolonged investigational trails. Being a good indicator of soil fertility, sorption isotherm provides reliable fertilizer recommendations. Freundlich and Langmuir adsorption isotherms are worldwide used to measure the behavior of nutrient in soil and fertilizer recommendation for a specific site and crop. A few experimental trails required for this kind of approach. Initially within laboratory, target soil solution levels to be set with the help of previously discussed adsorption models. At the end of trail, a precise targeted yield to be achieved through evaluation of yield data by using various models (quadratic, exponential/Mitscherlich, Boltzman sigmoid, Extended logistic, linear plus plateau models). Maize fodder crop tested by using above said approach. As a result of 14.50 mg L^{-1} soil solution level which is equal to 144 kg K ha^{-1}, the total fodder yield was 61.91 Mg ha^{-1}.The result indicates that a higher soil solution level required for maximum and better quality fodder trait output. Farshid *et al.* (2000) conducted an experiment to study potassium adsorption isotherms for different soil series. Dehno, Lavark, and Lordegan soil series were used for the adsorption phenomenon. Initially soil samples were saturated with Ca2+ through CaCl2 and then Ca-saturated samples equilibrated with high concentration of potassium. After equilibrating time period, final concentration to be measured. By the difference of initial and final K concentration, adsorbed amount of K calculated. Different adsorption models i.e. Langmuir, Frundlich, Temkin and Initial mass models were used to explain the adsorption data. Among all the models, Langmuir model revealed poor degree of fitness as compare to other. Doula *et al.* (2008) conducted an experiment to study dynamics of K adsorption from solution to exchangeable form on bentonite. Initially bentonite was saturated with Ca^{2+} by using $CaCl_2$. Adsorption time of K was determined on Ca-saturated samples using 125, 150, 200, and 250 mg L-1. Soil samples with appropriate solutions were equilibrated with different time periods (10, 15, 20, 30, 35, 45, 60, 75, 80 and 120 minutes). The pH of soil samples were ranged between 4 and 9. Equilibrium reached quickly at higher pH values at low K concentrations. On comparison of coefficients of determinations (r2), it was concluded that best fits of adsorption data was provided by the parabolic diffusion and modified Freundlich models. Constants were estimated for Freundlich equation and model was expressed as a function of pH. Bangroo *et al.* (2012) performed an experiment to highlight the potassium (K) adsorption trend and factors affecting to the process of adsorption in the northern maize growing areas of Kashmir. The soils were lacustrine. The adsorption isotherms for K were built through five gram soil samples equilibrated with 0, 1, 5, 10, 20, 60, 100 and 200 mg K. Average potassium adsorption amounts for 1 and 200 mg K were 13% and 11%, while the adsorbed ranges were 13-15% and 9-12% for both applied rats respectively. Freundlich, Langmuir and Temkin adsorption isotherms were used for the data analysis. Relative to Langmuir and Temkin adsorption equations, Freundlich equation perform better. Clay contents, pH and CEC of the soils were significantly correlated with Freundlich parameter (a) with >0.90 coefficient of determination. Jibrin (2010) conducted an experiment to study K adsorption behavior of 12 cultivated Fadama surface soils across Nigeria. The soils had 0.01- 0.23 (median 0.07), 0.21-6.83 (median 2.70), 0.20 – 1.73 (median 0.91) and 0.09-0.26 (median 0.14) Cmolc kg-1, water soluble, 0.5 M NaHCO3 extractable, 1 N HNO3 extractable, and exchangeable K concentrations, respectively. Five of the soils were low in exchangeable K, while the remaining seven had medium range of exchangeable potassium concentration. The Freundlich sorption model conformed to the K characteristics of the soils with R2 values ranging from 0.630 to 0.852 and had in the range of 54.1 to 71.8 L kg-1 KF (Freundlich coefficients) value. The soils had several types of sorption sites confirmed by the poor fit indication of the Langmuir model. The results of this study indicated that exchangeable K pools in the soil respond to high nutrient-demanding crops, such as rice with K fertilizer application. Deligianni *et al*, (1994) investigated the soils of agricultural areas in Greece. These are formed from the alluvial calcareous deposits, classified as Entisols. The main concerns of their study were to estimate the potassium adsorption isotherms which were most commonly used by Entisols. For this pH levels of 5.0, 6.0, 7.0, 8.0 and 9.0 and initial concentrations of 3.5, 10.7, 17.8, 22.1, 32.1, 37.1, 43.6, 53.6, 60.7, 69.3, 74.3, 78.6 and 85.7 μg K/ml of potassium solution were used. The Langmuir, Freundlich and Temkin adsorption isotherms were used. Then the adsorption data were fitted to the adsorption models by regression and then compared on the basis of goodness of fit. The potassium sorption by this soil was described with similar success by each adsorption isotherm, but the Freundlich model was slightly superior. The effect of the pH on the potassium adsorption by Entisol was studied. As adsorption characteristic vary between soils, so to predict the fate of added K fertilizers and to make accurate K fertilizer recommendations, knowledge about factors affecting K adsorption characteristic of soil is essential (Sparks and Haung, 1985). Many factors affect the potassium adsorption characteristics of soil like layer charge and particle size, interlayer and position of wedge zones, types of exchange sites on the colloids, ionic size/ type of cations, effect of temperature, concentration and pH.

Factors affecting potassium adsorption in soil

Layer charge and particle size

The K/divalent ion equivalent ratios generally increase in order: montmorillonite < vermiculite < biotite < muscovite. Dolcater *et al.* (1968) noted that this corresponded to the order of increasing surface charge density and layer charge of the exchangers, and with the exception of vermiculite, with decreasing CEC. Rich (1968) has noted that the size of negative charge as well as the charge density of the mineral may affect K selectivity. The degree of K fixation is influenced by the charge density of the layer silicates. Low charge montmorillonite at 1.5 nm interlayer space (d-spacing) when K saturated unless it is heated (Laffer *et al.*, 1966). Soil montmorillonites have higher charge density and a greater probability of having wedge positions near zones where K selectivity is high (Rich, 1968). Potassium selectivity increases with particle size in some soils. The high K selectivity of clay-size muscovite and many soil clay cannot be explained by selection of K at specific sites of such low exchange capacity. Much of the K selectivity most likely occurs in the interlamellar regions (Sparks and Huang, 1985).

Types of exchange sites on the colloid

There are three types of exchange sites for K. These sites are (a) interlattice sites spresent between layers of the mineral (b) edge sites (c) planner sites present on the outer surface of the crystal structure. Bolt *et al.* (1963) showed that the highest Gapopn selectivity coefficient (KG) is showed by interlattice sites, whereas planner sites exhibits the lowest kG.

Ionic size/ type of cations

The concentration and nature of the replacing cation also influence the critical K level of the cations tested in Cl^{-1} solutions. The activity of all these replacing ions in the solution phase should be much greater than the K for significant K release to occur. Rich and Black (1964) and Murdock and Rich (1972), found that in soils containing partially closed vermiculites and partially opened micas where wedge zones existed, NH4OAc removed more exchangeable K than did MgOAc even though Mg usually is a better replacer of K than NH4+. Rich (1972) found that Virginia soils, which contain appreciable amounts of K and hydroxyl Al interlayers, did not release K upon drying. Upon drying the release of K from soil is related to clay fraction (Scott and Hanway, 1960). Degree of rotation of weathered soil minerals may change, when a soil is dried. Thus the K-O bond may be modified.

Effect of pH on K fixation

Rich (1964) showed that the effect of pH on ion varies with associated cations. For NH4, pH has little effect, but for Mg^{2+} and Li^{+} the effect is pronounced. He ascribed the increased efficiency of Mg^{2+} and Li^{+} with a decrease in pH to an expension of crystal structure. Rich and Black (1964) found that K exchange was enhanced by low pH. In the case of H and OH exchange, it is known that ions do not migrate rapidly enough to account for the reaction rate, but rather there are rapid proton pump. The increase in K fixation between pH 5.5 and 7.0 can be ascribed to the decreased numbers of Al (OH) x species which decrease K fixation (Rich and Black, 1964). At this pH (8), Al^{3+} cannot prevent K fixation and does not neutralize the charge on the clay leading to potassium deficiency in alkaline calcareous soils. Potassium deficiency has been reported in alkaline calcareous soils of Pakistan especially under intensive potato-maize cultivation system (Bajwa, 1994; Malik *et al.*, 1989) because farmers in the area under study do not use K fertilizer to potato and depend on native soil K supply and K from irrigation source but on K deficient soils both sources cannot match the K requirements of crop. This insufficient K results in reduce yield (McDole, 1978; Satyanarayana and Arora, 1985). Choudhury and Khanif. (2003) investigated the K deficiency in different rice growing areas of Malaysia. A study was carried out on K adsorption in three rice soils of Malaysia (Hutan, Kangar and Guar series). Six K levels were used (0.00, 28.77, 33.57, 38.37, 43.16 and 47.96 mmol kg^{-1}). The data on the K adsorption were fitted into Temkin, Freundlich, and Langmuir, adsorption equations. Data was also correlated with organic matter content, pH and cation exchange capacity of the soils. Potassium adsorption linearly increased with increasing levels of added K in all the three soils. The increase in rate of potassium adsorption was the highest in Guar series followed by Kangar and Hutan series, respectively. Potassium adsorption in two soils (Hutan and Kangar) fitted into Langmuir equation while the adsorption data in Guar series did not fit into this equation. Adsorption data in none of the soils fitted well in Temkin and Freundlich adsorption equations. Correlation between pH and K adsorption was significant (r = 0.881), whereas, correlation of K adsorption with either cation exchange capacity or organic matter content was non-significant. The results indicated that K adsorption is mostly soil pH dependent. It was concluded that more K fertilizer may be needed for soils with higher adsorption capacity to get immediate crop response.

References

Ahmad, M., A. Waheed, A. Naiz, A. Hannan and A.M. Ranjha. 2009. Maize fodder quality characteristics and yield as affected by potassium application on calcareous sandy clay loam soil. Soil and Enivron. 28: 169-173.

Ali, A., M. A. Nadeem, M. Maqbool and M. Ejaz. 2005. Effect of different levels of Potash on growth, yield and protein contents of Mungbean varieties. Pak. J. Agric. Res. 44 (2): 121-126.

Arif, M., M. Arshad, H. N. Asghar. And M. A. Basra. 2010. Response of Rice genotypes varying in K use efficiency to various level of potassium. J. Agri and Bio. 12: 926-930.

Awan, T. A., Z. Manzoor, M. E. Safdar and M. Ahmad. 2007. Yield response of Rice to dynamic use of potassium in traditional rice growing area of Punjab. Pak. J. Agric. Sci. 44: 130-134.

Bajwa, M. I. 1994. Soil potassium status, potash fertilizer usage and recommendations in Pakistan. Potash Review No. 3/1994. Subject 1, 20th suite. International Potash Institute, Basel.

Bajwa, M. I. and F. Rehman. 1996. Potassium mineralogy and fertility of Pakistan soils. AEFC. M-29, Cvic Center, Model Town Extension Lahore, Pakistan.

Bangroo, S. A., Mushtaq A. Wani, Tahir Ali, M. A. Malik, N. A. Kirmani, J. A. Sofi and Faisul-ur Rasool. 2012. Potassium adsorption characteristics of soils under long term maize-legume cropping sequence. Afr. J. of Agri. Res., 7: 6502-6507.

Barber, S. A. 1977. Application of phosphorus fertilizers: method, rate and time of application in relation to the phosphorus status of soils. Phos. Agric. 70: 109-115.

Barber, S. A. 1984. Soil nutrient Availability: A mechanistic approach. New York, Wiley. 398.

Beringer, H. 1980. The role of potassium in yield formation. In: Saurat A. and El-Fouly (ed.) Proceedings of the international workshop on the role of potash in crop production held on 20-22 November 1979, Cairo, Egypt.

Choudhury, E. H., A. M. Ranjha, M. A. Gill and S. M. Mehdi. 2003. Phosphorus requirement of maize in relation to soil characteristics. Int. J. Agri. Bio. 5(4): 625-629.

Deligianni, Ch., A. AIoannou, A. Dimirkou and Ch. Paschalidis. 1994. Potassium sorption by Entisols of Greece as described by commonly used isotherms. Commun. Soil Sci. Plant Anal., 25(9&10), 1431-1445.

Dolcater, D. L., E. G. Loste, J. K. Syers, and M. L. Jackson. 1968. Cation exchange selectivity of some clay sized-minerals and soil materials. Soil sci. Soc. Am. J. 113-116.

Doll, E. C. and R. E. Lucas. 1973: Testing soils for potassium, calcium and magnesium. J. Soil Sci Soc. Am. J. Pp. 133-151.

Doula, M., A. Ioannou, A. Dimirkou and J. Mitsios. 2008. Potassium sorption by Calcium-bentonite. Communications in Soil Science and Plant Analysis. 25:1387-1400.

Du, Y.J., S. Hayashi and Y.F. Xu. 2004. Some factors controlling the adsorption of potassium ions on clayey soils. Appl. C. Sci., 27: 209–213.

Farshid, N. B., Kalbasi M and Rafiei F. 2000. A study on potassium adsorption isotherms in some soils. Ira. J. Soil and water sci., 14: 130-140.

Ghiri, M. N., A. Abtahi, F. Jaberian and H. R. Owliaie. 2010. Relationship between soil` potassium forms and mineralogy in highly calcareous soils of southern Iran. J. basic and applied science. 4(3): 434-441.

Haby, V. A., M. P. Russelle and E.O. Skogley. 1990. Testing soils for potassium, calcium, and magnesium. P. 181-228. In R. L. Westerman (ed.) Soil testing and plant analysis. Soil Sci. Soci. of Am. Medison, WI.

Hannan, A., M. Arif, A. M.Arif and M. Waqas. 2012. A Site-Specific Potassium Fertilization Approach to Overcome Sporadic Response of Crops. Cro. Pro. Agri. Impr. 619-636.

Hay, M. J. M., T. W. Walker, A. F. R. Adams and A. S. ampbell. 1976. The potassium status of six loessial soils of Canterbury, New Zealand, in elation to rain fall and rate of loess accumulation. J. Soil Sci. 27: 227-236.

Hundal, L. S. and N. S. Pasricha. 1998. Adsorption-desorption kinetics of Potassium as influenced by temperature and background anions. Geoderma. 83: 215-225.

Iqbal, T. 2000. Effect of potassium on wheat and maize crops. M.Sc. Thesis, Dept. soil sci., Univ. Agri. Faisalabad.

Jibrin, J. M. 2010. Forms of Potassium and Potassium Sorption in Some Fadama Soils of Nigeria Sav.J.Agri., 5: 1597 –9377.

Jones, Jr. J.B. 2003. Plant mineral nutrition. In: Agronomy Handbook. Baton Raton, FL, USA. CRC Press: 291-334.

Karim, J.H. Izharullah and A. Bari. 2006. Effect of time and levels of potassium application on the yield components of maize. Sarhad J. Agri. 22: 271-275.

Laffer, B. G., A. M. Posner and J. P. Quirk. 1966. Hysteresis in the crystal swelling of montmorillonite. Clay Mineralogy 6: 311-321.

Malavolta, E. 1985. Potassium status of tropical and subtropical region soils. P. 163-200. In R. D. Munson (ed.) Potassium in Agriculture. Am. Soci. Agron., madison, WI.

Malik, D.M., M R. A. Chaudhary and G. Hussain. 1989. Crop response to potash application in the Punjab. Pro. of Workshop on the Role of Potassium in Improving Fertilizer Use Efficiency. National Fertilizer Development Centre, Islamabad. 71-93.

McDole. R. E. 1978. Potassium fertilizer tails with potatoes in coarse textured soils in southern-eastern Idaho. Am. Potato J. 55: 161-170.

Mehdi, S. M., G. Hassan, M. Sarfaz, M. Sadiq, N. M. Hassan and G. Shabir. 2001. Potassium deficiency and response of rice to its application in Hafizabad Distrct. Commun. J. Bio. Sci. 1(12): 1112-1115.

Mengel, K. 1985. Dynamics and availability of major nutrients in soils. Adv. Soil Sci. 2: 65-131.

Metson, A. J. 1968a. Potassium. Pp. 82-95 in: soils of New Zealand. Part 2. New Zealand Soil Bureau bulletin 26. Wellington, New Zealand, Government printer.

Metson, A. J. 1980. Potassium in New Zealand soils. Department of Scientific and Industrial Research. New Zealand Soils Bureau report no. 38. 61 p.

Mitsios, J., A. Dimirkou, A. Ioannou, Ch. Paschalidis and M. Doula. 1994. The Sorption Isotherm of Potassium. Commun. Soil Sci. Plant Anal. 25: 1373-1386.

Mussgnug, F., M. Becker, T.T. Son, R.J. Buresh and P.L.G. Vlek. 2006. Yield gaps and nutrient balance in intensive, rice-based cropping system on degraded soils in the Red River Delta of Veitnam. Field Crop Res. 98: 127-140.

Nisar, A. 1985. Potassium requirement of wheat crop in different cropping systems. Fert. News. 30: 38-42

Nisar, A. 1988. Potassium use efficiency and soil test crop response correlation. Ph.D. diss. Dept. Soil Sci. Univ. Agric., Faisalabad, Pakistan.

Parfit, R. L. 1992. Potassium-calcium exchange in some new Zealand soils. Aust J. soil. Res. 30: 145-158.

Rashid, A. and E. Rafique.1998. Micronutrients in Pakistan Agriculture: Significance and Use. Technical brochure. Pakistan Agricultural Research Council, Islamabad.

Rich, C. I. 1964. Effect of cation size and pH on potassium exchange in nason soil. Soil Sci. 98: 100-106.

Rich, C. I. 1968: Mineralogy of soil potassium. Pp. 79-96 IN: the role of potassium in agriculture, V. J. Kilmer, S. E. Younts, N. C. Brady, (eds.) Madison, Wisconsin, U.S.A. soil Sci. Soci. of Am.

Rich, C. I. 1972. Potassium in minerals. Proceedings of Colloquium of International Potash Institute 9: 15-31.

Rich, C. I., and W. R. Black. 1964. Potassium exchange as affected by cation size, pH, and mineral structure. Soil Sci. 97: 384-390.

Saifullah, A.M., Ranjha, M. Yaseen and M.E. Akhtar. 2002. Response of wheat to potassium fertilization under field conditions. Pak. J. Agri. Sci., 39(4).

Satyanarayana, V. and P. N. Arora. 1985. Effect of nitrogen and potassium on yield and yield attributes of potato (var. Kufri Bahar). Indian J. Agron. 30: 292-295.

Scott, A. D. and J. J. Hanway. 1960. Factors influencing the change in exchangeable soil K observed on drying. Transactions of 7th Int. Congr. Soil Sci. 4: 72.

Sharpley, A. N. 1990. Reaction of fertilizer potassium in soils differing mineralogy. Soil Sci. 149: 44-51.

Sheng, W., Z. Hong, D. Feng, W. Zing and J. Jun. 2004. Effect of potassium fertilizer application rates on plant potassium accumulation and grain quality. Commun. J. Soil Sci. 37(10): 1444-1450.

Sofi, K.A., M.H. Chesti, Z.A. Baba and B.A. Lone. 2005. Growth and yield of maize as influenced by application of nitrogen and potassium. Environment and Ecology 23 S (Special 3): 586-588.

Sparks, D. L. 1987. Potassium dynamics in soil. Adv. Soil Sci. 6: 1-63.

Sparks, D. L. 2000. Bioavailability of soil potassium, D-38-D-52. In M.E. Sumner (ed.) Handbook of Soil Science, CRC Press, Boca Raton, FL.

Sparks, D. L., D. C. Martens and L. W. Zelazny, 1980: Plant uptake and leaching of applied and indigenous potassium in Dothan soils. Agron. J. 72: 551-555.

Sparks, D.L. and P.M. Huang. 1985. Physical chemistry of soil potassium. Page 201-276. In R.D. Munson (ed.) Potassium in Agriculture. Soil Science Society of America, Madison.

Tandon, H. L. S. and G. S. Sekhon. 1988. Potassium research and agricultural production in India. Fertilizer development and consultation organization. New Delhi.