Potash Use for Sustainable Crop Production in Pakistan: A Review

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Abstract

Pakistan is located in the sub-tropical zone and soils are deficient in a number of plant nutrients especially nitrogen (N) and phosphorus (P) including some micronutrients such as zinc (Zn) and boron (B). Apparently, country soils have high potassium (K) being rich in mica minerals but this high soil K does not account its availability for optimum plant growth as K bounded within minerals is not released to meet requirement for crop production. Nonetheless, some soils with low plant available K maintains its levels optimal for plant growth resulting in no response to K fertilization. Release and fixation of K depends on the type and content of soil minerals, based upon which, its distribution and retention properties are required to develop K fertilizer recommendations for sustainable nutrient management. Soil mineral composition and K chemistry also differ with development age and source of soil parent material. Use of K fertilizers in Pakistani agriculture is still under debate, due to diverse crop responses to K fertilizer. General K fertilizers recommendations are usually based on exchangeable K content in the soil and ignore the soil mineralogy and K dynamics which may lead to non-responsiveness of K applications. Nevertheless, K deficiency has been observed in many parts of the country. Recently farmers’ interest to use K has improved with enhanced knowledge about the balanced fertilizers concept and technological development in fertilizers applications. Being a key macronutrient for plant growth and yield, K is taken up in higher amounts by all crops. Application of K fertilizers is therefore vital for sustainable agriculture growth in Pakistan, for which comprehensive research programs to endorse K fertilization by presenting a clearer picture of crop response to K application are needed. In wake up, soil mineralogy and K dynamics-based recommendations may be an effective tool to maximize crop yield in the country as the population increases at ~2.0% per year. In conclusion, (i) Pakistani soils require the use of potash to balance the fertilizer use for better crop yields, (ii) site specific recommendations of K fertilizers based on soil mineralogy and K dynamics in soil can deliver its economic returns, (iii) use of potash can enhance the quality of agricultural produce for international market, (vi) potash use can enhance the ability of crops to withstand environmental stresses in the climate change scenario. © 2017 Friends Science Publishers

Keywords: Potash; Precise fertilizer-use; Crop yield; Soil minerals; Produce quality

Introduction

Potassium (K) is an important macronutrient required in the highest amount after nitrogen for plants and its ample supply is crucial for crop productivity. Generally, K plays important functions in plant systems by activation of more than 80 enzymes involved in different metabolic processes including photosynthesis, protein synthesis, respiration etc., charge balancing across the membranes of different cell organelles, particularly plasma membrane and tonoplast, and as osmoticum in stomatal regulation by maintenance of guard cells turgidity (Mengel, 2007).

Existing potassium contents in earth’s crust are more than 2.6% with micas and alkali feldspars as the major natural sources of soil containing 6–9% and 3.5–12% K, respectively. Typically, soil K exists in four fractions viz. mineral, non-exchangeable, exchangeable and soluble K (Sparks, 1987). Among these only soluble and exchangeable K are readily plant available and most of the fractions are fixed by clay minerals making it non-available for uptake by plants. This necessitates appropriate K fertilization to achieve optimum crop growth with good quality harvests.

Nonetheless, inadequate K fertilization is among the responsible factors for crop yield gaps in many parts of the world due to limited plant available K (Mengel, 2007), especially in developing countries. Further, soil K dynamics based on type and age of clay minerals play an important role in crop nutrition of potassium. To fulfill crop demand, usually higher K fertilizers are applied to achieve optimum growth but plants respond insufficiently to general fertilizer recommendations in soils rich with K-fixing clay minerals.

In a sandy clay loam soil of Michigan, about 92% of the applied K fertilizer was fixed and 1600 kg K ha\(^{-1}\) applied had significant response in tomato production (Doll and Lucas, 1973). The soil was rich in illite and vermiculite clay minerals with high cation exchange capacity (CEC) with major part of applied K as fixed making it immediately unavailable to the plants. Similar reports have been reported in other parts of the United States (Mengel and Kirkby, 2001). Recently, Wakeel et al. (2013) observed that presence of specific clay minerals affect the fixing and releasing capacity of K in three different soils. Smectite-dominant soils usually showed faster release of K than illite soils and poor response of sugar beet plants was found to K fertilization in these soil types (Bohn et al., 2001; Wakeel et al., 2013). Potassium sorption on exchange sites and its fixation also depend on the physicochemical properties of the soil along with the type and content of the clay minerals (Braunweigh, 1980). Similarly, the age of soil developed from mica and alkali feldspar also determines the extent of weathering and K dynamics. Thus, during K take up, plants reduce its concentration in the immediate root zone, which releases K-ions from the minerals (Kuchenbuch and Jungk, 1984). In fact, the release of K converts micas to secondary 2:1 clay minerals-illite and then vermiculite (Farmer and Wilson, 1970; Havlin et al., 1999; Fig. 1). Further, some fractions of applied K to illite and vermiculite rich soils K may get fixed by soil particles making it unavailable or slowly available to plant roots (Scott and Smith, 1987). Nonetheless, K in fixed fractions may become available to plant roots when released into soil solution particularly at low soil K levels (Cox et al., 1999), but is too slow release may not meet the plant-growth requirements.

Use of potash fertilizers is very low in agriculture which limits the crop growth, yield and quality. There are several reasons for low usage and K fertilization may increase economic crop production. Several reviews already available highlights the importance of potassium uses in agriculture (Zorb et al., 2014), potassium use efficiency in different crops and genotypes (Rengel and Damon, 2008), strategies to improve potassium use efficiency (Shin, 2014), potassium transport and signaling (Wang and Wu, 2013; Luan et al., 2016), potassium homeostasis to improve biotic and abiotic stress (Anschütz et al., 2014; Luan et al., 2016) and genetic approaches to improve potassium uptake and utilization efficiency (Wang and Wu, 2015). Here in present review we discuss the significance of K fertilization, reasons for low K usage, economics of its fertilization in arable and irrigated crops, current status of K research and possible directions to enhance its application to lessen the yield gaps for sustainable crop productivity particularly in context of Pakistan.

Significance of Potassium Fertilization in Pakistan

Agriculture is the mainstay for ever increasing population of Pakistan. It contributes about 23% to country’s total GDP with about 50% of labor force engaged. Agriculture depends on natural resources and climatic conditions and as dynamic system it requires excellent planning for sustainability. Green revolution was a great break through world-wide to fulfill the food requirement of huge population of the world; Pakistan was also among the active participant of green revolution of 1960s with drastic increase in food grain production. With Green revolution, introduction of high yielding varieties and fertilizers responsive crop varieties, a significant increase in food production was observed (Fig. 2). There was a continuous increase in yields of cereals since green revolution, however these gains have been static since last decade with no significant increase, despite crop varieties have still great potential to yield more by efficient use of inputs and management practices.

Since green revolution, continuous usage of nitrogenous and phosphatic fertilizer has been increased in Pakistan but of K is almost negligible. Critical comparison of fertilizer use with yield increase reveal that instead of increase in N and P fertilizers, the average gain in crop productivity is stagnant since last decade and neglected K fertilization may be one of responsible factors for stagnant productivity, because balanced use of fertilizers is crucial for maximum, economical and sustainable crop production. With increase in nitrogenous fertilizers usage, the ratio of K: N fertilizer has decreased severely from 1994 to onward contributing to less economic agricultural returns (Fig. 3).

The available, soluble and exchangeable, K fractions have been reduced in Pakistani soils due to cultivation of high yielding crop varieties and no inputs of K fertilizers. With high crop demands for K, there is also plausibility of its depletion from these soil fractions. Based on average production of crops, Pakistani soils are removing 100–150 Kg O kg ha\(^{-1}\) per year. The data provided by soil fertility research institute also revealed obvious decrease in available K under different cropping systems (Fig. 4). Therefore, severe deficiency of K is expected in coming years with more depletion if K use in fertilization practices is neglected and even soil fertility may be at alarming risk of sustainability.

**Use of Potash Fertilizers**

Since the green revolution in 1960s, use of chemical fertilizers was promoted in Pakistan, as in many other parts of the world. In beginning, with nitrogenous fertilizers, phosphatic (P) fertilizers were introduced later in 1970s and the use was increased over time (Fig. 5). Since the times, use of nitrogenous fertilizers was significantly higher with the plausibility of better, quick and more cost-effective crop response for crop yields and therefore at present, nitrogenous fertilizers contribute 78% to total fertilizer use in Pakistan (NFDC, 2015). Slow and steady increase in P fertilizer usage sustained and since
last few years until 2013–2014, its use has been reduced due to higher prices of P fertilizer. Pakistan’s soils contain mica with K concentration of ~7%; however, plants’ requirements of this mineral are not fulfilled due to less plant-available potassium. Potassium application has been discouragingly low in all the major crops, except for potatoes, where farmers use potash fertilizers for better yields and improved tuber quality.

About 50% of total fertilizer-offtake in Pakistan shows possibly its applications in wheat due to more certainty of economic returns (Fig. 6). Cotton is the second most fertilized crop and occupies 25% of total fertilizer use. Other crops have not been fertilized to a great extent except potato in which utilization of K fertilizer is greater than any other crop in Pakistan.

Many efforts have been made by government, national and international fertilizers associations, but the use of potash in agriculture crops have remained miserably low. Average use of fertilizers per hectare is 132 kg for N and 32 kg for P fertilizers, whereas for potassium is less than 2 kg ha\(^{-1}\) instead of higher recommendations for many crops in Pakistani soils (Table 1). Imbalanced fertilization is always uneconomical and very small ratio for K to N results into several problems, such as crop lodging particularly in rice and wheat. Recently, we found improved stem strength in rice with balanced use of K and N by decrease in basal internode length (Zaman et al., 2015). Although, with introduction of compound fertilizers, such as NPK has increased K fertilizer use in field crops to some extent, but situation has grown up with the dilemma of reduced K\(_2\)SO\(_4\) (SOP) availability in the market and worsen with rare SOP availability. Nonetheless, over the last few years, potassium containing liquid fertilizers have been introduced in the market by various private companies and are recommended as fertigation or foliar but their adaptability by farmers is very low. Moreover, application of these K fertilizers with active ingredient in small amount cannot fulfill crop requirements.

A recent development has been observed with the import of KCl (MOP) as alternate to SOP by national fertilizer companies, which is economical and may help to improve potash use in Pakistan due to its low price (~2/3 of SOP) and with greater acceptability among farming community. However, long term consequences are required to analyze the situation with addition of chloride (Cl\(^-\)) by use of MOP under Pakistani conditions.

Economics of Potassium use in Arable Crops

The profitable use of K in different crops depends on costs of inputs especially fertilizers, increase in crop yield and appropriate superior price of produce (Ahmad and Muhammad, 1998; Majumdar et al., 2012). Concept of balanced use of fertilizers involves not only increase in physical output of crop and also maximizes profitability in terms of economic returns for every unit of fertilizer applied. Increases in economic returns or value cost ratio may decrease when fertilizers use tend to be balanced (Table 3), therefore, growers should consider use of inputs and outputs in such a balanced manner that specific input costs are administered in economical way especially with considerable increase in K fertilizer prices. Very few studies highlight the economics of K fertilizers as increase in net returns or value cost ratio and showed that crops response to applied K is highly variable and due to different agro-ecological zones of country, response depends on soil type, previous crop history, soil nutrient capacity and specific crop nutrient requirement even use of K-efficient genotypes.
The use of K specifically in arable crops of rain-fed area can be high due to reduced release or its availability from soil and in case of irrigated crops; K gradient from canal irrigation should be measured and considered in K fertilization practices (Ahmad et al., 2014). This may not only help to reduce the K requirement but also the economical use of fertilizers. Under low K or deficient soil conditions, growing of K efficient genotypes may improve the K use efficiency (KUE) for sustainable crop production (Hassan et al., 2014).

Causes of Low Use of Potassium Fertilizers

Mica based rich soils; however, due to continuous weathering, intensive cropping and soil mineral-K release, these have been converted to illite and vermiculite-dominant clay minerals. High yielding crop varieties mine the soil for K, without being replenished by application of K fertilizers. Small land holdings of Pakistani farmers with limited financial resources not allow them to use high price potassium fertilizers.

Lack of Awareness about Balanced Fertilizer Use Concept

Poor education and lack of awareness about the balanced fertilization is one of reasons for low potassic fertilizers use among growers. No Farmer’s education program is available to create awareness about balanced fertilization. Participatory approach can be advantageous to increase potash use, because the effectiveness of this approach was visible in the very high increase in nitrogen use during the early part of green revolution. Likely, increase of diammonium phosphate (DAP) increased among farming community with better and positive response on plant growth and yield as compared to single superphosphate (SSP) and triple superphosphate (TSP). Another possibility for better response towards DAP may be of its N gradient contributing towards its acceptability.

Slow crop response to K fertilizers than N and P may be one of possible reasons for its low off-take. Further, soil response to applied K is different than N and P which is diverse (Wakeel et al., 2013). Farmers’ education about potassium application and its effects on different crop mechanisms and productivity are needed. A good example is reduction in negative effects of abiotic stresses with K nutrition (Cakmak, 2005) such as drought, salinity and frost. This may also function to attract farmers towards balanced fertilizer use.

K Gradient Supply from Canal Irrigation Water, a Misconception

Canal water is good source of K, however there is misconception among farming community that potash
In Pakistan, generally, fertilizer supplies are being phenomenally high due to the cultivation of high-yielding varieties over decades, which have contributed to soil degradation and depletion of essential nutrients such as potassium (K). Fertilizers are not required in soils supplied with canal irrigation water. Potassium gradient in canal water can be alarming with very small K concentration compared to groundwater. Continuous cropping without K or organic matter inputs since decades has exacerbated soil degradation and nutrient depletion. With climate change and increased silting of water reservoirs, canal water supplies are being limited, and therefore, crop must be supplemented with ground water. With increasing use of ground water that contain very small K gradient, it is necessary to add K to soils to maintain agricultural sustainability.

### Table 1: Fertilizer recommendations provided by Punjab Agriculture Department for major crops of Pakistan

<table>
<thead>
<tr>
<th>Crops</th>
<th>Nitrogen kg ha⁻¹</th>
<th>Phosphorus</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>200-400</td>
<td>88-175</td>
<td>95-125</td>
</tr>
<tr>
<td>Wheat</td>
<td>80-130</td>
<td>58-115</td>
<td>62</td>
</tr>
<tr>
<td>Rice</td>
<td>85-172</td>
<td>68-102</td>
<td>62-80</td>
</tr>
<tr>
<td>Maize</td>
<td>250</td>
<td>115-172</td>
<td>62-125</td>
</tr>
<tr>
<td>Potato</td>
<td>250</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>172-300</td>
<td>58-172</td>
<td>62-125</td>
</tr>
<tr>
<td>Sugar Beet</td>
<td>125</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Oilseed Crops</td>
<td>32-88</td>
<td>32-88</td>
<td>32-62</td>
</tr>
<tr>
<td>Sunflower</td>
<td>150</td>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>Kharif Fodders</td>
<td>58</td>
<td>58</td>
<td>32</td>
</tr>
</tbody>
</table>

Source: http://dai.agripunjab.gov.pk/croptechnologies

### Table 2: Response of potassium fertilization in different crops grown on Pakistani soils

<table>
<thead>
<tr>
<th>Crop</th>
<th>K Source</th>
<th>Application rate of K application</th>
<th>Application method</th>
<th>Increase over control</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>K₂SO₄</td>
<td>60 kg ha⁻¹ soil 60 kg ha⁻¹</td>
<td>Soil</td>
<td>10% shoot growth</td>
<td>Khan et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>90 kg ha⁻¹, 120 kg ha⁻¹</td>
<td>Soil</td>
<td>19% shoot growth</td>
<td>Khan et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>42 kg ha⁻¹ 84 kg ha⁻¹</td>
<td>Soil</td>
<td>20% shoot growth</td>
<td>Khan et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>126 kg ha⁻¹ 168 kg ha⁻¹ 210 kg ha⁻¹</td>
<td>Soil</td>
<td>39% shoot growth</td>
<td>Majid et al. (2007)</td>
</tr>
<tr>
<td>Wheat</td>
<td>K₂SO₄</td>
<td>60 kg ha⁻¹ 80 mg K kg⁻¹ solution</td>
<td>Soil</td>
<td>13% yield</td>
<td>Khan et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>60 mg K kg⁻¹ solution 500 ppm</td>
<td>Soil</td>
<td>18% shoot growth</td>
<td>Khan et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>3.3 mmol kg⁻¹ soil 4.5 mM Foliar</td>
<td>Soil and foliar</td>
<td>18% shoot growth</td>
<td>Khan et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>3.3 mmol kg⁻¹ soil, 4.5 mM Foliar</td>
<td>Soil and foliar</td>
<td>18% shoot growth</td>
<td>Khan et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>6.6 mmol kg⁻¹ soil, 9 mM Foliar</td>
<td>Soil</td>
<td>18% shoot growth</td>
<td>Khan et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>60 mg pot⁻¹ 60 mg K kg⁻¹ solution</td>
<td>Soil</td>
<td>18% shoot growth</td>
<td>Khan et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>K₂SO₄</td>
<td>30 mg pot⁻¹</td>
<td>Soil</td>
<td>18% shoot growth</td>
<td>Khan et al. (2007)</td>
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<tr>
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agriculture department. Due to least soil testing facilities, farmers usually don’t analyze their soils and general trend of fertilizers application are practiced. Site-specific fertilizer recommendations are very rare and at district level, soil fertility laboratories established by provincial governments are not enough to meet farmer’s requirements. Usually, N and P general recommendations are followed, but for K, these recommendations often result in poor crop response due to variations in soil mineralogy and K dynamics. This may be one of plausible reason among growers for low potash application and hence, difficult to get positive response to apply additional amount of fertilizers without any gain in income.

Fertilizer Prices and Availability of K Fertilizer

With small land holdings (~2 hectares), limited financial resources are constraints for farmers to go for balanced fertilizer use. On other hand, high costs of potash restrict its use by farmers when they are already spending a lot on N and P fertilizers. Many available reports available highlights the importance of K fertilization in country for sustainable and economic agricultural productions, but escalating prices of K fertilizers is a big constraint for balanced fertilizer use. Poor interest of government and no aggressive campaign by fertilizer industries for K fertilization have embarrassed the situation. Subsidizing agriculture inputs especially fertilizers including K can be of top importance to increase its use. The paramount example is of increased use of nitrogen when urea subsidized in early green revolution, even until now nitrogenous fertilizers consumption is high even after withdrawal of subsidy. Such significant measures should be considered for K increase and to propagate its use at farm level. Another reason for limited K application in agricultural crops is that very few groups of fertilizers suppliers are involved in this business and thereof had least availability of K in the country.

### Instability in Market Prices of Agricultural Produce

Economic values of agricultural inputs and stabilized support price of agriculture produce are main drivers for balanced fertilization. The prices of agricultural inputs are more instable than agricultural produce which creates uncertainty in economic returns limiting the farmers’ choice to use agricultural inputs. Existing rice and cotton support prices are creating frustration due to loss is farmers’ income despite huge expenditures on purchase of inputs. In such scenario, adoption of recommended agricultural practices among small landholders is reduced.

### Potassium Research in Pakistan

Main research focus on potassium in Pakistan agriculture

has been to improve the crop productivity and very few studies highlight prospects of soil applied K in different cropping systems and its role in reducing the devastating effects of biotic and abiotic stresses.

It is believed that country’s soils could supply sufficient K required for plant growth. However, recent soil analyses have shown a significant decrease in soil K status (Fig. 4) and a considerable research data available indicate that most of crops respond to K fertilization (Gurmani et al., 1986; Khattak and Bhatti, 1986; Ranjha, 1995; Mian et al., 1998; Akhtar et al., 2002; Tariq et al., 2011). Nonetheless, some studies also report no significant improvement in crop yields with K application despite high apparent crop potential (Bajwa, 1985; Akhtar and Dixon, 2013) suggesting crop response may be specific with diverse mineralogy and K dynamics of the soil.

Fixation of K by different clay minerals has been considered as one of the reasons for reduced crop response to K fertilization. Mehdi and Ranjha (1995) found that K fixation increased with the K fertilization, but it was high in fine textured soils than coarse one. Khattak (2002) reported that that amount and type of clay minerals result in fixation of added K as well as recovery of non-exchangeable soil K. Soils differing in clay mineralogy also vary in response to applied K (Akhtar and Dixon, 2013). For instance, smectite types of clay minerals in Lyallpur soils usually don’t respond to added K required for optimum plant growth. And K fixation does not directly depend on total clay content but with the types of clay mineral in the soil present (Awan et al., 1998a). Nonetheless, clay content and the weathering of parent material have a strong relationship with extractable potassium (Awan et al., 1998b). Linear response of potassium addition was observed on maize growth in sandy clay loam and sandy loam as compared to clay loam soils where applied K response reduces, perhaps due to its fixation or presence of sufficient K in soil (Wakeel et al., 2002).

During early profile development, long-term fertilizer effect on K-fixation in the soil has not been observed. However, marginal changes in soil plant available K and in the mineral composition had been observed with less K fertilization in the canal irrigated cotton-wheat system (Sheikh et al., 2007). Bhatti (2011) concluded that for promotion of K recommendations should be based on K-fixing capacity and clay mineralogical composition of soils. Clay mineralogy is strongly related with the profile development and weathering stage of the soils and later may have a significant role in determining the K availability.

Due to K role in biological systems, various studies on ameliorating effect of K application under salt and drought stresses are also available. These studies employed different physiological traits with few highlights on grain yield. Foliar applied potassium improved the plant growth and grain yield in wheat under saline conditions (Khan and Aziz, 2013) and foliar fertilization may be more effective in soils with K-fixing clay minerals. Application of potassium sulphate improved crop yield by mitigating the toxic effect of Na+ and it was concluded that K supplementation can be an effective tool for optimum crop production in saline and saline-sodic soils (Hussain et al., 2013).

Beneficial effects of K fertilization were observed in maize under salt stress when a decrease in Na+ and NH4 toxicity was observed in hydroponic culture (Yousra et al., 2013). Potassium stimulated maize growth under saline conditions was attributed to increase CAT activity, higher photosynthetic capacity and increased K concentration in plant leaves (Abbasi et al., 2014). Nonetheless, potassium applied mitigation in adverse effects of drought have also been reported in maize (Zhang et al., 2014). In another study, Kausar and Gull (2014) reported improved wheat biomass and calcium (Ca), magnesium (Mg) and phosphorus (P) uptake K application under salt stress. Thus, it may be suggested that K fertilization can be very helpful for crop production under salt and drought stress conditions with un-predictable rain-fall and reduced canal water supply. Response of Potassium fertilization response in different country soils had been reported by many researchers for which details are given in Table 2.

Future Research Outlooks

Despite of well recognized facts of K in sustainable crop production, its application has been continuously ignored. A solid research and awareness plan is urgently needed to promote K application for which precise K recommendations and produce quality should be prioritized.

Precise Potash Recommendations

The soil physicochemical properties and K forms present in the soil has evidence with different clay minerals (Surapaneni et al., 2002; Srinivasarao et al., 2006). Sharpley (1989) found a strong relationship between clay mineralogy and potassium forms in the soil and suggested its function to predict soil fertility and potassium uptake by plants. Bhatti (2011) concluded that K fertilization in Pakistan should be based on soil K-fixing capacity and clay mineralogical composition due to varied response of clay mineralogy to applied K (Akhtar and Dixon, 2013). Precise fertilizer recommendations based on soil mineralogy and K dynamics can be more effective tool cost-effective use and management of K fertilizers. A large number of soil series based on physicochemical properties are present in Pakistan, however only few are dominant and covers ~70–80% of agricultural land. Analysis of these dominant series for soil mineralogy and K dynamics may provide useful data for precise K recommendations.

Potassium for Produce Quality

One of most striking role of potassium is to enhance crop quality and define produce quality as primary plant nutrient
is well established (Pettigrew, 2008). Synthesis of photosynthates and their translocation is directly affected by K deficiency in crops deteriorating the quality of fruits, grains and vegetables. In citrus, K affect the fruit size, peel thickness, sweetness and color of the fruit (Alva et al., 2006). It improves the weight per kernel in corn, oil contents in soybean, milling and protein quality of wheat (Mengel and Kirkby, 2001). Potassium also improves the quality of cotton fiber, sugar content in sugar cane and sugar beet. In addition to improving physical quality, K increases disease resistance and the shelf life of fruits. Quality can also be affected indirectly due to lodging in K deficient crops and its fertilization improved lodging resistance by increasing stem strength (Zaman et al., 2015). Nevertheless, plants resist against wilting and winter kill of alfalfa is also improved by K fertilization.

In Pakistan, very little intention has been given to the quality aspects of agricultural produce. Due to competition in global market, produce quality is very important to consider for export of agriculture commodities. Produce quality based price and export reflects the needs for balance use of fertilizers, especially potash. Sugar cane with increased sugar contents with use of potash may have more economic value.

**Soil Sustainability and Abiotic Stresses**

Application of potassium to improve plant growth and yield is well propagated at different forums in Pakistan, however, its use to combat environmental stresses and sustainable crop production is not exemplified. In arid and semi-arid regions, water is major limiting entity for plant growth and prolonged exposure to drought may damage the plants by production of reactive oxygen species (ROS). Adequate supply of K improves the osmotic adjustment and develops tolerance in plants to water deficit (Egilla et al., 2005). Likely, many researches on potassium function to improve salt stress are available (Cakmak, 2005; Ashraf et al., 2012; Wakeel et al., 2013). Potassium minimizes the detrimental effects of sodium (Na) under salt stress by improving K: Na ratio in plant tissue and plant cell (Wakeel et al., 2013). It also improves plant resistance against waterlogging and low temperature stress (Wang et al., 2013). However, practical implications of plant improved stress resistance still missing that should be explored under local soils and environmental conditions for sustainable crop production. Moreover, K fertilization is important for soils with respect to nutrient depletion that is very much higher in case of K as compared to negligible addition of organic or inorganic sources. Severe K deficiency effects on crop yield may be higher in future if the soils are not provided with sufficient amount of potash.

**Use of Potassium Chloride in Pakistan Agriculture**

Potassium sulfate (SOP) is usually recommended for Pakistani soils due to extra benefits of sulfur addition; however, high increase in SOP price in past few years has made it out of reach of Pakistani farmers. With local market potential, the fertilizer industry has started to import potassium chloride (MOP) due to its low price. Use of MOP in Pakistani soils is safe and beneficial for crops without any residual accumulation of Cl⁻ in the root zone (Shafiq and Ranjha, 1998; Ghaffar et al., 1999; Tariq et al., 2011). However, long term and comprehensive studies are needed to find out the residual effects of MOP and Cl⁻ on quality of produce and Cl⁻ accumulation into soils.

**Conclusion**

The available information indicates that most of the Pakistan agricultural soils require K fertilization because many of these are deficient in it and other are at margins. Due to negligible use of potash in Pakistan soils since decades, it has been depleted from the soils, especially grown with intensive cropping and high yielding cultivars. For sustainable crop production, it is very important to apply potash. Well-planned efforts are required to highlight the significance of potash in agriculture possibly by, (a) promoting agricultural advisory services and progressive farmers to create the awareness about the benefits of potash, (b) providing a clear message to policy makers for possible subsidies to attract the farmers for its use, (c) precise K fertilizer recommendation based on soil mineralogy and K dynamics in the soils for better economic returns, (d) improving the produce quality for export and providing better prices to farmers based to enhance K content and quality of produce. However, research on comparative studies of MOP and SOP are still needed to investigate the Cl⁻ dynamics in the system and its possible effects on produce quality.

**References**


Taylor & Francis, Boca Raton, Florida, USA


NFDC, 2015. Annual Fertilizer Review. National Fertilizer Development Center, Islamabad Pakistan


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