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REVIEW PAPER

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Comparative effectiveness of SOP and MOP for crop productivity in Pakistani soils - A review

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Abstract

The world population is increasing rapidly and it is expected that it will rise up to 8 billion in 2025. In this condition, there is a huge population pressure and ultimately this pressure transfer to agricultural soils to feed such a huge crowd of people. Pakistan is an agriculture country with most of the areas deficient of inherent soil fertility. Because of increasing population, there is a need to increase the cropping intensity. This increased crop intensity requires fertilizer application, especially of primary macronutrients along with micronutrients. Soils are becoming deficient of K which may be due to either imbalance fertilizer use of ignorance of farmers to use K fertilizer due to escalating fertilizer prices. So, it is need of time to use those K sources which are economical, profitable and ensure adequate crop yield and quality. This article compares Sulphate of Potash (SOP) and Morate of Potash (MOP) for their effectiveness for crop productivity as well as profitability according to specific soil conditions. No matter, MOP is cheap source but it cannot be used in every condition or some extra practices required like excessive irrigation which is quite difficult in present scenario of water shortage. So, need of the time is along considering the effectiveness of MOP and SOP, It would also evaluate the effectiveness of another source of potassium which have also considerable amount of K_2O in them like potassium nitrate containing 44% K_2O and 13% nitrogen and potassium magnesium sulphate with 20-30% K_2O, 11% magnesium (Mg) and 22% sulphur (S).

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Introduction

Any nutrient meeting the essentiality criteria for crop plants is called as essential plant nutrient. All the nutrients which are applied to soil among them the role of potassium (K) in plant growth and development is well pronounced (Tisdale *et al.,* 1985; Yong *et al.,* 2009). Potassium is one of the macro-nutrients needed for the application to soil and it is a major factor in controlling crop production (Glass, 1989). Essentiality of K has been proved by its role in different physiological processes of plant life.

Potassium deficiency in soils of Pakistan

Potassium is one of the important nutrients for the proper plant growth and functioning. The total deposits of potassium in the world are estimated to be around about 40-57 million tons of K_2O. Major portion of these deposits are in Germany, Canada and USSR (A hand book of Soil, Fertilizer and Manure). Now in Pakistan, soils are becoming deficient to K due to many reasons. In Pakistan, yield is very low due to many reasons among them imbalance fertilizer application is most prominent (Anonymous, 2008). Sufficient amount of K is present in Pakistani soils but it is unable to fulfill the crop requirements (Akhtar *et al.,* 2003). Potassium fertilization has given response due to increasing crop intensity and usage of high yield varieties and soil and crop are deficient of potassium (Malik *et al.,* 1989). In Pakistan, now mineral weathering is not an enough source of K due to intensive cropping and inappropriate use of N and P fertilizer, so there is need of inorganic K sources for K fertilizers (Ranjha *et al.,* 2001).

Sources of potassium

There are five different mineral sources of potassium in the world, like potassium chloride or murate of potash containing 60-62% K_2O, Potassium sulphate or sulphate of potash containing 48-52% K_2O, potassium magnesium sulphate containing 20-23% K_2O, potassium nitrate containing 44% and bittern potash containing 7% potash in it (A hand book of Soil, Fertilizer and Manure). Among these sources of potassium, mostly SOP and MOP are important world-wide.

SOP is commonly used as a K source in Pakistan, while most of the countries consider MOP as an appropriate source due to its relative cheapness as compare to SOP (David *et al.,* 1986). MOP is cheaper but contains 48% chloride which is a threat to saline soils of Pakistan (Hussain *et al.,* 2000). Pakistani soils are inherently rich with chloride therefore; MOP is not preferred which has high level of chloride in it. But reduction of SO_4 to SO_2 carried out with the help of this in the wet anaerobic conditions (Glander and Peter, 1962). Potassium nitrate, potassium oxide and other organic sources are also used.

Potassium fertilization

When potassium is applied to poorly fertile soils, crops showed response to K application. Potassium fertilizers are as follows:

KCl fertilization (MOP)

MOP is an important source of K as well as of chloride, so when it is applied to soil it is not only provides potassium but also provides chloride to plants and soil. It has high salt index. Flax (*Linum usitatissimum L.)* crop production cost was reduced but it affected the soil fertility when K_2SO_4 was replaced by KCl.

Yield and yield related parameters are affected by KCl application but it negatively affected shoot dry weight. Soil analysis was performed and observed that there are no potential hazards of Cl^{-1} concentration in the rhizosphere. This is due to leaching of chloride because it is very mobile in soil due to its negative charge (Shaaban *et al.,* 2012). K fertilization by MOP could be used in those areas where good leaching conditions in soil are present (Krauss, 1992). MOP as a K source for maize crop could be used because of its ability to provide salt tolerance (Tariq *et al.,* 2011).

K_2SO_4 fertilization (SOP)

SOP consumption world-wide accounts for 6-7%. SOP is better source for oil seed crops because along with K, it also provides sulfur. SOP is an efficient mean of increasing salt tolerance in the in plant mainly due to three main reasons: low salt index, effects of K and SO_4 (Saurat and Boulay, 1985). In Asia, usage of SOP as a K source is almost12% (Peter, 1981).

K_2SO_4 is more useful as a K fertilizer because it contains sulphur (S) (Zhao *et al.,* 1999). Also, it enhances the activity of enzymes containing Fe (Singh, 1998). Due to its acidic reaction, it is mostly recommended in alkaline soils (Shaaban *et al.,* 2012). In Northern areas, plants respond well to SOP application due to presence of S (Fricker, 1985). MOP is not a better source of K in arid areas as compare to SOP due to its hazardous effects (Zehler, 1982).

Foliar application of K

Foliar application of potassium in sandy and clayey soils improves yield and quality of crops where availability of K is restricted (Marchand *et al.,* 1999). MOP has more scorching effects on the leaves of tea plants than SOP, especially when foliar application is used (Rahman *et al.,* 1978).

Role of potassium (K)

There is an increasing trend to use potassium fertilizer along with N and P due to its importance in many processes in plants. Protein synthesis, photosynthesis, enzyme activity, carbohydrates and resistance development against diseases all these qualities developed in the plant just due to the application of potassium (Tisdale *et al.,* 1985). Potassium is very important for several physiological processes of the plants such as energy metabolism, solute transport, osmoregulation, phloem transport and uptake of other nutrient elements (Marschner 1995; Mengel and

Kirkby 2001; Sadanandan *et al.,* 2002; Fischer, 2004; Yong *et al.,* 2009). Proteins negative charge neutralization is also associated with potassium (Yong *et al.,* 2009). Electrochemical potential gradient is the main cause for the translocation of K and it is mobile in plants. More than 60 plant enzymes which actively control plant activities have been activated by the presence of potassium (Aparna, 2001). It also increases fruit size, ascorbic acid concentration, yield, soluble solids, shelf life, improved fruit color and shipping quality of horticultural crops (Lester *et al.,* 2006).

Lint and fiber quality of cotton is reduced due to deficiency of potassium. Inadequate K supply results in inhibition of root elongation and lateral root formation. Potassium affected the nutrients use efficiency of soil (Yong *et al.,* 2009). Sugar accumulation in chloroplast, reduction in starch synthesis (Amtmann *et al.,* 2006) and leaf area are affected because of potassium deficiency (Zhao *et al.,* 2001).

Potassium application also provides capacity to resistance against environmental stresses. It has great contribution in the physiological processes, like photosynthates translocation into leaves and fruits, maintenance of turgescence, activation of enzymes, and reducing excess uptake of ions such as sodium (Na) and iron (Fe) in saline and flooded soils (Marschner, 1995; Mengel and Kirkby, 2001).

Effect on physiological processes in plants

The application of potassium as MOP and SOP increased sugar contents of tomato plants (Akhtar *et al.,* 2010). Vitamin C content also increased by the application of MOP (Kaviani *et al.,* 2004; Akhtar *et al.,* 2010). Fruit firmness and calyx freshness also improves and damaged fruits also reduce in response to the application of both K sources e. g. SOP and MOP (Chapagain and Wiesman, 2004). Blackspot appeared on the potatoes grown in K deficient soil (Anonmyous, 1981).

SOP is considered better option in improving fiber quality parameters of cotton in comparison of MOP in arid and semi-arid areas (Pervez *et al.,* 2004). When K was applied on tea in combination with N, there was improved flavor index, amino acid and polyphenol content of crop shoots (Venkatesan and Ganapathy, 2004).

Increase nitrogen fixation and protein content of pulse grains was observed when K is applied (Srinivasarao *et al.,* 2003). Potassium application in the form of SOP increases the chlorophyll concentration and carbon exchange rate in alfalfa, it also increases the N_2 fixation due to a number of reasons as increase in carbon exchange rate, enhanced carbohydrate movement from shoot and increased nodulation (Collins and Duke, 1981). Borowski and Michalek (2009) found that when SOP and MOP was applied on spinach, SOP application was proven more promising in improving stomatal conductance; it also positively affected intensity of photosynthesis. But MOP in comparison to SOP increased transpiration significantly; it also significantly increased the crude protein content of spinach leaves.

Table 1. Comparative effectiveness of MOP and SOP in different growth and yield parameters of plants.

Crop	Potassium source	Percent increase	References
Sugar cane	MOP	13.59% (Sucrose contents)	Khadar *et al.*, 2004
	SOP	13.55% (Sucrose contents)	
Wheat	MOP	1.8% (wheat grains)	Ranjha *et al.*, 2002
	SOP	4.8% (Wheat yield)	
Cotton	MOP	27% (fiber length)	Parvez *et al.*, 2007
	SOP	27.5% (fiber length)	
Rice	MOP	10.8% (Straw yield)	Hussain *et al.*, 2000
	SOP	2.9% (Straw yield)	

Abiotic stresses

It has been studied in many experiments that abiotic stresses affect plant resistance.

Effect on plant chemical composition

Nutrient uptake rate of plants is also affected by potassium. Therefore, nutrient content of different plant parts are also altered in response to potassium application. The N, P, K and Zn uptake markedly affected by MOP treatment in flax crop (Shaaban *et al.,* 2012).

Nitrogen

Ranhja *et al.* (2002) found that N concentration in grains and straw of wheat was not shown any significant change by application of both SOP and MOP. These results were similar to Ashraf (1982). Uptake of all nutrients except N in flax was increased by application of K_2SO_4 (Shaaban *et al.,* 2012). Both SOP and MOP application showed no effect on N level in straw of rice crop (Ranjha *et al.,* 2001). Significant increase in nitrate content of spinach leaves by the application of SOP is reported (Borowski and Michalek, 2009).

Phosphorous

SOP is better than MOP in slightly increasing the P concentration in grains and straw of wheat but this increase was non-significant if SOP used in place of MOP because sulphate decreases the calcium activity and increases the availability of P in the soils (Hannemann, 1964; Ranjha *et al.,* 2002). Phosphorus content of tomato plant increases both by SOP or MOP (Akhtar *et al.,* 2010) but in another study, MOP application showed non-significant effect on P content of tomato plants (Chapagain and Wiesman, 2004). SOP application increases P content of paddy straw (Ranjha *et al.,* 2001) and also resulted in reduction in Mn and P in potato petioles (Walforth *et al.,* 1990).

Potassium

Ghosh and Varade (1976), Sharma *et al.* (1980) and Ranjha *et al.,* (2002) observed that there was an increase in K content of grains of wheat in response to potassium application but MOP was more effective as compared to SOP. Potassium level in tomato pulp and paddy increased but the difference was insignificant by the application of both sources SOP and MOP (Chapagain and Wiesman, 2004; Akhtar *et al.,* 2010). Linear increase in K level in the leaves of maize with K application increased in K level was independent of sources whether it is SOP or MOP (Tariq *et al.,* 2011). K level was significantly increased in dry petiole tissue of potato plants (Kelling *et al.,* 2002).

Chloride

When MOP is applied chlorine concentration increases significantly but concentration will not exeed from a critical level. However, there is no change in chloride content in grains and straw of cereals with SOP application (Rashid *et al.,* 1992; Ranjha *et al.,* 2002). Insignificant increase in chlorine content was observed in tomato crop in comparison to SOP and control (Akhtar *et al.,* 2010). Rice and wheat straw have more chlorine content with MOP application over SOP (Rashid *et al.,* 1992; Ghaffar, 1999). Khan (1985) found that by the application of MOP, there is increase in chloride content of wheat straw and grain.

SOP is better than MOP in slightly increasing the P

The locations (areas) where MOP was applied in maize crop, chlorine contents enhanced. Leaching of chloride ions or salt tolerance of maize crop may be one of the cause of it (Tariq *et al.,* 2011), higher chloride content in tomato leaves but no chloride toxicity by the application of MOP was found (Chapagain and wiesman, 2004).

Sulphur and magnesium

In wheat grains and straw, there was no increase in sulphur concentration with K application from both SOP and MOP sources (Tisdale *et al.,* 1985; Ranjha *et al.,* 2002). Sulphar contents increased in paddy straw when SOP was applied (Ranjha *et al.,* 2001). In those plots, where MOP in comparison with SOP was applied, S content in maize leaves was decreased (Tariq *et al.,* 2011). In tomato leaves, Mg contents were significantly deceased in response to SOP and MOP application (Chapagain and Weisman, 2004).

Effect on disease resistance

Tomato resistance against insect pest damage and diseases was increased by the application of Potassium. Leaf blight Septoria and Alternaria solani resistance increased in tomato plants. Attack of fruit borers (Heliothus armigarh) and white fly (Bemisia tabacci) on tomato was significantly reduced by SOP than MOP application. But SOP application slightly increased in resistance comparatively (Kirali, 1976; Akhtar *et al.,* 2010). Potatoes diseases like early and late blight of potatoes resistance also influenced by the application of Potassium (Kelling *et al.,* 2002).

Effect on drought resistance

Osmo-regulation is a process to confer resistance against water stress is also performed by K. (Malavoltaei *et al.,* 1997). K improved the water use efficiency by controlling and regulating stomatal conductance by the opening and closing of stomata. Due to this ability K provides drought resistance in plants and reduces the negative effects of drought (El-Ashry *et al.,* 2005). Soluble protein contents were also at its maximum amount with SOP application (Kumar and Kumar, 2008).

Effect on yield and yield parameters

Potassium has great influence on plant growth so it affects the plant yield and yield parameters (Table 1) Tomato yield was significantly increased by both sources of K, but SOP was considered better choice in improving yield and quality of tomato (Akhtar *et al.,* 2010). Tomato increased yield with MOP than SOP when both were applied in the field (Kaviani *et al.,* 2004; Akhtar *et al.,* 2010).

Dry weight yield and fresh weight yield of potato increased by the application of K. But its effect on dry matter was non-significant (Allison *et al.,* 2001). Potatoes yield increased if SOP or MOP were applied in the soil deficient in K (Walforth *et al.,* 1990). Bhandari *et al.,* (1987) found that SOP was better for potato tubers because of negative effects of chloride on starch and dry matter by MOP application. These results were similar to the findings of Prummel (1983).

Banana yield affected in terms of number of hands, total number of fingers, finger weight, length and circumference when k is applied in the form of SOP. It was revealed that banana showed increased growth rate with SOP than with MOP (Kumar and Kumar, 2008). S that is responsible for starch application and protein synthesis markedely increased the dry matter of banana (Singh and Trehan 1988). Sulfur is involved in chlorophyll synthesis. When K was applied through SOP, there was a marked increase in chlorophyll contents in banana (Kumar and Kumar, 2008). Its application increases in fiber maturity, fiber fineness, fiber length and fiber strength of cotton (Pervez *et al.,* 2004).

There is no significant effect on grains per head, shelling percentage and harvest index when potassium is applied to the sunflower, also increased the thousand grain weight (TGW). Those plots where K was not applied, lowest grain yield was obtained (Amanullah and Khan, 2010). Both (SOP and MOP) the K sources, had no significant effect on the plant height and stem diameter. But there was a significant increase in seed yield and grain weight of sunflower (Ayub *et al.,* 1999). According to Al-Nawaz (1988) plant height and head diameter of sunflower plant showed no response to K application. Potassium application irrespective of source positively affecte the protein contents of wheat (Bakhsh *et al.,* 1986) but K application has no impact on tillering. Ranjha *et al.,* (2002) reported that grain and straw yield increased slightly both with SOP and MOP but the increase was least significant. Comparatively both had same effect on wheat grain yield, straw yield and number of tillers. Wheat grain and straw yield was affected by both SOP and MOP to same extent (Hussain *et al.,* 2002). Its application failed to improve the grain and straw yield of rice and wheat along with no ill effects of chloride both application of SOP and MOP. N, P and K concentration in grain and straw of wheat and rice are also affected in similar way (Khan 1985; Ghaffar *et al.,* 1999). Promising results obtained from SOP than MOP for the yield of wheat and rice (Rehman, 1992). Yield of rice (Amin *et al.,* 1990) and wheat (Malik *et al.,* 1988a) showed same response for both K sources (Hussain and Jilani, 1991) but Rehman (1992) reported that wheat and rice showed better yield with SOP compared to MOP.

In paddy, parameter remains unaffected both from the application of SOP and MOP like plant height, number of tillers per pot, paddy yield, 1000-grain weight and straw yield (Ranjha *et al.,* 2001). High application of KCl reduced the grain and straw yield of rice due to chlorine toxicity (El Kholy *et al.,* 2003). Paddy yield was affected in same way so MOP was considered better option for rice production where it shown no hazardous effects (Hussain *et al.,* 2000).

KCl and K_2SO_4 treatments caused no change in the capsule weight of the flux. There is strong need of K_2SO_4 to improve yield and maximum output of crop (Shaaban *et al.,* 2012). Kafkafi *et al.,* (1977) alfalfa yield increased by the application of MOP than SOP. He (Nabhan *et al.,* 1989) other crop showed more response to SOP than MOP. Leaf weight of spinach increased by the application of both SOP and MOP but the difference was non-significant (Borowski and Michalek, 2009).

Effect on soil properties

Potassium fertilizers did not affect the EC and pH of the soils (Hussain *et al.,* 2002). Gosh and Varade (1976) and Ashrad (1982) also showed similar results. SOP decreases the soil pH due to presence of sulphur in it while on the other hand MOP favors increase in pH (Roemheld, 1983). Marchal *et al.* (1981) found that potato yield decreased due to more solubility of MOP. MOP also caused soil acidity compared to SOP. It increased the sulphate contents of soil, where SOP was applied (Hussain *et al.,* 2002).

Muriate of potash (MOP)

Potassium, Ca and Mg showed a marked increase in the soil in result to KCl application (Shaaban *et al.,* 2012). After harvesting the crop chloride content increase and this increase vary with the soil depth because under the adequate supply of soil moisture leaching of chloride ion occurs (Ghaffar *et al.,* 1999) but it was contradictory due to the results reported by Waheed *et al.* (1994) and Shafiq and Ranjha (1983) who said under MOP application after rice harvesting chloride content remain same upto the depth of 40 cm.

Subsoil chloride content markedly increase in the soil where MOP was applied (Ghaffar *et al.,* 1999). Chlorine content increased as depth increases because chloride ions are mobile in soil and leached down. While chloride level decreased when SOP is applied (Tariq *et al.,* 2011).

MOP application has no negative effect due to high solubility characteristics and irrigation water movement (Schumacher and Fixen, 1990; Rashid *et al.,* 1992; Mian *et al.,* 1998).

Negative effects of MOP

Many experiments in which K sources were compared to determine the chloride effect in soils were done (kafkafi *et al.,* 2001; Abd El Hadi *et al.,* 2002; El Kholy *et al.,* 2003). Parker *et al.,* (1983) reported that MOP application results in chloride toxicity. When KCl is applied, chloride negatively affects the grain and straw yield of rice (El Kholy *et al.,* 2003), the dry matter and starch of potato (Bhandari *et al.,* 1987) and the tuber contents of cysteine, ascorbic acid, methionine and protein which otherwise significantly increased by SOP application (Duka, 1973). When MOP was applied at higher rates to the potato it resulted in reduction of tuber dry weight (Allison *et al.,* 2001).

Bhandari *et al.* (1987) reported that chloride adversely affect dry matter and starch of potato tubers so K_2SO_4 is a better choice of K than KCl. In arid regions, where soil salinity is a problem K_2SO_4 is preferred source of K due to lower salt index (Kafkafi *et al.,* 2001).

Positive effects of chloride

Chloride to plants supplied by when MOP applied to soil. Affect the soil properties by the residue chloride in the plants. Chloride is an essential micronutrient and it is beneficial under many conditions e.g. in osmoregulation and disease suppression (Fixen, 1987; Beaton *et al.,* 1988).

Residual K

SOP and MOP application has a significant role in the availability of K (Hussain *et al.,* 2000). Tariq *et al.,* (2011) stated that the application of K fertilizers either SOP or MOP increased the K content not only in soil but in cereals grains as well. Conversion of non-exchangeable K into exchangeable K in soils has also been increased due to this practice. He also found that SOP supply less K to soil than MOP.

Comparison between SOP and MOP

Malik *et al.* (1988) wheat has reported non-significant difference among sources after experimentation. Both SOP and MOP sources have similar effects on many crops tested (Akhtar *et al.,* 1998). Tomato yield affected to similar extent by the both the SOP and MOP (Chapagain and Wiesman, 2004). Davide *et al.* (1986) in punjab SOP is important source than MOP. SOP was significantly better than MOP on the average in Pakistan (Gurmani *et al.,* 1984). MOP is not a preferred source of K (to improve quality of leaves) over SOP in saline soils (Morad, 1979). It was similar to the facts reported by Ramana *et al.* (1984) under saline conditions foliar application of SOP give better results than MOP. Tariq *et al.* (2011) grain yield of maize crop was not affected by the chloride of MOP because chloride leaching from root zone. So MOP was considered better source of K than SOP from economic prospects. Grain nutrient ratio (GNR) and value cost ratio (VCR) both are affected by SOP and MOP in the same way. SOP and KNO_3 leached less than MOP (Koo and Reese, 1973). MOP effected only in those areas where excessive water available for leaching of chloride. Under climatic conditions of Pakistan MOP is not a good source of Potassium (Davide *et al.,* 1986).

Conclusion

From all the above discussion it is concluded that both SOP and MOP can be equally used because both affect the crop yield to the same extent. As MOP is cheaper its adverse effects can be avoided by the application of sufficient irrigation. While in those areas where salt index is high and sufficient precipitation and irrigation is not available, MOP is not favorable because it has high salt index. So, in most of the areas of Pakistan, where salinity is a problem, SOP is considered better choice of potassium as compare to MOP. MOP can be used but there is a condition along its usage is that it must be used along with excess good quality irrigation water.

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