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Potassium: A key role player in potato (*Solanum tuberosum* L.)

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ABSTRACT

Potato (*Solanum tuberosum* L.) is an important crop which is widely used for human consumption. Potato is one of the primary nutrient sources which are used in diets all over the world. It is the main crop for both developing and developed countries which is used for the preparation of a variety of processed items. From many studies, it has been found that yield of the potato is affected by nitrogen, phosphorus, and potassium management, as well as environmental factors and crop response to these factors varies between cultivars. Among all these Potassium (K) is an important macronutrient for crop growth, yield potential, product quality, and stress resistance. Potatoes require considerably high potassium content compared to other irrigated crops. To achieve the best yield and quality, potato needs abundant of potassium. K plays very important role in contributing to yield attributes and quality, such as Vitamin C content, reducing sugar, specific gravity, total yield and shelf life of tubers.

Keywords: Potato, potassium, yield, quality and tuber.

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae. It is a nutritious food and is used as a primary nutrient source throughout the world. It has originated in South America and nowadays commercially cultivated globally. In India, it has been introduced in the early 17th century by Portuguese traders and progressively converted as commercial crop of all over India. Potato is one of the adaptable crop with a global production of just about 368 million tons over 1 billion people globally consumes potato; its importance in cultivation follows cereals like rice, wheat, and maize **(FAOSTAT, 2018).** Potato is a healthful food containing of around 77% water, 16.3% starch, 0.9% sugar, 4.4% protein, 0.9% minerals, 0.59% fiber, 0.14% crude fat, and a significant source of vitamins A, B and C, and such minerals as potassium (K), magnesium (Mg) and iron (Fe) **(Zaheer *et al*., 2016; Camire *et al*., 2009; Ezekiel *et al*., 2013).**

Potassium plays an important role in photosynthesis, enhancing enzyme activity, promoting protein, carbohydrate, and lipid synthesis, and facilitating photosynthate transfer, allowing plants to fight pests and diseases. The potato crop is frequently used as an indicator crop for K+ availability due to its high K need **(Ulrich and Ohki 1996)**. Potassium is also a key osmotic active cation in plant cells **(Mehdi et al., 2007),** where it improves water uptake and root permeability, as well as acting as a guard cell controller, in addition to its role in boosting water use efficiency **(Zekri and Obreza, 2009)**.

Application of potassium increases the plant height, crop vigour, rate and duration of tuber bulking. In addition, its use aids in the transport of carbohydrates from leaves to tubers. There is increase in size of tuber but not in tuber number **(Trehan *et al*., 2001)**. Potassium fertilizer is applied in a wide variety of ways, including banding, fertigation, and spraying liquid fertilizers on plants. Potassium is used in a variety of forms, including potassium chloride (KCL), potassium nitrate (KNO_3) potassium sulphate (K_2SO_4), and mono-potassium phosphate (KH_2PO_4) **(Magen, 2004)**.

Beneficial roles of Potassium in potato

Potatoes do have high K requirement, which requires great consideration to their development. In comparison to cereals, pulses, oilseeds, and other commercial crops, these requirements are substantial. According to **Zaag (1991)**, K fertilizer should be used to maintain high yields. Potassium boosts yield and enhances tuber consistency by strengthening stems and preventing lodging **(Omran *et al.*, 1991)**.

Effect of different potassium sources

Regardless of exchangeable soil K levels, various sources such as potassium sulphate (K_2SO_4), potassium chloride (KCL), and potassium nitrate (KNO_3) are used. KCL and K_2SO_4 were found to be superior to KNO_3 in terms of increasing tuber output, with K_2SO_4 having a positive impact on the number of tubers. A field work conducted by **Panique *et al.*, 1997** in Wisconsin found that K_2SO_4 increased yields more than KCL application at rates up to 280 kg K/ha, when the potassium soil test ranges from 75 to 110 mg/kg. It is assumed that KCL fertilization results in a higher plant osmotic potential than K_2SO_4, leading to increased water uptake and vegetative growth, as well as increased competition for assimilates between the shoot and the tuber, as the shoot is a good sink for assimilates**(Mc Dole, 1978)**.

In an experiment conducted by **Salim *et al.*, 2014** under semi-arid conditions and a loamy sand soil and reported that despite a substantial increase in plant height, foliar application of KNO_3 did not increase tuber yield and number of tubers. Polyhalite [$K_2 Ca_2 Mg (SO_4)_4 .2H_2O$], one more K fertilizer, had a positive impact on tuber skin appearance, but this may be based on local conditions and potato cultivar form **(Keren-Keiserman *et al.*, 2019)**. K fertilization rates increased from 100 to 300 kg K_2O/ha, potato growth parameters improved drastically **(Asmaa and Hafez, 2010)**.**)** When K fertilization rates were increased from 50 to 200 kg K2O/ha, plant height and shoot biomass in potato plants increased significantly **(Singh and Singh, 1996)**.

Effect on growth and tuber yield of potato

Potassium promotes leaf expansion, particularly early in the growth cycle, and prolongs leaf area by delaying leaf shedding near maturity. It accelerates tuber bulking and extends its length. By activating a range of enzymes involved in photosynthesis, carbohydrate metabolism, and protein synthesis, potassium aids in the transport of carbohydrates from leaves to tubers **(Gamal, 1985)**. Plant height and leaf area increase as a result of K treatment **(Trehan et al., 2001).**According to **Zelelew *et al.*, 2016**, the number of tubers per plant increases gradually and significantly as potassium levels increases. The application of 300 kg K_20/ha resulted in the highest tuber number per plant, while control yielded the lowest. Several studies have shown that K deficiency reduces potato yield significantly **(Rouphael *et al.*, 2011; Zhang *et al.*, 2018)** and several researchers have observed an increase in potato tuber yield as a result of increased K fertilization **(Kolbe *et al.*, 1995; Nandekar, 2005)**.

Size of tuber

According to previous studies, increased K application rates increased the yield of potato tubers weighing <25 g, whereas tubers weighing between 25 and 50 g and 51 and 75 g were unaffected. However, it has been stated that K has no impact on the yield of tubers weighing <25 g **(Westermann, 2005).** And **Singh and Lal, 2012** reported that it is essential to apply K to potatoes in combination with N in order to increase tuber yield and quality as well. According to **Trehan (2012)**, K activates a variety of enzymes involved in carbohydrate metabolism, photosynthesis, protein synthesis, and aids in the translocation of carbohydrates from leaves to tubers, which increases size of tuber but not in number of tuber. Potassium nutrition dramatically increases tuber average size **(Singh and Bansal, 2005),** which may result in increased aggregate yield **(Kavvadias *et al.*, 2012)**.

Quality of tuber

External characteristics like shape of tuber, size, colour of skin and flesh, depth of eyes, greening, and mechanical damage, as well as internal characteristics such as dry matter content, growth cracking, hollow heart, and internal bruising, are all considered when determining tuber quality. Cooking quality parameters such as enzymatic and non-enzymatic browning, texture, and taste are also assessed on potatoes **(Westermann *et al.*, 1994)**. Quality criteria such dry matter, specific gravity, starch content, vitamin C content, and ash content were all influenced by K fertilization.

According to **Perrenoud, (1993)** potassium is one of the most important nutrients affecting potato tuber quality, Potassium fertilization enhances tuber quality more than it improves yield **(AbdelGadir *et al.*, 2003)**. The significance of K in potato quality can be due to its role in promoting photosynthesis and photosynthate translocation, as well as improving photosynthate transition to starch and protein **(Wibowo, *et al.*, 2014)**. With increase in K fertilizer levels, the specific gravity of potato tubers decreases **(Mc Dole, 1978; Westermann *et al.*, 1994)**. Furthermore, greater K levels have no consistent and direct effect on the color of potato chips **(Eastwood and Watts, 1956)**.

The effect of K on lowering sugar and amino acid contents in potatoes can also lead to the lighter colour of chips/fries, as high levels of these compounds may darken chips during frying **(Sharma and Sud**

2001). According to **Hannan *et al.*, 2011 & Koch *et al.*, 2020**, increasing K application rates up to 237 kg/ha sugars concentrations were decreased while increasing tuber starch content. Potassium also enhances the storage value and shelf life by decreasing the risk of blackspot bruising **(Young, 2009)**.

Reducing sugar content

In a study it has been observed that with the addition of K, the sugar content of potato tubers increases **(Kamal *et al.*, 1974)**. At different levels of K, MOP produces a narrower difference in reducing sugar content in potato tubers, while SOP produces a broader difference in reducing sugar content in potato tubers at different levels of K. **Trehan *et al.*, 2009** found that a higher dose of K results in decreased amount of reducing sugars content. Since K stimulates starch synthesis, it has the ability to lower the reducing sugar content of potato tubers **(Marschner, 2011)**. In comparison to tubers that receive low potassium fertilization, moderate potassium fertilization increases starch content in tubers **(Baniuniene and Zekaite, 2008)**. However, the amount of K fertilizer used had no effect on total soluble solids **(Latif *et al.*, 2011)** as presented in below table 1.

Table 1: TSS content in potatoes with various potassium doses

K fertilizer rate	TSS gm/litre (2009)	TSS gm/litre (2010)
Control	44.81	43.86
72 kg /ha	44.70	43.60
96 kg /ha	45.31	44.32
120 kg /ha	45.50	44.45

(Source: Latif *et al.*, 2011)

Starch content

In several studies, the amount of starch in tubers was proportional to the amount of potassium applied. High starch concentrations are said to require about 1.8 percent K in tuber dry matter **(Bansal and Trehan 2011)**. In comparison to control or tubers fertilized only with NP tubers, high doses of potassium fertilizers decreased starch content in tubers by an average of 1.3-2.2% and dry matter by 0.9-2.4% **(Baniuniene and Zekaite, 2008)**.

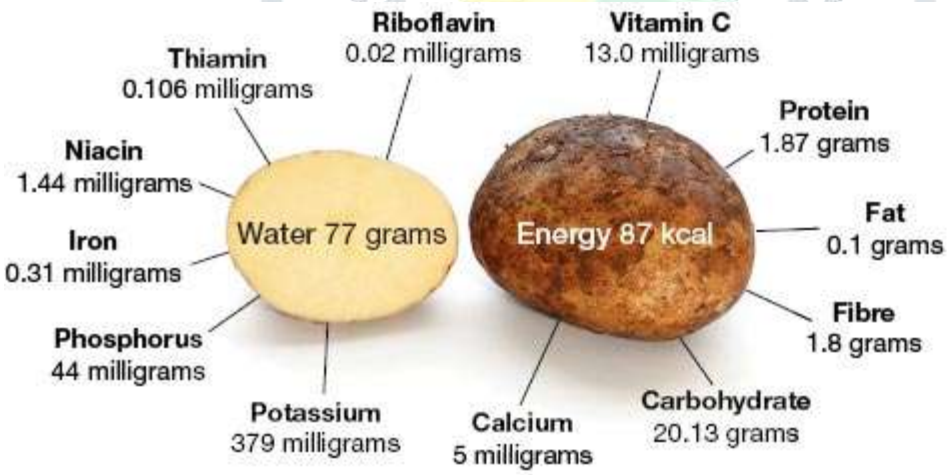
As K improves the overall growth of the plants, starch accumulation is linked to tuber cell and tissue growth **(Singh and Singh, 1996)** and facilitates assimilate translocation to sinks/tubers **(Beringer, 1978)**, potentially increasing tuber bulking capacity and, as a result, biomass. The maximum potassium level in potato tubers was found in plants treated with K, while the lowest was found in control plants. In potatoes, there is starch and reducing sugar interconversion. The transformation of starch to sugar alters the taste of potatoes, making them sweeter, which is not a good characteristic. Temperature, K fertilizer, and other factors influence the conversion of starch to sugar **(Bhattarai and Gautam 2006)**. Starch is converted to sugar in lower doses of K fertilizer and vice - versa in higher doses of K fertilizer. A modest dose of potassium, on the other hand, has no effect on sugar synthesis **(Marschner, 2011)**.

Vitamin C (ascorbic acid) content

One of the main vitamins present in potato tubers is ascorbic acid (vitamin C) **(Hamouz *et al.*, 2009)**. Since potatoes are high in vitamin C, it's important to understand the relationship between fertilizer application and vitamin C content. One of the most significant yield attributes is vitamin C content. Potatoes have a significant dietary contribution of vitamin C, accounting for approximately 40% of the recommended intake **(OECD 2002)**. Vitamin C content in tubers varies widely, with the typical range for freshly harvested tubers being 10-25 mg/100 g FW. **Brown (2005)** found an average of 20 mg/100 g FW, which could account for up to 13% of tuber's total antioxidant ability.

The effects of changes in ascorbic acid concentration in potato tubers during the vegetation phase have a significant impact on ascorbic acid content in freshly harvested tubers **(Hamouz *et al.*, 2009)**. Ascorbic acid content drops after harvest, during storage and other damage occurs during boiling and potato processing into foodstuffs **(Weber and Putz 1999)**. In a three-year experiments conducted in Poland in 1977 by **Smith and Smith** and they found that applying 50 kg K/ha increased vitamin C content, while applying 100 kg K/ha had no effect, and applying 150 and 300 kg K/ha decreased it. At 150 kg K/ha, K application as SOP and MOP increased vitamin C by 10.8% and 14.7%, respectively.

In one more pot experiment, KCL treated potato tubers contained less vitamin C than control and K_2SO_4 treated samples. This indicates that KCL has a negative impact on the vitamin C content of potato tubers. Even at the lowest K levels of 200 mg K/kg soil, KCL fertilization reduced the concentration of vitamin C by 46%. The higher KCL fertilization values of 400 mg and 600 mg K/kg soil decreased vitamin C content by 50% **(Manolov *et al.*, 2015)**. As a result, using MOP as a potassium source is preferable to SOP or KCL for increasing vitamin C content in tubers. Higher doses of K (>150 kg/ha) tend to decrease vitamin C content, while lower doses of K (<150 kg/ha) tend to increase it **(Khan *et al.*, 2010; Smith and Smith 1977)**.



(Per 100 g, after boiling in skin and peeling before consumption)

Source: United States Department of Agriculture, National Nutrient Database; http://www.fao.org/potato-2008/en/potato/factsheets.html

Figure: Nutrient content of potatoes

Specific gravity

One of the quality markers is a tuber's specific gravity. It's also linked to the starch, total solids, dry matter, or ash content, and mealiness of potato tubers **(Teich and Menzies 1964).** Fertilizer K-source has been shown to impact tuber specific gravity. The specific gravity of potato tubers falls as K fertilizer levels rise **(Mc Dole (1978) and Westermann et al., 2000). (1994).** However, **Al-Moshileh and Errebi (2004)** observed that no unique gravity response to potassium treatment was found. According to **Khan *et al.*, 2010,** there is an increase in specific gravity progressively with increase in application of K up to 150 kg/ha and at application up to 225 kg/ha then it slowly decreases fertilizer K-source as presented in table 2.

Table 2: Effect on Specific Gravity of Potato With Different Doses of Potassium

K-fertilizer rate	Specific gravity (Source: SOP)	Specific gravity (Source: MOP)
Control	1.069	1.069
150 kg/ha	1.081	1.087
225kg/ha	1.092	1.086
150 kg/ha + 1% K_2O foliar application	1.086	1.086

(Source: Khan *et al.*, 2010)

Increased nitrogen and potassium levels in a potato field beyond the threshold level resulted in a significant decrease in specific gravity **(Adhikari and Sharma 2004)**. Potato specific gravity is determined by a number of factors including potato variety, place, increasing temperature, and so on. However, when it comes to determining the specific gravity of potato tubers, K fertilization is more important **(Laboski and Kelling 2007; Malik, 1995)**.

Yield and its attributes:

In a study on potato, it has been reported that with the addition of P and K, the quality parameters such as dry matter, specific gravity, starch content, vitamin C(ascorbic acid) content, and ash content are affected (**Khan *et al.*, 2010)**. Potassium has a major impact on plant height, number of leaves, and marketable yield of tubers, **(Singh and Lal, 2012)**.

Singh and Lal, 2012 also reported from their experimental results that between N and K, there was a significantly positive correlation. Increasing levels of K application increased tuber yield, N and K uptake by potato at harvest for each level of N. Potassium and nitrogen application increased large and medium grade tuber yield while decreasing small and very small tuber yield. When N and K were applied at 225 kg/ha and 150 kg K_2O/ha, a maximum yield of 39.83 t/ha was obtained, compared to a tuber yield of only 14.36 t/ha when N and K were not applied. Application of K at 150 kg/ha as K_2O from both K sources resulted in substantial increase in tuber yield over NP treatment **(Khan *et al.*, 2010)**. When comparing 150 kg K_2O/ha to 225 kg K_2O/ha, the increase in tuber yield was statistically insignificant. Potassium also helps to dramatically improving carbohydrate content, which in turn helps to increase tuber size in potato**(Al-Moshileh and Errebi, 2004) (Table 3)**.

Table 3: Different potassium doses on potato quality attributes

K fertilizer dose/ha	Specific gravity	Carbohydrates (%)	Marketable yield (ton/ha)
0	1.067	36.66	17.91
150	1.069	39.66	21.53
300	1.069	42.66	28.66
450	1.084	50.66	31.90
600	1.086	51.33	31.96

(Source: Al-Moshileh and Errebi, 2004)

In another field experiment conducted by **Dkhil *et al.*, 2011** reported that at 95 Days After planting (DAP) plant height, number of leaves, leaf area, relative water content of leaf, and chlorophyll a concentration all increased significantly with values of 79.1 cm, 70 leaves/plant, 400 cm^2, 93%, and 0.71 mg/litre, respectively, after increasing potassium nitrate rates. **Kang *et al.*, 2014** performed the similar experiments in pot and field both to see whether excessive potassium (K) absorption by potato plants occurs in both irrigated and non-irrigated conditions. Potato biomass and tuber yield peaked at a certain level of external K and did not grow as the amount of K increased. However, potato plant uptake increased within the range of K utilized. Furthermore, higher K availability in the media was found to result in luxury K absorption by potato plants. Based on these findings, it can be stated that not only potassium fertilizer rate, but also potassium fertilizer source, influence potato yield features.

Shelf life of potato

Potassium plays very important role in shelf life of potato. Potassium fertilizer applied prior to harvest has a major impact on potato storage quality. Potassium has aided in the slowing of senescence, the reduction of physiological disorders in storage, and the extension of potato tuber shelf life **(Martin-Prével, 1989)**. With an adequate supply of potassium, internal blackening and mechanical damage rates are low, and stress tolerance is higher **(Roberts and Mc Dole, 1985)**. According to **Jackson and Mc Bride (1986)**, found that potassium application reduces the occurrence of hollow heart and highly resistant to pests and diseases in storage. They also reported that KCL was more effective than K_2SO_4 at reducing the number of tubers with hollow hearts and browning.

Conclusion

It is observed that in potato nutrient requirement is high and various studies suggest that we should consider potassium as one of the most important macronutrient in crop growth and development. This luxury element is important for potato growth (plant height, number of leaves), yield (tuber size, number of tubers, marketable yield of tubers), and quality (dry matter, specific gravity, starch content, vitamin C (ascorbic acid) content, reducing sugars, ash content, potato shelf life by slowing senescence, decrease in physiological disorders during storage).The source of K, as well as the fertilization and dose, all these affect the quality and yield of potato tubers. However, it has also been observed that this also depends upon the variety, climate, soil type, and management practises.

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