Effect of Potassium on Quality and Yield of Potato Tubers – A Review

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Abstract:

Potassium (K) aids in maintaining osmotic potential which enhances water uptake and root permeability, control ionic balances, regulate plant stomata and activate enzymatic processes. Potassium (K) plays significant role in quality as well as yield attributes of potato such as reducing sugar, Vitamin C content, specific gravity, shelf life and total yield. K application has found to increase reducing sugar content in potato tubers to threshold level and tends to decrease after that. The reason behind this is conversion of sugar to starch at high rate of K application. Vitamin C content is found to increase at moderate level of K application and tends to decrease in high concentration. Among the different sources of K, use of Muriate of Potash (MOP) is found better than Sulphate of Potash (SOP) for increasing Vitamin C content. Specific gravity and dry matter content are found to decrease with higher dose of K application. K lowers down senescence and reduces physiological disorders, increasing shelf life in potato tubers. Potassium Chloride (KCl) is more effective in reducing the incidence of physiological disorders during postharvest compared to other source of K. K application plays significant role in increasing yield of potato tubers which is either due to formation of large sized tubers or increasing number of tubers per plants or both by helping in accumulation of carbohydrate. There is low replenish and high loss of Potassium by leaching in soil and shows widespread deficiency in intensively potato growing areas. Therefore, careful attention should be given in Potassium fertilization to maximize the quality and yield of potato tuber.

Keywords: *Potassium, Potato, Reducing Sugar, Specific gravity, Vitamin C, Yield.*

I. IMPORTANCE OF POTATO

The potato is the world's most important and widely cultivated tuber crop. Potato is grown in more than 125 countries and consumed everyday by more than a billion people. According to the report published in 2008 by FAO, on international year of potato, Asia and Europe were the world's major potato producing region which accounts for more than 80 percent of world production. Whereas harvests in Africa and Latin America were low. North America had the highest yield record more than 40 tonnes per hectare. Asia alone consumed almost half of the world's potato production, but per capita consumption was about 24 kg/capita/year due to its huge population. The per capita potato consumption was highest in Europe followed by North America with 88 Kg and 60 Kg respectively [11; 12].

Potatoes are used for a variety of purposes: as a fresh vegetable, as raw material for processing into food products or in different food ingredients, to manufacture starch and alcohol and as fodder for animals. From the nutritional point of view, potato is the best source of energy and vitamin. It contains high amount of carbohydrate (19.4%) in the form of starch, protein (2%) and fat (0.1%). In comparison to cereal crops, starch and protein in potato has high digestibility. Except vitamin – A & vitamin – E, it contains all most all vitamins. However, vitamin – B_6 and vitamin – C are present in adequate amount and minerals like Fe, Ca, P, Mg, and S are also present in sufficient amount [33]. According to FAO, consumption of 125 – 150 gm of potato daily fulfils the need of vitamins [11].

II. OVERVIEW OF POTASSIUM FERTILIZATION ON POTATO:

Though, potato is grown commonly and is adaptable in wide ranges of climatic conditions, it has strict requirement for a balanced fertilization, without which yield and quality of tubers are directly affected. Potato are heavily fertilized since they have a high nutritional requirements. Fertilizers application depends upon soil type, soil fertility, crop rotation, irrigation facilities, etc. Similarly, nutrient uptake by the potato crops also depends on the climatic condition, soil type and fertility status, variety cultivated and crop management practice [41]. Around, 30 tons of production per hector removes 150 Kg N, 60 Kg P and 250 Kg K, 90 Kg CaO and 30 Kg MgO [49].

Potato crops prefers well-drained, light, deep, loose soil that have high organic matter. Potassium is a limiting factor in such type of soil, as soil solution K has a high chance of leaching and thus loss from the soil system. Because of higher loss and low replenishment of potassium, widespread deficiency of potassium have been reported in many of the intensively cultivated soil [2] and application of K fertilisers have responded satisfactorily [37].

Potassium is one of the most essential nutrient required for plant development. It plays vital role in several physiological processes such as photosynthesis, translocation of photosynthates, control of ionic balance, regulation of plant stomata and transpiration, activation of plant enzymes and many other processes [46]. Potassium also enhances N uptake and protein synthesis resulting in better foliage growth [27]. In a plant cell potassium maintains osmotic potential which enhances water uptake and root permeability and acts as a guard cell. Beside this, it also increases water use efficiency [31; 51]. Combine application of K and N increases foliage and leaf area index [29; 39].

Potato plants require much more potassium than many other vegetable crops, therefore it is also regarded as an indicator crop for K availability [3]. However, potato producing areas are more concerned about the use of nitrogen (N) and phosphorus (P) whereas potassium (K) application is ignored which causes serious decrease in yield and potassium content in soils [36].

III. EFFECT ON REDUCING SUGAR

Sugar content in potato tubers increase with K application [19]. It is found higher in tubers treated with K as compared to N and P [21]. Narrower difference of reducing sugar content in potato tuber is obtained at different levels of K application of MOP, while wider difference of reducing sugar content in potato tuber is obtained at different levels of K with application of SOP.

Higher dose of K leads to a lower amount of reducing sugars content [5; 13; 34]. As K has a potential to decrease reducing sugar content of potato tubers as it activates starch synthesis [27]. Application of moderate potassium fertilizer rate increases starch content in tubers, compared with the tubers that receive low potassium fertilization [4]. However, total soluble solid was not much affected by K fertilizer dose [10].

Table 1: TSS Content in Potato With Different Doses of Potassium.

K fertilizer Rate	TSS gm/ltr (2009)	TSS gm/ltr (2010)
72 kg /ha	44.70	43.60
96 kg /ha	45.31	44.32
120 kg /ha	45.50	44.45
control	44.81	43.86

(Source: El-Latif, Osman, Abdullah, & El-Kader, 2011)

In most experiments starch content in tubers was positively correlated to potassium application. Around 1.8 % K in tuber dry matter is reported to be necessary for high starch concentration [5]. High dose of potassium fertilizers reduced starch content in tubers by average 1.3 – 2.2, and dry matter by 0.9-2.4 percentage, compared to control or fertilized with only NP tubers [4]. Whereas Terman in 1950 reported that there is a consistent decrease in the starch content of potato tubers with increase in the rate of K application. Such difference can be due to additional factors such as genetic variations, growing environmental condition and tuber storage methods [35].

It was found that plants treated with K gives highest potassium level in potato tuber and the lowest in control. There is inter-conversion of starch and reducing sugar in potato. The conversion of starch into sugar makes potato sweeter in taste, which is not desirable quality. This conversion between starch and sugar is affected by factor such as temperature, K fertilizer, etc. [7]. In lower dose of K there is conversion of starch into sugar and vice versa in higher dose of K fertilizer. Whereas, there is no synthesis of sugar in moderate dose of K [27].

IV. EFFECT ON VITAMIN C CONTENT

Ascorbic acid (vitamin C) is one of the essential vitamin found in potato tubers [14]. As potato being rich in vitamin C content, it is necessary to have knowledge on effect of fertilizer application and vitamin C content. Vitamin C content is one of the important yield attribute.

According to experiments performed by Smith & Smith in 1977 for three years in Poland, application of 50 kg K ha^{-1} increased vitamin C content, while 100 kg K ha^{-1} had no effect, and 150 and 300 kg K ha^{-1} reduced it. K application as SOP and MOP at 150 kg K ha^{-1} increased vitamin C by 10.8% and 14.7%, respectively. The difference in vitamin C content regarding sources of K was significant, while for the levels and methods of K application were non-significant [43].

In another pot experiment potato tubers treated with KCl contained lower vitamin C compared to control and K_2SO_4 treated sample. This indicate the detrimental effect of KCl on vitamin C content in potato tubers. Fertilization with KCl diminished the concentration of vitamin C to 46% even at the lowest K rate of 200 mg K/ kg soil. The higher rates of KCl fertilization of 400 mg and 600 mg K/ kg soil reduced the content of vitamin C to 50% [26].

Hence, it means that use of MOP as source of potassium is better than SOP or KCl to increase vitamin C content in tubers. 150 kg K ha^{-1} from MOP would be favourable for improving vitamin C content while higher doses of K (>150 kg ha^{-1}) will tends to decrease it [21; 43].

V. EFFECT ON SPECIFIC GRAVITY

The specific gravity is one of the quality measure of potato tuber. It is also associated with starch content, total solids or dry matter or ash content and mealiness of potato tubers [44]. The specific gravity is positively correlated with P as well as K fertilization [3]. However, K fertilization reduces specific gravity, if applied in excess rates [8; 22; 23]. Similarly by McDole (1978) and Westerman et al. (1994), states that the specific gravity of potato tubers decreased with increasing rates of K fertilizers. However, Al-Moshileh & Errebi (2004) did not agree with the above findings. They found that there was no any response of specific gravity to K application (Table 3). TSS level is also significantly affected by the application K [36].

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)

The specific gravity gradually increases in potato tubers with increase in K application up to 150 kg per ha and gradually decreases at higher rate of application up to 225 kg per ha [21]. Similarly, tubers from plants receiving higher Nitrogen and Potassium doses have lower specific gravity [6; 24; 50]. Increasing levels of Nitrogen and Potassium in a potato field beyond threshold level significantly decreased specific gravity [1]. Many factors such as potato variety, location, growing temperature, etc. are responsible for specific gravity of potato. However, K fertilization plays greater role in determining the specific gravity of potato tuber [22; 25].

Not only K fertilizer dose but also source affects the specific gravity in potato tuber. The specific gravity is more affected with Sulphate of Potash (SOP) than Muriate of Potash (MOP). The specific gravity was found to be more in potato tubers treated with SOP than those treated with MOP [20]. Whereas Potassium Chloride (KCl) is slightly detrimental and reduce dry matter content of tubers [5]. High K concentration above 2% in tuber due to oversupply with Potassium Chloride may lower the contents of dry matter [21]. This might be due to physiological effect of chloride on enzyme activity of plants.

VI. EFFECT ON SELF LIFE:

Pre harvest application of potassium fertilizer significantly affects the keeping quality of potato. Potassium have helped in slowing down senescence and reducing the physiological disorders in storage and increasing shelf life of potato tubers [28]. Applying K in potato increases the vitamin C content and reduced post-harvest weight losses from the tubers [17].

Adequate supply of potassium have resulted on low internal blackening and mechanical damage rate with increased stress tolerance [38]. Similar result have been reported by FAO in 2009, that potassium reduces susceptibility to internal blackening. Jackson and Mc Bride (1986) found that potassium application reduced the incidence of hollow heart and provides resistance against pest and diseases during storage. And they also found application of KCl was more effective than K_2SO_4 in reducing the percentage of tubers affected by hollow hearts and browning [18].

VII. EFFECT ON YIELD ATTRIBUTES:

The quality parameters such as dry matter, specific gravity, starch contents, vitamin-C and ash contents are affected with application of P and K [20]. Application of Potassium is not only responsible to increase K concentration but also affects the concentration of N and P in potato tubers [32]. According to Singh and Lal in 2012 potassium significantly affect plant height, number of leaves per plant and marketable yield of potato tubers.

Application of Potassium fertilizer plays vital role in yield of potato. Researcher have shown that increasing the levels of potassium increases the potato tubers yield [9; 16]. Such increases in yield of potato tubers is either due to the formation of large size tubers or increasing of the number of tubers per plant or both. Westennann in 2005 stated that insufficient K resulted in smaller-sized tubers. Potassium increases the size but not the total number of tubers [47]. Potassium helps to increase the content of carbohydrate significantly which ultimately helps to increase the tuber size [3].

Table 3: Different Dose of Potassium on Quality Attributes of Potato.

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 & Errebi, 2004)

Research performed by Khan, et al. in 2010 recorded highest yield of 17.18 ton ha^{-1} at 150 kg K ha^{-1} + 1% K foliar spray of SOP whereas 16.9 ton ha^{-1} at 150 kg K ha^{-1} + 1% K foliar spray from MOP source while lowest yield was recorded at 250 kg N ha^{-1}. Furthermore, application of 225 kg K ha^{-1} was found to be less effective than 150 kg K ha^{-1}. Yield increase was only 6% from applied 225 kg K ha^{-1} with SOP and 4% with MOP over 150 kg K ha^{-1}. In another study, application of 100 kg K ha^{-1} significantly increased the tuber yield over control [1].

Another research, conducted on different doses of potassium, 0, 150 and 225 kg K ha^{-1}, from Sulphate and Muriate of potash and dose of nitrogen (N) and phosphorus (P) applied uniformly, showed significant increase in tuber yield at 150 kg K ha^{-1} from both the sources over control. Increase in tuber yield with 225 kg K ha^{-1} was statistically non-significant compared to 150 kg ha^{-1}. This result have indicated, application of K at 150 kg ha^{-1} enhance the marketable potato tuber yield significantly. Also, the increase in yield was more with MOP as compared to SOP [20].

Similarly, in another pot experiments designed to evaluate potato responsiveness to increasing rates of K was supplied with either as K_2SO_4 or KCl at the rate of 0, 200, 400 and 600 mg K/ kg soil. Ammonium Nitrate and Triple Superphosphate were also added to all variants to provide 200 mg/ kg N and 150 mg/ kg P_20_5 respectively. The result showed that effect was more pronounced in treatments with KCl where the decrease of dry matter content reached 15% at the highest K level (K600) when compared to the control [26]. Bansali & Trehan in 2011 observed similar result of reduction of dry mater content in tubers when fertilized with KCl.

From these results, it can be concluded that yield attributes on potato is not only affected by rate of potassium, is also affected by source of potassium fertilizer. K_2SO_4 have showed best result over KCl. Plants treated with K_2SO_4 translocated more photosynthates from the leaves and stems to the tubers compared with plants treated with KCl [5]. Also, foliar spray of K @ 1% contributed to increase potato tuber yield. Hence, application of K through foliar spray is recommended along with soil application [3; 5; 21; 26]. Also, to achieve high tuber quality it is recommended to fertilize less with nitrogen and increase phosphorus and potassium fertilizer rates [48].

VIII. CONCLUSION

There are lots of scientific papers describing the role of potassium on reducing sugar, vitamin C content, specific gravity, self-life, yield, etc., however, there still lacks the overall role of potassium on those parameters of potato. These attributes of the potato determine the quality and its taste. Since, nutritional requirement of potato is high and supplied with greater dose of potassium compared to most of the annual crops, we must consider its effect on quality and tuber yield of potato.

Sugar content in potato tubers increase with K application to certain threshold level, and starts to decrease. Lower dose of K converts starch into sugar and vice versa at higher dose. Vitamin C content also increases with increasing potassium fertilizer dose and decreases at higher dose. MOP source of potassium is better than SOP or KCl to increase vitamin C content in tubers. Dry matter of potatoes decreases with increasing K level. The dry matter and specific gravity is more affected with Sulphate of Potash (SOP) than Muriate of Potash (MOP). Potassium have helped in slowing down senescence and reducing the physiological disorders in storage and increasing shelf life of potato tubers. Application of K at 150 kg ha^{-1} gives the best economical tuber yield. The increase in yield was more with MOP as compared to SOP.

Potato grows best in sandy loam to loam soil and K is limiting nutrient in such soil as it is easily leached. Quality and yield of potato tuber not only depends on the fertilization dose but also on the source of K. It also depends on the variety, climatic condition, soil type, management practice, etc. Studies have shown that 125 to 150 Kg K ha^{-1} of MOP gives economically profitable yield and quality tuber. However, it is recommended to apply K fertilization based on soil analysis, variety of potato to be grown, climatic condition and irrigation.

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