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Mini Review

Potassium Fertilization in Potato

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Abstract

Potato (*Solanum tuberosum* L.) is one of the major vegetable crops of Nepal. Potato is grown all over the globe and consumed as either vegetable or staple food depending upon the crop production scenario. It is also an integral part of human diet. Potato is a high nutrient mining crop and needs higher fertilization for economic tuber production. Despite sufficient application of Nitrogen (N) and Phosphorus (P_2O_5), low replenishment and widespread potassium deficiency are limiting the potato production in Nepalese condition. Growth parameters such as plant height, leaf area and chlorophyll% was positively correlated with potassium application. Potassium alleviated stresses of frost and drought and reduced incidence of diseases like late blight, black scurf and hollow heart. Potassium also decreased the reducing sugar content and improved chips color and quality. Similarly, potassium application before harvest was found to increase storage life of potato tubers. Furthermore, potassium application significantly increased the yield of potato tubers and quality parameters such as Vitamin C content and specific gravity. Source of potassium and method of potassium application also affected growth, yield and quality parameters. Soil application of potassium in splits coupled with foliar spay was found to perform better. Optimum dose of potassium was recommended for economic tuber production.

Keywords: Potassium fertilization; Specific gravity; Reducing sugar; Yield

Introduction

Evolution of potato started around 350 million years ago from the poisonous ancestor of the plant nightshade. Slowly, potato evolved in its present form in the South American Andean highlands between Peru and Bolivia. Later, domestication of wild potato started around 8 millennia BC. The first record of potatoes in Nepal dates back to 1793. Potato (*Solanum tuberosum* L.) is one of the major vegetable crops of Nepal. Its production is widely distributed throughout the country but primarily centered in Himalayas and hilly regions. It is also consumed as a staple food in the Himalayan region. 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. Similarly, it is grown in more countries than any other crop with the exception of maize, and ranks fourth in volume of production. Potato is an integral part of human diet. Potato tuber contains about 80% water and the rest is dry matter. Starch is the major component of the dry matter accounting for approximately 70% of the total solids. It is a cheap source of energy due to its large carbohydrate content (13 to 23%). The average raw material composition of a potato tuber is as: dry matter (20%), starch (13-16%), total sugars (0-2%), protein (2%), fibre (0.5%), lipids (0.1%), vitamin A (trace/ 100 g fresh weight), vitamin C (31 mg/

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100 g fresh weight), minerals (trace), ash (1-1.5%), amylose (22-25%) and glycoalkaloids (<1 mg/100 g fresh weight) as an anti-nutritional factor. Due to its high nutritional value and production potential per unit time, it has immense potential to sustain burgeoning global population and ward off malnutrition and hunger (Kumar and Chandra 2018). Potatoes are used for different purposes such as fresh vegetable for home consumption, raw material for food processing industries, raw material for beverage industry etc.

Potato is a high nutrient mining crop and needs higher amount of N, P and K for its economic tuber production. 20-25 t ha^{-1} of compost/farmyard manure applied by farmers are not sufficient to replenish the harvested nutrients and hence need sufficient amount of mineral fertilizer addition with heavy manure application (Joshi, 1997). Widespread potassium deficiency and low replenishment are major reason behind lower productivity of potato in Nepalese conditions. Despite the application of sufficient amount of N and P_2O_5, lack of potassium has limited yields in Indo Gangetic Plains (IGP) of Nepal (Regmi *et al*., 2002). Balanced fertilization is found to enhance the potato crop yield significantly. Potato tubers are rich in starch so require relatively higher potassium than any other vegetable crop. Sometimes, potato is also regarded as an indicator crop for K^+ availability because of its high K^+ requirement. Potassium (K) in soil is present in three different forms that is total K, exchangeable and K in soil solution. Soil solution K has a high chance of leaching and is removed from the soil system. Exchangeable K plays an important role in soil plant availability. Potassium acts as an osmoticum in plants and is important for the translocation of sugars and synthesis of starches in potatoes. Potassium has a crucial role in higher productivity of potato tubers because it plays an important role in photosynthesis, regulation of opening and closing of stomata, favors high energy status which helps in timely and appropriate nutrients translocation and water uptake in plants (Bergmann, 1992). It also affects yield, quality, general health and vigor of plant (Marschner, 1995). Anonymous (2002) reported that the continuous and excessive use of N and P fertilizer accelerate drainage of soil native K reserves. It will not only impoverish soil K but also adversely affect crop yields.

Effect on Growth Parameters

Crop emergence mainly depends upon the genetic makeup and micro-climate. Significant difference in tuber emergence was observed by (Pervez *et al*., 2013). Highest emergence percentage was observed at 150 kg K_2O ha^{-1}, and gradual decline at higher levels. This might be due to negative impacts of K at higher levels. Similarly, (Kumar *et al*., 2007) reported significantly higher plant emergence with the application of K-nitrate than with K-sulphate and K-chloride. Al-Moshileh *et al*. (2005) reported that plant height is significantly affected by increasing K rates. The highest plant height was obtained when 600 kg K_2SO_4 ha^{-1} was applied (Table 1). These reports are in accordance with the data obtained by (Adhikari and Karki, 2006; El-Latif *et al*., 2011; Kumar *et al*., 2007; Pervez *et al*., 2013). Ati and Nafaou (2012) found that increasing the rate of application of potassium fertilizer (K_2SO_4) to soil resulted increase in vegetative growth of potato plant. Length and plant leaf area index were increased, and the increase was significant with the levels of irrigation in the study (after depletion of 50 and 75% of available water). Plant height and leaf area reached to 85.76 cm, 41.22 cm^2 per plant and 74.23 cm, 34.78 cm^2 per plant in irrigation with 50% and 75% depletion of available water, respectively in 600 kg K_2SO_4 ha^{-1} level. (Dkhil *et al*., 2011) studied the effects of foliar potassium fertilization on growth, yield and quality of potato and reported that increasing K_2O concentration from 0 to 0.95 g L^{-1} significantly increased height of potato shoots. From the 45th until the 95th day after planting, the 0.95 g K_2O/L gave the highest significant values for plant height compared with other treatments (79.1 cm at the 95 day). Similarly, with the increase of foliar application of potato significant increase in plant height, leaves number, leaf area, leaf relative water content and chlorophyll a concentration was also reported.

Table 1: Effect of different levels of potassium in growth parameters

K_2SO_4 Treatment (Kg ha^{-1})	**Plant height (cm)**	**Leaf area (cm^2 per plant)**	**Number of stems (per plant)**	**Chlorophyll (%)**
0	28.0	1127.7	4.0	25.0
150	28.7	1502.7	4.3	27.7
300	39.3	1797.0	3.7	31.0
450	46.3	2504.0	4.7	40.3
600	47.3	2603.3	4.3	43.0

Source: Al-Moshileh *et al*. (2005)

Response to Different Crop Stresses

Frost Resistance

Frost generally appears when the potato crop is in an active bulking phase and its effect brings yield losses up to 40%. Grewal and Singh (1980) conducted field experiments to study the effect of potassium nutrition on frost damage and reported higher frost damage in the soils with lower potassium content. Similar reports were obtained by (Black, 1967 & Saini, 1978). Saini (1978) found that K application not only reduced frost damage in potato plants but also helped in recovering plants affected by frost. Similarly, leaf K content is found to be inversely related to the frost damage index. A high concentration of K in leaf depresses the freezing point of the cell sap thereby protecting the plant from the frost (Trehan *et al*., 2009). Furthermore, Grewal and Singh (1980) opined that increased frost resistance by sufficient K supply might be due to its favourable effect on morphological, physiological and biochemical aspects of plants, such as proper turgor of plant cells, healthy deep roots, large xylem vessels, creation of protoplasm structures, reduced respiration and water loss, regulation of osmatic pressure, binding of water by cell protein, resistance of dehydration, high sugar and carbohydrate reserves, high soluble protein, high cation content, synthesis of polymer compounds and increase in the lipid content etc. (Levitt, 1956; Nelson, 1978; Yoshida & Sakai, 1973).

Disease Interaction and Shelf life

It is no new fact that plant nutritional status affects the incidence of pests and diseases in crops. There is a prevailing view that a high K status decreases the incidence of many pests and diseases. Farmers are therefore recommended to use K fertilizers in order to improve crop health. (Panique *et al*., 1997) observed a significant decrease in hollow heart with increasing K rates. Furthermore, he found higher disease incidence when KCl was used instead of K_2SO_4 as potassium source. K is found to develop resistancy against late blight, a disease of economic importance common in hills (Sharma *et al*., 1999). K also reduces the occurrence of black scurf in potato.

Similarly, keeping quality of potato tubers are significantly affected by pre-harvest application of potassium. Potassium is found to slow down senescence and reduce physiological disorders in storage ultimately increasing shelf life of potato tubers (Martin-Prével, 1989). Roberts & Mc Dole (1985) opined that adequate supply of potassium results on low internal blackening and mechanical damage rate with increased stress tolerance.

Resistance to Drought

Potassium application improves Relative Water Content (RWC) of plants under normal as well as water deficit conditions (Umar, 2006). (Umar and Moinuddin, 2002) opined that maintenance of plant water economy by K application in terms of a high RWC level under water stress condition might be due to the anticipated role of K in stomatal resistance, water use efficiency and lowering transpiration rate. Potassium is involved in hydration and organization of cell protoplasm and, thereby, in maintenance of turgor and growth of the plant in water stress condition (Khanna-Chopra *et al*., 1994; Sinclair & Ludlow, 1985). In case of potato, this is particularly true in rainfed crop in the hills where moisture stress often occurs during the time of plant emergence and at the tuber initiation stage. Potassium application, although not economizing on the water needs of the potato crop, does increase water use efficiency in terms of tubers yield/mm water (Trehan *et al*., 2009).

Effect on Quality Parameters

Specific Gravity

Specific gravity and tuber dry-matter percentage are important quality measure of potato tubers. In general, both variables are positively correlated. They are of prime importance to processors, as the recovery of the finished product is directly linked to them. Specific gravity is considered an important quality character particularly for chips and flour making industries. Higher the specific gravity the higher will be the quantity of dry matter. Potatoes with high specific gravity are preferred for preparation of chips and French fries. Potatoes with low specific gravity are used for canning purpose. However, potatoes with very high specific gravity (1.10) may not be suitable for French Fries production because they become hard or biscuit like. There are many factors that affects the specific gravity of potato tubers like potato variety, location and fertilizer used etc., (Malik, 1995). However, several researches have suggested very important role of K fertilization in determining the specific gravity of potato tubers. The specific gravity is also associated with starch content, total solids and mealiness of potato tubers (Teich & Menzres, 1964). Khan *et al.*, (2010) conducted field experiments comprising of three K_2O levels, 0, 150 and 225 kg ha-1 from two sources, SOP and MOP. They reported that specific gravity was positively affected by both P and K fertilization. Specific gravity of potato tubers increased with increase in K application up to 150 kg ha^{-1} and decreased at higher rate of 225 kg ha^{-1} (Table 2). Fertilizer dose was not the sole reason for specific gravity of potato tubers, higher specific gravity was reported from the potato harvested from the plots treated with SOP than those of MOP. Specific gravity increases on increasing K rates (Al-Moshileh 2005; Chamberland and Scott 1968; Khan 2012; Kunkel and Gardner 1965; Kunkel and Holstad 1972; Maier *et al*. 1994; McDole 1978; Murphy and Goven 1966; Panique *et al*. 1997; Roberts and Beaton 1988; Sandstra *et al*. 1968; Tawfik, 2001; Terman *et al*. 1953; Timm and Merkle 1963; White *et al*. 1974;). (Kumar *et al*., 2007) reported that higher specific gravity was observed in the potato tubers fed with sulphate and nitrate sources of K than potassium chloride (KCl). The reason behind this could be, chloride sources of K is detrimental for the potato tubers and is anticipated to decline dry matter content because of physiological effect of chloride on the enzymatic activity of plants. Adhikari & Sharma (2004) reported increasing levels of Nitrogen and Potassium decreased specific gravity of tubers. Tubers from plants receiving highest Nitrogen and Potassium doses had lower specific gravity. Similar reports were obtained by (Beukema and Vander Zaag, 1990; Dubetz & Bole, 1975; Teich & Menzies, 1964; Westermann *et al*., 1994). On the other hand, (Abdelgadir *et al*., 2003; Davenport & Bentley, 2001) found that specific gravity did not respond to K application. But, this could be due to the high content of K on the soil initially. Excessively large reserves of exchangeable potassium in the soil detrimental to tuber specific gravity. Mohr, & Tomasiewicz, (2012) observed linear decline in the specific gravity of potato tubers with increasing preplant applied KCl. This might be due to greater uptake of K from potassium chloride and the higher salt index of potassium chloride (Murphy and Goven 1958; Panique *et al*., 1997). This results in tubers absorbing more water due to the osmotic effects of the increased tissue salt concentrations (Stark and Love, 2003). But, split application of KCl had minimal effects on specific gravity of tubers.

Effect On Reducing Sugar and Chip Color

Reducing sugars (glucose + fructose) are of great concern to potato processing industries because of their undesirable darkening effect during frying and reduced sweating characteristics. The less sugar contents the better tuber processing quality for chips (Khan *et al*., 2012; Perrenoud, 1993). Sugar content in potato tubers increase with K application (Kamal *et al*., 1974). (Khan *et al*., 2010) conducted field experiments and found sugar content was relatively higher in tubers treated with K as compared to N and NP treatments. Furthermore, source of K fertilizer also affected the sugar content of potatoes. In case of K supplied by SOP, Greater difference in the sugar content among K levels was pronounced. Whereas, narrower difference was observed when K was supplied by MOP. Significant increase in sugar content was observed with higher levels of applied K directing use of higher rates of K in potato that would tend to enhance sugar contents in potatoes. Stanley & Jewell (1989) observed no significant correlation between reducing sugars and rate and source of potassium while studying the influence of source and rate of potassium fertilization on the quality of potatoes for French fry production. Lower reducing sugar content is desirable to obtain good quality of chips. Chips and french fries prepared from potatoes containing high amounts of sugars turn brown or black, which are unacceptable to consumers. This discoloration occurs due to chemical reaction between sugars and amino acids known as Miallard reaction. This reaction takes place when chips are fried – because of heat sugars react with amino acid and organic compound (a non-enzymatic process). This type of problems W observed in the potato tubers from low K nutrition levels (Martin-Prevel, 1989; Usherwood, 1985). Light chip colour was reported at higher potassium rates, regardless of its source (Murphy & Goven, 1966; Wilcox, 1961). (Khan *et al*., 2012) reported that the taste of the chips improved with K use. The effect of MOP source was more pronounced regarding taste of chips as compared to that of SOP source. Westermann *et al*., (1994) reported decreasing fashion of reducing sugars in both stem and apical end of potato tubers with higher K doses. Furthermore, he opined that potassium source had very little effect on reducing sugars and sucrose, but it indirectly affected the relationship between tuber N and K concentrations in the stem end via the chloride ion (Cl) concentration when KCl was applied. Generally, K applications are reported to decrease reducing sugars and lighten chip color (Chapman *et al*., 1992; Herlihy & Carroll, 1969; Sharma & Arora, 1988). Potassium is found to decrease the reducing sugar content of potato by activating starch synthesis. The phenomenon of inter-conversion of starch and reducing sugar occurs in potato. This interconversion phenomenon is affected by several factors such as temperature, K fertilizer, sunlight, etc. In lower dose of K there is conversion of starch into sugar and vice versa. The conversion of starch into sugar makes potato sweeter in taste, which is not desirable quality for chip color. For potatoes with higher sugar content within, sugar levels can be reconverted into starch when potatoes are re-conditioned. This can be achieved by placing potatoes in store at 15–20◦C for a couple of weeks. The sugar levels are reduced and discoloration of product is prevented to some extent (Khan *et al*., 2012)

Effect on Vitamin C Content

Vitamin C (Ascorbic Acid) is a water-soluble vitamin that acts as an antioxidant stabilizing free radicals and prevents cellular damage. It is an essential vitamin found in potatoes which also aids in collagen production and assists in iron absorption. Potatoes are rich in Vitamin C and are important yield and quality attribute. (Khan *et al*., 2012) reported the optimum dose of K (150 kg ha^{-1}) significantly increased the vitamin C content in potatoes and the higher rates did not give significant results for SOP. But in case of MOP, both rates showed significant results. Similarly, KCl was found to have detrimental effects regarding vitamin C content of potatoes (Manolov *et al*., 2015).

Table 2: Effect of source and level of K on yield and quality of potato

Treatment	Dry matter	Specific gravity	Vitamin C (mg $100g^{-1}$)	Ash contents	Yield
Control (N alone @ 250)	17.36	1.069	17.12	6.90	11.67
N and P @ 250 125 kg ha^{-1})	18.07	1.074	17.12	8.66	12.62
K_2O @ 150 kg ha^{-1} as SOP	19.60	1.081	19.61	9.72	15.47
K_2O @225 kg ha^{-1} as SOP	20.57	1.092	19.57	9.09	15.74
K_2O @150 kg ha^{-1} as MOP	19.49	1.087	20.33	8.64	15.49
K_2O @225 kg ha^{-1} as MOP	19.66	1.086	19.40	8.42	15.80
K_2O @150 kg ha^{-1} soil + 1% K_2O foliar SOP	20.48	1.086	19.54	9.24	17.18
K_2O @150 kg ha^{-1} soil + 1% K_2O foliar MOP	20.20	1.086	19.44	8.81	16.9

Source: Khan *et al.* (2010)

Effect on Tuber Yield

Potassium is crucial for proper growth and development of potato tubers. Application of potassic fertilizer plays vital role in the yield of potato tubers. Several researches have suggested that increasing the potassium level have increased the potato tuber yields (Adhikari & Karki, 2006; Al-Moshileh *et al* 2005 ; Cordova and Valcerede, 2001; Dubey *et al*., 1997; El-Latif 2011; Govindakrishan *et al*., 1994; li *et al*., 2015; Mohr & Tomasiewicz, 2012; Moinuddin *et al*., 2005; Mondal *et al*., 1996; Rao and Sekhon, 1989; Singh *et al*., 1997; Singh *et al*., 2001; Singh and Bansal, 2000; Sud and Grewal, 1991; Tawfik, 2001; Umar and Moinuddin, 2002; Yogesh *et al*., 1999).This increase in the potato yields could either be due to increased tuber size or increased number of tubers per plant or both. (Bourke, 1985) conducted two factorial trials involving four levels of N and four levels of K in sweet potato. As a result, nitrogen and potassium fertilizer were found to increase tuber yields of sweet potato significantly, nitrogen having greater effect than that of potassium. He suggested that N influenced yield by increasing the leaf area duration which in turn increased mean tuber weight and hence tuber yield. He also opined that potassium influenced tuber yield via an increase in proportion of dry matter diverted to the tubers and a rise in number of tubers per plant. Similarly, Khan *et al*., (2010) conducted field experiments to study comparative effect of source, levels and methods of K fertilization on yield and quality of potato produce. Nitrogen and phosphorus were applied at 250 and 125 kg ha^{-1} respectively, whereas three K_2O levels, 0, 150 and 225 kg ha^{-1} from two sources of potash (SOP and MOP) were tested. Potassium (SOP and MOP) was also applied as foliar spray at 1% K_2O solution at 30, 45 and 60 days after germination (DAG) and soil was also amended by 150 kg K_2O ha^{-1}. Increase in tuber yield with K application at 150 kg ha^{-1}as K_2O from both the K sources was found significant over NP treatment. Increase in tuber yield with K_2O @ 225 kg $ha^{-1}$was statistically non-significant compared to 150 kg K_2O ha^{-1}. Superimposing foliar spray of K_2O @ 1% solution increased potato tuber yield up to 11% over that of applied soil K at 150 kg ha^{-1} from both sources of K which indicated that K application in latter crop growth stage can optimize the potato yield. Trehan and Sharma (1998) evaluated effects of soil and foliar application of potassium to potato on the alluvial soils of Jalandhar (Punjab) for yield and fertilizer use efficiency. They stated that application of potassium through soil or foliar spray significantly increased tuber yield of potato. Increasing dose of soil applied K from 0 to 99 kg/ha enhanced tuber yield significantly from 266 to 358 q/ha. Foliar spray of 2% KCl at 50 DAP increased tuber yield by 43 q/ha but could not supplant soil application of K. This indicated that foliar spray of K could only supplement the soil application of K. Panique *et al*., (1997) also conducted field experiments over eleven sites where five rates of K (0, 93, 280, and 373 kg K ha^{-1}) were band applied at planting of potato. Tuber yield was significantly increased up to 332 kg K in five out of eleven sites where initial soil test K ranged from 75 to 110 mg kg^{-1}. The increase in the tuber yield was associated with the increase of tuber size (170 to 370 g). Lack of yield response at other sites could be because of high initial soil test K (125 to180 mg kg^{-1}). This is also consistent with others who observed no yield response to K fertilization when soils test high in K (Dubetz and Bole, 1974; McDole, 1978; Roberts and Beaton, 1988). Wilcox (1961) conducted a study on effect of sulfate and chloride sources and rates of potassium on potato growth and tuber quality at 4 different rates of 0, 75, 150, 225 pounds/acre. The tuber yields were increased with addition of K fertilizer. Nearly maximum yields were obtained after the first increment of potassium was applied as KCL with a slight, but not significant, increase occurring at the highest rate.

All these results drive us to a conclusion that, yield of potatoes are significantly affected by the rates of potassium application. Similarly, source of potassium and time of potassium were also found to equally important in increasing the tuber yields. Potassium applied by sulphate source was found to be better than chloride source. Bansal & Trehan (2011) opined that plants supplied with K_2SO_4 translocate more photosynthates from leaves and stems to the tubers than the plants supplied with KCl. Soil application of K accompanied by foliar spray could be far better for the higher yields in potato. Similarly, split application of potassium was found to perform better than basal application.

Conclusion

Potato is a high nutrient mining crop and needs sufficient amount of mineral fertilization for its proper growth and development. Several scientific literatures can be found describing the role of potassium in growth, specific gravity, reducing sugar, vitamin C content, shelf life, yield etc. Potassium was found to affect the growth parameters of potato like plant height, leaf area index and chlorophyll significantly. Crop stresses like frost stress and drought stress were alleviated by potassium application. Diseases like hollow heart, late blight and black scurf was minimal with increasing rates of potassium application. Similarly, potassium is found to slow down senescence and reduce physiological disorders in storage ultimately increasing shelf life of potato tubers. Specific gravity in potato tubers was significantly affected by potassium application. Not only the rates of potassium but source of potassium was also equally responsible for specific gravity of potato. SOP was found to be better than MOP. In case of reducing sugar, contradictory reports were obtained of the role of potassium. Since reducing sugar and chip color are very important industrial quality parameter there is high necessity of research activities in this topic. Higher vitamin C was obtained when the field was supplied with optimum K levels, higher rates did not exhibit significant effects. KCl was found to have detrimental effects to vitamin C content of potatoes. Potato yield was also significantly affected by potassium application.

In nutshell, the growth, development, yield and quality of potato was found to be significantly affected by potassium application. Optimum dose of potassium was found to perform well; higher rates did not affect the parameters significantly. Similarly, source of potassium also had significant effect on the growth, yield and quality parameters. Soil application of K accompanied by foliar spray was found to be efficient than soil application alone. Split application of potash was better compared to basal application. Growth, yield and quality of potato depends upon the rates of K application, sources of K and method of K application. It also depends on variety, climatic condition, soil type, management practice etc. Generally, 150 kg K ha^{-1} is assumed as optimum dose and found to be economically profitable. However, it is recommended to apply K based on soil test, variety of potato being cultivated, climatic conditions etc.

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