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Effect of Foliar Spray of Different Potassium Sources on Growth, Yield and Mineral Composition of Potato (*Solanum tuberosum* L.)

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ABSTRACT

Two field experiments were conducted during 2013 and 2014 winter seasons to study the effect of foliar spray with potassium nitrate, potassium silicate, potassium chloride and mono potassium phosphate at the rates 1000 ppm and 2000 ppm on growth, yield parameters and some biochemical constituents of potato plant (*Solanum tuberosum* L.). Two samples were taken after 65 days from sowing and at harvest. At the 1st sample date, plant length, shoot fresh weight, shoot dry weight, total chlorophyll reading, total nitrogen and proteins, P, K, Mg, Fe, Mn and Zn concentrations (in potato leaves) were determined. At the 2nd sample date (harvesting stage), tubers number per plant, tubers weight/plant, yield/plant and yield/fadden were recorded. The higher rate of potassium silicate and potassium nitrate were more effective than the rest treatments on enhancing the vegetative growth parameters and yield components. In general, all potassium treatments have strongly stimulating effect on mineral nutrients (N, P, K, Mg, Zn, Mn and Fe) and protein concentration of potato leaves in both seasons.

Key words: Potato, *Solanum tuberosum* L., Foliar nutrition, Potassium.

Introduction

Potato (*Solanum tuberosum* L.) is a crop of major significance in human nutrition, ranking fourth in food production, after wheat, corn (maize), and rice. It is the first in energy production, and second in carbohydrate and protein production (Nieder, 1992). Some of the worlds largest and smallest, richest and poorest and most progressive and most backward farmers grow potatoes (Horton and Anderson, 1992). Potatoes are grown on over 19.3 million hectares in more than 124 countries, with annual production of more than 331 million tons (FAO, 2009).

Fertilization is an important factor in potato production technology to achieve optimum yield and quality of tubers. The potato is a plant with high nutrient demands because of forming abundant vegetative mass and a high quantity of tubers at the unit area. It is a great consumer of nitrogen, phosphorus, potassium, magnesium and calcium, as well as micro elements (Fit and Hangan, 2010). Also, Regmi *et al.* (2002) reported that potato being a high nutrient mining crop it needs higher amount of N, P and K for its economic tuber production.

Potato is regarded as an indicator crop for soil K availability due to its high K requirement (Roberts and Mc Dole, 1985). In this respect, Cao and Tibbittis (1991) indicated that low K nutrition not only reduced potato growth, but also affected nutrient balance between major cations. Potassium (K) is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving synthesis of protein, carbohydrates and fats, translocation of photosynthetic, enabling their ability to resist pests and diseases. Also, potassium is considered as a major osmotically active cation of plant cell (Mehdi *et al.*, 2007). Potassium is an important nutrient for plant meristematic growth and physiological functions, including regulation of water and gas exchange in plants, protein synthesis, enzyme activation, photosynthesis and carbohydrate translocation in plants. Potassium has favorable effects on metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson *et al*., 1994; Bednarz and Oosterhuis, 1999). Wang *et al*. (2013) and Salami and Saadat (2013) pointed out that K plays an essential roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomata movement, energy transfer, phloem transport, cation-anion balance and stress resistance. Potassium is a part of many important regulatory roles in the plant. It is essential in nearly all processes needed to sustain plant growth and reproduction, i.e. photosynthesis, translocation of photosynthesis products, protein synthesis, control of ionic balance, regulation of plant stomata, turgor maintenance, stress tolerance and water use, activation enzymes and many other processes (Sangakkara *et al*., 2000; Cakmak, 2005). Moreover K enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency (Zekri and Obreza, 2009). Potassium has favorable effects on metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson *et al*., 1994; Bednarz and Oosterhuis, 1999).

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Foliar fertilization is a supplemental nutrition with macro and micro nutrients. Foliar nutrition is ideally designed to provide many elements in conditions that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (Hiller, 1995). Large applications of fertilizers and soil amendments for potato production may cause the accumulation of heavy metals in tubers and eventually become toxic in the soil environment. It self, foliar sprays are effective for most nutrients in correcting foliar deficiencies, but not effective to correct tuber nutritional problems if the nutrient is not mobile in the phloem (Westennann, 2005). Therefore, foliar feeding of nutrients has become an established procedure in crop production to increase yield and quality of crop products (Roemheld and El-Fouly, 1999) and it also minimizes environmental pollution and improves nutrient utilization through reducing the amounts of fertilizers added to the soil (Abou-El-nour, 2002).

In addition, foliar applications of K can improve yield and tuber quality, especially in heavy clay or in sandy soils where K is not readily available for the plants (Marchand and Bourrie, 1999). Various sources of K salts are used for plants nutrition such as potassium chloride (KCl), potassium sulfate (K_2SO_4), mono potassium phosphate (KH_2PO_4), and potassium nitrate (KNO_3) (Magen, 2004). Also potassium silicate ($K_2O.4SiO_2$) caused very good results to improve the growth and yield of plants under saline conditions (Salim *et al.* 2011 and 2013; Salim, 2014). Jabeen and Ahmad (2011) demonstrated the beneficial effects of KNO_3 application on growth, nutrients concentration, nitrate reductase activity and soluble proteins of sunflower and safflower plants, irrespective to their growth under non saline or saline conditions.

The aim of study was to investigate role of different potassium sources on source-sink relationship and act upon growth and yield of potato plant.

Materials and Methods

In this study, the field experiment was carried out during the two growing seasons of 2013 and 2014, at the experimental farm, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Egypt, in order to investigate the effect of foliar application with different sources of potassium on growth, productivity and mineral composition of potato in sandy clay soil. The chemical and physical analyses of the experimental soil are shown in Table (1).

Table 1: Some chemical and physical analysis of the experimental soil

pH	EC ds/m	$CaCO_3$ %	Cations meq / l			Anions meq/ l		
			Ca^{++}	Mg^{++}	Na^{+}	HCO_3^-	CL^-	SO_4^{--2}
8.71	0.65	1.27	7.54	2.47	1.78	3.10	3.25	1.54
N	P	K	Sand %		Silt %	Clay %	Soil texture	
(ppm)								
61	85	387	49.72		11.47	38.81	Sandy clay loam	

Tubers of potato cv. Cara were sown on 25th of January during 2013 and 2014 seasons. The experimental plot area was 10.5 m^2 involved five rows, each row was 3 X 0.7 meter. The plant distance was 25 cm apart on one side of row.

Calcium super-phosphate (15.5 % P_2O_5) at 400 kg / feddan was banded on rows and added during the soil preparation. Ammonium nitrate (33.5% N), at 300 kg / feddan, was applied as soil application in three portions, the first addition (100 Kg) was added at complete tubers germination, the second one (100 kg) was carried out after two weeks from the first addition and the third one (100 kg) was added two weeks later. Potassium sulphate (48 % K_2O) was applied at a rate 150 kg per feddan at two times, the first portion took place one month from sowing, whereas, the second part was added one month later. Cultural management, disease and pest control programs were followed according to the recommendations of the Egyptian Ministry of Agriculture.

The experimental design and treatments

The experiment included nine treatments as follows; control (sprayed with tap water), potassium nitrate (46 % K_2O), potassium silicate (60 % K_2O), potassium chloride (63 % K_2O) and mono potassium phosphate (34.5 % K_2O) were used at two concentrations, i.e., 1000 and 2000 ppm foliar application and supplied at 25, 40 and 55 days after planting. Tween-20 (0.1%) was used as a wetting agent for each treatment. Spray was carried out between 07:00 and 9:00 AM. The experiment was arranged in a randomized complete block design with nine treatments and three replications per treatment.

Growth parameters

Plant samples in the two seasons were randomly taken from each treatment at 65 days from planting. The recorded growth parameters of potato included plant length, shoot fresh weight (g), shoot dry weight and total chlorophyll reading. Chlorophyll reading was recorded by Minolta Chlorophyll Meter SPAD – 502.

Chemical analyses

At 65 days from planting, leaf samples were cut gently at random from the inner rows for each treatment, leaf samples were dried at 60 °C in a forced air oven for 72 h. Leaf samples of potato plants were collected to determine nitrogen, total proteins, phosphorus, potassium, magnesium, iron, manganese and zinc concentrations. Tenth gram sample of leaf samples was wet digested using (H_2SO_4 and H_2O_2) mixture as described by Cottenie (1980). Total nitrogen percentage (N) was determined according to the method described by A.O.A.C. (1975) and the crude protein concentration was calculated by multiplying total nitrogen concentration by factor of 6.25. Total phosphorus (P) in plant was determined calorimetrically using ascorbic acid method described by Watanabe and Olsen (1965). The concentration of potassium (K) was determined in the digested material using flame photometer as described by Eppendrof and Hing (1970). The concentration of magnesium (Mg), iron (Fe), manganese (Mn) and zinc (Zn) were determined by using atomic absorption spectrophotometer (Chapman and Pratt, 1961), in Central Lab, Fac. Agric. Ain shams Univ.

Yield components

Number of tubers /plant, mean tuber weight and tuber yield/plant as well as tuber yield/feddan were recorded.

Statistical analysis

Data of the two seasons were arranged and statistically analyzed using Mstatic (M.S.). The comparison among means of the different treatments was determined, as illustrated by Snedecor and Cochran (1982).

Results and Discussion

Growth parameters

Data presented in Table (2) revealed that plant length, shoot fresh weight, shoot dry weight and chlorophyll reading were significantly increased by the most foliar application of different sources of potassium as compared with the control. Generally, the highest values of all growth parameters were observed with potassium silicate at 2000 ppm treatment as compared to the other foliar application treatments in both seasons. Potato plants which received foliar application of 2000 ppm potassium nitrate and potassium silicate gave the highest values for plant length as compared with other treatments, these results were true in the first season. Foliar application of 2000 ppm potassium nitrate or 2000 ppm potassium silicate produced the highest values of shoot dry weight compared with other tested foliar applications during tow seasons of growth. Potato plants foliar application of 2000 ppm potassium nitrate and potassium silicate gave the highest values for chlorophyll reading in both seasons. This might be due to that the potassium affects photosynthesis at various levels.

Table 2: Effect of foliar application of different sources of potassium on vegetative growth of potato plants in both seasons.

Treatments	Plant length (cm)		Shoot fresh weight (g)		Shoot dry weight (g)		Chlorophyll reading (SPAD)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	77.3g	88.7e	234.7g	258.3f	28.7e	22.0d	35.5g	39.1d
KNO_3 1000 ppm	90.7ef	100.0d	457.0e	461.7d	84.3ab	87.7b	47.2e	48.6bc
KNO_3 2000 ppm	122.0ab	114.0b	553.3c	545.0b	86.7ab	92.0b	60.7a	58.9a
KCl 1000 ppm	84.3fg	90.7e	376.7f	384.3e	76.3b	76.0c	43.1f	46.7c
KCl 2000 ppm	97.0de	100.0d	541.7c	451.7d	77.7b	89.7b	52.9cd	61.5a
K_2O. $4SiO_2$ 1000 ppm	112.3bc	115.0b	584.0b	553.0b	44.3d	92.3b	56.2b	59.1a
K_2O. $4SiO_2$ 2000 ppm	129.7a	126.3a	875.0a	588.3a	92.3a	103.7a	59.6a	61.8a
KH_2Po_4 1000 ppm	95.3de	105.0cd	448.3d	453.3d	39.0d	74.0c	51.9d	52.8b
KH_2Po_4 2000 ppm	103.0cd	112.3bc	482.3c	510.0c	61.0c	77.7c	54.8bc	57.4a

Means followed by different letters are significantly different at P≤0.5 level; Duncan's multiple range tests.

This increment in vegetative growth of potato plants which sprayed with potassium sources may be due to the role of potassium on plant nutrition, i.e. promotion of enzymes activity and enhancing the translocation of assimilates and protein synthesis. The results confirm that soil potassium content is not enough to the needs of potato plants as indicated in Table (1). In this connection, Sangakkara *et al.* (2000) attributed the increase in the growth of potato plants for role of K in biochemical pathways in plants and it increases the photosynthetic rates, CO_2 assimilation and facilitates carbon movements.

Marschner (2012) reported that K plays a crucial role in turgor regulation within the guard cells during stomatal movement. Potassium is an important nutrient for plant meristematic growth and physiological functions, including regulation of water and gas exchange in plants, protein synthesis, enzyme activation, photosynthesis and carbohydrate translocation in plants. Furthermore, K is also essential for the translocation of photo assimilates in root growth also root growth promotion by increased appropriate K supply under K-deficient soil was found to increase the root surface that was exposed to soil as a result of increased root water uptake (Romheld and Kirkby, 2010). In this respect, Cao and Tibbittis (1991) found that different K concentrations gave significant shoot dry weight, leaf area and dry matter accumulation in potato plants harvested and significantly increased concentration of chlorophyll in potato leaves compared to control treatment.

Moreover, K is also essential to the performance of multiple plant enzyme functions, and it regulates the metabolite pattern of higher plants, ultimately changing metabolite concentrations (Mengel, 2001; Marschner, 2012).

Leaf biochemical composition

Data in Tables (3 and 4) indicated that foliar application of different sources of potassium gave the highest values for leaf biochemical composition as compared with control treatment in the two seasons. Foliar application of potassium nitrate treatments improved nitrogen percentage and protein concentration in the two seasons. These results agree with those of Singh and Bansal (2000). Protein concentration is an important quality parameter and depends on the efficiency of nitrogen assimilated by plants (Selim *et al*., 2009). The biofortification of crops through application of mineral fertilizers, combined with breeding varieties with an increased ability to acquire mineral elements, is advocated as an immediate agronomic strategy to increase minerals concentrations in edible produce and to improve crop productivity on infertile soils (White and Broadley, 2005). In addition, K^+ which is needed for stimulating the plasmalemma ATPase that produces the necessary conditions for the metabolites, such as sucrose and amino acids (Barker and Pilbeam, 2007).

Table 3: Effect of foliar application of different sources of potassium on N, P, K and protein concentration of potato leaves in both seasons.

Treatments	N%		Protein (%)		P%		K%	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	1.9^{f}	1.8^{c}	11.8^{f}	11.0^{c}	0.6^{b}	0.6^{e}	2.5^{d}	2.3^{c}
KNO_3 1000 ppm	2.7^{ab}	3.3^{a}	16.9^{ab}	20.5^{a}	1.0^{a}	0.9^{a-c}	2.8^{a-c}	3.3^{ab}
KNO_3 2000 ppm	2.8^{a}	2.8^{ab}	17.4^{a}	17.5^{ab}	0.9^{ab}	0.9^{b-d}	2.8^{a-c}	2.9^{a-c}
KCl 1000 ppm	2.4^{d}	2.2^{abc}	15.1^{d}	13.7^{abc}	1.1^{a}	1.0^{a-c}	2.7^{bc}	2.7^{bc}
KCl 2000 ppm	2.6^{a-c}	2.5^{bc}	16.5^{a-c}	15.3^{bc}	1.1^{a}	1.0^{ab}	2.6^{c}	2.5^{c}
K_2O. $4SiO_2$ 1000 ppm	2.5^{cd}	2.2^{bc}	15.3^{cd}	13.9^{bc}	1.1^{a}	1.1^{a}	3.1^{ab}	2.8^{a-c}
K_2O. $4SiO_2$ 2000 ppm	2.2^{e}	2.0^{bc}	13.6^{e}	12.6^{bc}	0.8^{ab}	0.7^{de}	3.0^{a-c}	2.9^{a-c}
KH_2Po_4 1000 ppm	2.6^{b-d}	2.3^{bc}	16.0^{b-d}	14.4^{bc}	0.8^{ab}	0.7^{de}	2.7^{bc}	2.5^{c}
KH_2Po_4 2000 ppm	2.4^{cd}	2.2^{bc}	15.2^{cd}	13.6^{bc}	0.9^{ab}	0.8^{cd}	3.2^{a}	3.4^{a}

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range tests.

Table 4: Effect of foliar application of different sources of potassium on Mg, Fe, Mn and Zn concentration of potato leaves in both seasons.

Treatments	Mg%		Fe (ppm)		Mn (ppm)		Zn (ppm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	0.9^{e}	0.8^{e}	910^{f}	886^{f}	42^{f}	32^{b}	19^{d}	18^{c}
KNO_3 1000 ppm	2.0^{c}	2.1^{bc}	1312^{e}	1432^{e}	64^{a-c}	63^{ab}	21^{d}	19^{c}
KNO_3 2000 ppm	2.1^{bc}	2.0^{cd}	1482^{de}	1807^{c-e}	60^{b-d}	56^{ab}	23^{d}	25^{bc}
KCl 1000 ppm	2.3^{ab}	2.1^{bc}	1672^{b-d}	1665^{de}	71^{ab}	74^{a}	48^{c}	48^{ab}
KCl 2000 ppm	1.7^{d}	1.0^{d}	2013^{a}	2323^{b}	68^{a-c}	67^{a}	65^{b}	69^{a}
K_2O. $4SiO_2$ 1000 ppm	2.2^{bc}	2.2^{bc}	1720^{bc}	1713^{de}	50^{d-f}	45^{ab}	80^{a}	29^{bc}
K_2O. $4SiO_2$ 2000 ppm	2.5^{a}	2.6^{ab}	1590^{cd}	1913^{b-d}	72^{a}	67^{a}	28^{d}	29^{bc}
KH_2Po_4 1000 ppm	2.5^{a}	2.5^{a-c}	2030^{a}	2223^{bc}	48^{ef}	52^{ab}	31^{d}	29^{bc}
KH_2Po_4 2000 ppm	2.6^{a}	2.7^{a}	1850^{ab}	2747^{a}	58^{c-e}	57^{ab}	30^{d}	26^{bc}

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range tests.

Phosphorus concentration was increased by foliar applications of different sources of potassium comparing with the control. The maximum value of phosphorus concentration was recorded by potassium silicate at 1000 ppm and potassium chloride treatments. All treatments showed a significant increase in potassium concentration in potato leaves as compared to control in the first season but in the second season the treatments of mono potassium phosphate at 2000 ppm and potassium nitrate at 1000 ppm caused a significant increase. In this respect, Cao and Tibbittis (1991) found that all different K concentrations gave high significant increase for K in potato leaves. Increasing rates of potassium caused significant increment in K and Zn concentration in sweet potato leaves in both seasons Abd El-Baky *et al*., (2010).

The observed increment in the percentage of K in the leaves due to increasing of K application rate can be explained on the basis of increasing the availability of nutrients in the soil (Marschner, 1995). Moreover, Wallingford, (1980) mentioned that potassium is involved in the activation of more than 60 enzymes, which are necessary for essential plant processes such as energy utilization, starch synthesis, N metabolism and respiration this can explain the previous findings.

Foliar application of mono potassium phosphate at rate at 2000 ppm gave the highest values of potassium concentration of potato leaves in both seasons. All treatments showed a significant increase in magnesium concentration in potato leaves when compared to control plants. The highest value of magnesium concentration was recorded by mono potassium phosphate and potassium silicate at 2000 ppm treatments respectively in potato leaves. All treatments showed a significant increase in iron in both seasons and increased Mn concentrations in potato leaves in both seasons and the highest concentration of Mn in potato leaves resulted in potato plants which received KCl at 1000 ppm. While KCl treatments (in both seasons) and potassium silicate at 1000 ppm in the 1st season gave significantly increase in zinc concentration.

Mono potassium phosphate at 1000 ppm and potassium chloride at 2000 ppm treatments were gave the highest value of iron concentration in the first season while mono potassium phosphate and KCl at 2000 ppm gave the highest value in the second season. Potassium silicate foliar application at 1000 ppm gave the highest value of zinc in the first season while potassium chloride at 2000 ppm gave the highest significant value in zinc concentration in potato leaves when compared as rest treatments in the second season. Eleiwa *et al.* (2012) found that increasing the supplied NPK levels significantly increase pigments content in potato shoots. Increased leaf activities stimulate the need of water uptake and consequently, it increases the nutrients uptake from the soil.

Foliar feeding of a nutrient promotes root absorption of the same nutrient or other nutrients through improving root growth and nutrient movements from terminal leaves to depth roots (El-Fouly and El-Sayed, 1997).

Cao and Tibbittis (1991). Found that the low K concentration 0.10 meq l^{-1} gave high significant increase for Mg, Ca and S in potato leaves. On the other hand potassium silicate increased mineral nutrients (N, P, K, Ca, Mg, Zn, Mn and Fe) also the highest significant values in potassium concentration in wheat leaves was noticed by potassium silicate at 400 ppm (Salim *et al*., 2011 and 2013).

Marchand and Bourrie, (1999) indicated in their experiments on spinach, green pepper, tomato, and tobacco also suggested to apply K_2SO_4 as foliar application to increase the K concentration in the leaves for better quality crop.

Yield components

As shown in Table (5), in the most cases of the foliar applications exhibited high significant increases of yield components included number of tubers per plant, tuber weight/plant, total yields per plant and feddan in the two tested seasons compared to control treatment. Foliar application of potassium silicate at 2000 ppm gave the highest values of number of tubers, total yields per plant and feddan in the two seasons. Also, using potassium nitrate at 2000 ppm as foliar application gave a significant increase in potato yield as compared with control plants in both seasons.

The increment in vegetative growth and significant yield of potato plants as response to different sources of K was reported previously by Marschner, (1995).

The application of mineral fertilizers to the potato crop accelerates plant growth and increases tuber yield (Allison *et al.,* 2001; Trehan and Sharma, 2003; White *et al*., 2005). Boliglowa (2003) reported an increase of tuber yield with foliar application of 6% solution of urea. Potassium was supplied as KCl and K_2SO_4 to explore the need for additional S under local potato production conditions and to determine the effects of the chloride (Cl) and sulfate (SO_4) anions on production and quality of potato tubers. In addition, Mg and Ca were added to determine whether the background levels of these nutrients were adequate for optimum production.

Table 5: Effect of foliar application of different sources of potassium on yield components of potato plants in both seasons.

Treatments	Tubers number/plant		Tubers weight/plant (g)		Yield/plant (g)		Yield/Fedden (ton)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	9.6^{d}	8.0^{e}	41.1^{f}	41.7^{d}	382.9^{f}	362.0^{f}	8.30^{f}	8.42^{f}
KNO_3 1000 ppm	10.7^{bc}	11.0^{cd}	46.5^{b-d}	45.3^{c}	502.2^{cd}	501.7^{de}	10.86^{cd}	10.82^{de}
KNO_3 2000 ppm	11.3^{b}	12.7^{b}	50.7^{a}	49.6^{ab}	574.9^{b}	625.7^{ab}	12.38^{b}	13.51^{ab}
KCl 1000 ppm	10.3^{cd}	9.7^{e}	42.5^{ef}	48.2^{a-c}	438.8^{ef}	467.1^{e}	9.50^{ef}	10.02^{e}
KCl 2000 ppm	10.7^{bc}	10.7^{d}	43.7^{d-f}	47.7^{a-c}	466.3^{de}	509.7^{c-e}	10.13^{de}	11.05^{de}
K_2O. $4SiO_2$ 1000 ppm	11.3^{b}	11.7^{c}	45.8^{c-e}	48.0^{a-c}	518.8^{b-d}	557.5^{cd}	11.23^{b-d}	12.02^{cd}
K_2O. $4SiO_2$ 2000 ppm	13.0^{a}	13.7^{a}	50.1^{ab}	48.4^{a-c}	652.8^{a}	659.2^{a}	14.05^{a}	14.30^{a}
KH_2Po_4 1000 ppm	10.3^{cd}	12.0^{cd}	47.4^{a-d}	50.4^{a}	491.0^{c-e}	571.6^{bc}	10.58^{de}	12.31^{bc}
KH_2Po_4 2000 ppm	11.3^{b}	12.7^{d}	48.4^{a-c}	45.9^{ab}	549.5^{bc}	489.9^{e}	11.91^{bc}	10.59^{e}

Means followed by different letters are significantly different at P≤0.5 level; Duncan's multiple range tests.

The potato has a relatively high potassium requirement, which has led to the suggestion that high doses of the element are needed for potato production (Panique *et al*., 1997). Potassium is a monovalent cation and its capture is highly selective; is coupled with metabolic activity. It is characterized by high mobility in plants at all levels; is the most abundant cation in the cytoplasm and along with its accompanying anions makes a high contribution to the osmotic potential of cells and tissues. In addition, this element has an important role in water relations of the plant, furthermore K is not metabolized and forms easily interchangeable weak complexes (Marschner, 2002).

Moreover, K stimulates the activity of the enzyme (starch synthase) associated with starch synthesis (Mengel and Kirkby, 1987). Developing fruits are stronger sinks for photo assimilates than roots and vegetative tissues. This competition for photo assimilates reduces root growth energy supply for nutrient uptake including K (Marschner, 1995). Pettigrew (1999) stated that the elevated carbohydrate concentrations remaining in source tissue, such as leaves, appear to be part of the overall effect of K deficiency in reducing the amount of photosynthesis products available for reproductive sinks and thereby producing changes in yield and quality seen in cotton. In addition, it facilitates the translocation of assimilates to the tubers, which ultimately increases the bulking capacity of the tuber and its biomass.

Trehan and Sharma (1998) reveal that application of K through foliar application of 2% KCl at 50, 70 or 50 and 70 days after planting although increased tuber yield of Kufri Badshah by 35 to 43 q/ha but could not supplement soil application of K. However, utilization efficiency of absorbed K was more in foliage-applied K than soil-applied K. In frost prone areas of north- western plains, the application of K protects the crop from frost damage. This increase in K concentration in leaves in turn lowers the freezing point of the cell sap, thereby allowing the crop to escape the frost injury (Upadhaya *et al*., 1999).

Leonardite applications increased number of tubers per plant by 22%, marketable tuber yield by 38% and total tuber yield by 15% compared with the control (Arif *et al*., 2013). Yields of potatoes have increased significantly over the last 50 years as a result of the widespread use of fungicides, fertilizers, and irrigation. The application of mineral fertilizers to the potato crop accelerates plant growth and increases tuber yield (Allison *et al.,* 2001). In this respect, Marchand and Bourrie, (1999) reported that foliar applications of K can improve yield and tuber quality, especially in heavy clay or in sandy soils where K is not readily available for the plants.

The K foliar feeding has shown that supplemental feeding can enhance production and quality at critical stages of growth. Foliar-applied K in form of KNO_3 has indicated more yield compared to both K-applied as KCl and control (Oosterhuis *et al*., 1993). Total yield per plant and yield/fed showed a positive response to supply with potassium (Abd El-Baky *et al*., 2010).

Also, Salim (2014) indicated that potassium silicate treatments achieved significant increases in ear length, weight of 100 grains and grains weight of maize.

The favorable influences of foliar spraying with potassium sources on increasing potato yield and its components might be attributed to its effects on enhancing vegetative growth (Table, 2) and leaf mineral composition (Tables, 3 and 4).

Conclusion

* Foliar spray with potassium nitrate, potassium silicate, potassium chloride and mono potassium phosphate at the rates 1000 ppm and 2000 ppm led to stimulate growth, increasing yield and enhancing some biochemical constituents of potato plant (*Solanum tuberosum* L.).
* Spraying potato plants by potassium silicate or potassium nitrate at 2000 ppm gave the highest values of the most of growth parameters, yield components and minerals concentration in potato plants.

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