Middle East Journal of Applied Sciences Volume : 10 | Issue :01 |Jan.-Mar.| 2020
EISSN: 2706 -7947 ISSN: 2077- 4613 Pages: 120-137
DOI: 10.36632/mejas/2020.10.1.15

Effect of Foliar Application of Boron and Potassium Sources on Yield and Quality of Potato (*Solanum tuberosum* L.)

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Received: 10 Dec. 2019 / Accepted 10 Mar. 2020 / Publication date: 20 Mar. 2020

ABSTRACT

Two field experiments were conducted at EL-Gemmiza, Agric. Res. Station, (30º 43″22.5 ′ N, 31° 07″34 ′ E, elev. 10 m), Agric. Res. Centre, El-Gharbia Governorate, Egypt, during two successive winter seasons of 2017/2018 and 2018/2019 to study the effect of foliar application with different sources of potassium and three rates of boron as well as their interactions on tuber yield and quality (dry matter, starch, reducing sugar, total carbohydrates and specific gravity) of potato cultivar spunta. The experiments were conducted in split design with three replicates. The experiment included fifteen treatments as follows; control (sprayed with tap water), potassium nitrate (46 % K_2O), potassium silicate (60 % K_2O), potassium humate (10 % K_2O) and mono potassium phosphate (34.5 % K_2O) were used at 1000 ppm and three rates of boron (control, 50 and 100 ppm) as foliar application. The obtained results showed that the high values of tubers number per plant, tubers weight/plant, total tuber yield and marketable tuber yield were recorded by the plants which sprayed with potassium sources compared to control treatment. Also, the plants which sprayed with 100 ppm boron gave the highest total tuber yield, average tuber weight and marketable tuber yield. Application of boron significantly increased the yield of large and medium grade tubers and decrease proportionately small tubers. Mineral nutrients (N, P, K and B), total carbohydrates, specific gravity and starch content of tuber were significantly affected with foliar spraying with potassium sources than control treatment. In addition, the plants, which sprayed with potassium nitrate (KN) or potassium humate treatments were more effective than the rest treatments on enhancing the yield and yield components. Conclusively, from the obtained data in this study, it can be recommended by foliar spraying with 1000ppm potassium sources to improve growth, number of tubers, yield per plant and total yield. Also, the combination of foliar spraying by potassium sources and 100ppm boron has been found to be highly beneficial in improving potato size, dry matter, average tuber weight, total yield and other quality parameters.

Keywords: Boron, foliar application, Potato, Sources of potassium, Tuber quality

Introduction

Potato (*Solanum tuberosum* L.) is the fourth most important crop in the world after wheat, maize and rice with314.1 million tons of annual production on 18.1 million hectares of land (Arslanogul *et al.*, 2011) .Potato is an important source of food which contains high levels of carbohydrate, protein, vitamins and minerals. It is also source income, and employment opportunity in developing countries (FAO, 2008). Due to its correct balance between protein and calories, it is considered a good weaning food and these traits make it an efficient crop in combating world hunger and malnutrition (Berga *et al.*, 1994). The commercial value of potatoes is increased considerably when they are processed into edible products that appeal to consumers on flavor, texture, appearance, and most of all convenience (Kirkman, 2007).Potato consumption has increased in the developing world, and over the last decade world potato production has increased at an annual average rate of 4.5 percent Furthermore; Kirkman (2007) has estimated that global consumption in processed form will increase from 13%of total food use in 2002 to nearly 18% by 2020.

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 .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

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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 andCakmak2005). 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).Horticultural crops take potassium in large quantities, especially at fruit filing stages. Potassium fertilizer application can be made in several ways by banding, fertigation or by spraying liquid fertilizers on to the leaves. Various sources of K salts are used such as potassium nitrate (46 % K_2O), potassium silicate (60 % K_2O), potassium humate (10 % K_2O) and mono potassium phosphate (34.5 % K_2O).

Boron is an essential element required in micro amount but producing a macro impact on plant growth and development. Boron is involved in numerous important processes, including protein synthesis, transport of sugar, respiration, RNA, plant hormones and carbohydrate metabolism, flowering and fruiting (Tariq and Mott, 2007 and Havlin *et al.,* 2005). Moreover, functions of boron are related to cell wall synthesis, lignification and cell wall structure by crosslinking of cell wall polysaccharides as well as the structural integrity of bio membranes (Tanaka and Fujiwara, 2008). The requirement for boron fertilization is rising because of higher crop yield and reduced quantity of organic matter and severe boron removal by crops. Boron is critical for the process of cell differentiation at all growing tips of plants (meristems), where cell division is active (Adiloglu and Adiloglu, 2006). Bari *et al.,* (2001) reported that application of boron (as a borax form) increased fresh haulm weight /plant, No. of tubers/plant, dry matter of tuber and total yield as compared with control. Using boric acid in potato fertilization caused an increase in tuber size and weight by increasing of cell diameter in the tuber per medullary zone (Puzina, 2004). Boron also plays an important role in production of any crop in terms of yield, quality and control of some diseases. Boron plays an essential role in the development and growth of new cells in the meristem, proper pollination and fruit or seed set, translocation of sugar, starches, nitrogen and phosphorus, synthesis of amino acids and proteins, regulation of carbohydrate metabolism and stabilize the oxidative system in plants.

The objective of this study was to investigate the effects of foliar application of boron and different potassium sources on yield and yield component and quality of potatoes.

Materials and Methods

Two field experiments were conducted at EL-Gemmiza, Agric. Res. Station, (30º 43′ 22.5″ N, 31° 07′ 34″ E, elev. 10 m), Agric. Res. Centre, El-Gharbia Governorate, Egypt, during two successive winter seasons of 2017/2018 and 2018/2019, to study the effect of foliar application of boron and different potassium sources as well as their interactions on potato tuber yield and quality (*Solanumtuberosum* L.) cv. Spunta.Representative soil surface sample (0-30 cm) was taken from the experimental site before sowing and prepared to determine some physical and chemical properties according to the methods described by Page *et al.,* (1982) and Klute, (1986) and the obtained data are shown in Table (1).

Table 1: Physical and chemical characteristics of the soils under investigation

a) Physical analysis

Particle size distribution (%)			Texture class
Sand	**Silt**	**Clay**	
15.80	45.9	38.3	Clay loam

b) Chemical analysis

pH (1:2.5) Soil :Water Suspension	ECe (dSm^{-1}) Soil paste extract	Soluble ions in soil paste extract ($m.eL^{-1}$)								Available nutrients ($mgkg^{-1}$)		
		Cations				Anions						
		Na^+	K^+	Ca_2^+	Mg_2^+	CO_3^-	HCO_3^-	Cl-	SO_4^{2-}	N	P	K
7.89	2.11	8.35	2.04	6.23	5.42	-	9.43	8.59	4.02	40.3	7.0	370

The experimental plot area was 10.5 m^2 involved five rows, each row was 3 by 0.7 meter. The plant distance was 25 cm apart on one side of row. All plots were fertilized with N fertilizer at the rate of 150 kg N /fed as ammonium sulphate (21.5%N), which was added in three equal doses, after 4, 6 and 8 weeks from planting. Phosphorus was also applied to all plots during the soil preparation as calcium superphosphate (15%P_2O_5) at the rate of 75 kg P_2O_5/ fed. Potassium sulphate (48 % K_2O) was applied to all plots at a rate (96 kg K_2O/fed.) 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 was arranged in a randomized complete block design with fifteen treatments and three replications per treatment. The treatments

were arranged in split plot design with three replicates, where foliar application with different sources of potassium were assigned to the main plots and boron levels were arranged to the sub plots. The experiment included fifteen treatments as follows; control (sprayed with tap water), potassium nitrate(46 % K_2O), potassium silicate (60 % K_2O), potassium humate (10 % K_2O) and mono potassium phosphate(34.5 % K_2O) were used at 1000 ppm foliar application and supplied at deferent stages of potato growth which were vegetative growth (F1), tuber initiation (F2) and of tuber bulking (F3).Boron treatments were used at three levels, i.e., control, 50 and 100 ppm foliar application and supplied at 60 and 75 days after planting as borax fertilizer (11% B).

Measurements

Tuber yield:

Tuber number/plant, average tuber weight (g) and total yield/plant (g) were measured by counting and weighing tubers of 10 plants. Total tuber yield (ton/fed) was calculated from tuber yield per plant.

Chemical analyses

Samples of tubers from five potato plants were chosen randomly at harvest stage to determine the concentrations of nitrogen, phosphorus, potassium and boron in tuber tissues of potato, samples were taken from each plot, dried at 70^0C, and grounded using stainless steel equipment. From each sample 0.5 g was digested using 5 cm^3 from the mixture of sulfuric ($H_2 SO_4$) and perchloric ($HClO_4$) acids (1:1) as described by Cottenie *et al.,* (1982).Total nitrogen percentage (N) was determined using the modified micro Kjeldhal method (Cottenie*et al.,* 1982)and phosphorus by colorimetric method using spectrophotometer Ryan *et al.,* (1996). Potassium content was measured using a flame photometer method as described by Chapman and Pratt (1982) and protein percentage was estimated by multiplying nitrogen percentage by the factor 6.25. according to A.O.A.C., (1990).Boron concentration was determined colorimetric by Azomethine-H method at spectrophotometer at wave length 420nm (Wolf, 1971).

Tuber quality characteristics:

Quality parameters analyzed included starch, reducing sugars, specific gravity, total carbohydrate, crude protein, and dry matter content. Total carbohydrates were determined by using a colorimetric method as described Dubois *et al.,*(1956).The crude protein concentration was calculated by multiplying total nitrogen concentration by factor of 6.25 was used for determining protein yield: Tuber protein yield = tuber dry weight × tuber protein content. Total dry matter was determined by oven drying at 70°C to constant mass.

Tuber dry matter content (%)

Dry matter content was determined using an oven and balance method as prescribed by kabir and Lemaga (2003) and CIP (2006). Replicates of 10 tubers were cut in to 1-2 cm pieces and mixed thoroughly; three sub-samples of 200 g (fresh weight) each was taken and placed in an open aluminum container. The oven was set at 80°C and then the samples of each treatment were dried for 72 h until the weight is constant. The weight of oven dried samples was recorded and then finally dry matter content was calculated and expressed on a percentage basis.

$$\text{Dry matter (\%)} = (\text{dry weight / fresh weight}) \times 100.$$

Specific gravity

Specific gravity was determined from the raw tubers by adopting weight-in-air/weight-in-water method as prescribed by CIP (2006). Sample tubers of each treatment were placed in calibrated basket, weighed in air to get weight in air and then it was weighed in cold tap water to determine weight in water after that specific gravity was calculated using the following formula: The SG was calculated by Talburt and Smith (1975).

Specific gravity = (weight in air) / (weight in air - weight in water).

Percentage of starch content in tuber was determined according to A.O.A.C (1995).

Tuber size distribution in weight:

At harvest, tubers were collected from rows in each plot, and categorized into small (25-39 g), medium (40-75 g) and large (>75 g). Then converted to %and tonfed^{-1}for each of the three categories (Lung'aho *et al.,* 2007).

Statistically, all data were analyzed according to the technique of analysis variance (ANOVA). Also, the least significant difference (L.S.D) method was used to compare the deference between the means of treatment values to the methods described by Gomez and Gomez, (1984). All statistical analyses were outright using analysis of variance technique by means of CoSTATE Computer Software.

Results and Discussion

Effect of foliar application of potassium sources on Yield and its components

Data in Table (2) indicated that foliar application of different sources of potassium such as potassium nitrate (KNO_3), potassium silicate (K_2SiO_3), potassium humate and mono potassium phosphate (KH_2PO_4) exhibited high significant increases of yield components included number of tubers / plant, average tuber weight/plant and total yields / fed. compared to control treatment. Foliar application of potassium sources play vital role in yield of potato. 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. Foliar application of potassium nitrate (KNO_3) gave the highest values of number of tubers, average tuber weight/plant and total yields / fed. Foliar spray of potassium nitrate (KNO_3) had increased the plants growth through enhancing the physiological processes as K has a key role in the stomatal conductance, photosynthesis osmoregulation, protein synthesis and turgor pressure-driven solute transport in xylem to plants, nitrate metabolism(Nitrogen is an active participant of chlorophyll).Also, using potassium humate as foliar application gave a significant increase in the parameters tested (number of tubers / plant, average tuber weight/plant and total yields / fed.as compared to the control. Potassium humate and potassium nitrate as foliar application were more effective than the rest treatments on enhancing the vegetative growth parameters and yield components. These results are an agreement with those obtained by Prakash *et al*., (2012) and Barakat *et al*., (2015). Increasing growth parameters and yield may be due to that humic acid plays a main role in improving chlorophyll pigments and consequently, increases photosynthesis a plant production because they are hormone-like substances as reported by Nardi *et al.,* (2002) and Yang *et al.,* (2004).Potato plants which received foliar application of potassium silicate (K_2SiO_3) gave the highest values for number of tubers / plant, tuber weight/plant, total yields / plant and fed.as compared with control. The role of foliar application of different sources of potassium in increasing the yield and its components might be attributed to its function in plants which includes energy metabolism and enzyme activation that increase exchange rate and nitrogen activity as well as enhance carbohydrates movement from shoots to storage organs. Foliar application of potassium enhanced the stomata resistance coupled with reduced transpiration rate and increased relative water content, thus, may improve water storage capacity of the cells and providing favorable conditions for better yields (Umar and Bansal 1995). They found that application of potassium increased CO_2 assimilation and photosynthetic rate. Application of potassium increased photosynthesis that increase nutrient translocation from the upper parts of plant to be accumulated in the tuber.

Effect of foliar application of boron on Yield and its components

The results of this study revealed that foliar spray with boron increased number of tubers / plant, average tuber weight/plant and total yields / fed. as compared to control (Table 2).Increase in yield and yield attributes due to boron application may be attributed to enhanced photosynthetic activity and increased production and accumulation of photosynthesis, carbohydrates and favorable effect on vegetative growth which increased tubers yield per plant. This may be due to increase in the amount of chlorophyll in leaves and photosynthetic area which in turn leads to enhanced photosynthetic rate and ultimately accumulation of nutrients in tuber which improves protein, sugars and starch content of tubers. Foliar spray of boron improves photosynthetic activity, enhances activity of enzymes and plays significant role in protein and nucleic acid metabolism. Boron seems to protect plasma membrane against peroxidase damage and helps in maintenance of structural integrity. Boron is also involved in stomata regulation the finding was also supported by Bari *et al.,* (2001).

Effect of interaction between potassium sources and Boron on Tuber yields

With regard to the interaction between foliar spray with boron and different sources of potassium, data presented in Table (2) revealed that foliar spray with boron and different sources of potassium produced higher tuber yield and its components compared to control. Greater tuber yield may further be attributed to increased availability of these nutrients for the actively growing plants (Singh *et al.,* 2014), increasing RNA and DNA contents in reproductive tissues (Sathya *et al.,*2009), and thereby increased translocation of photosynthesis from source to sink or tubers during entire tuber growth stage. In addition to other functions, B was also known to facilitate such translocation of starch by forming B-sugar-alcohol complexes (Brown *et al.,* 2002). In the present study, use of B also increased the number of tubers per plant besides improving the tuber size which ultimately leads to higher yield of potato.

Effect of foliar application of potassium sources on nutrient uptake by potato plants

Data in Table (3) and fig (1) indicated that foliar application of different sources of potassium gave the highest values for N, P and K uptake in tuber yield as compared with control treatment. Foliar application of potassium nitrate treatments improved nitrogen percentage and protein concentration. These results agree with those of Singh and Bansal (2000). Foliar application of potassium nitrate or potassium humate increased nitrogen and potassium concentrations and uptake compared to the other applications of potassium sources. Phosphorus concentration was increased by foliar applications of different sources of potassium comparing with the control.

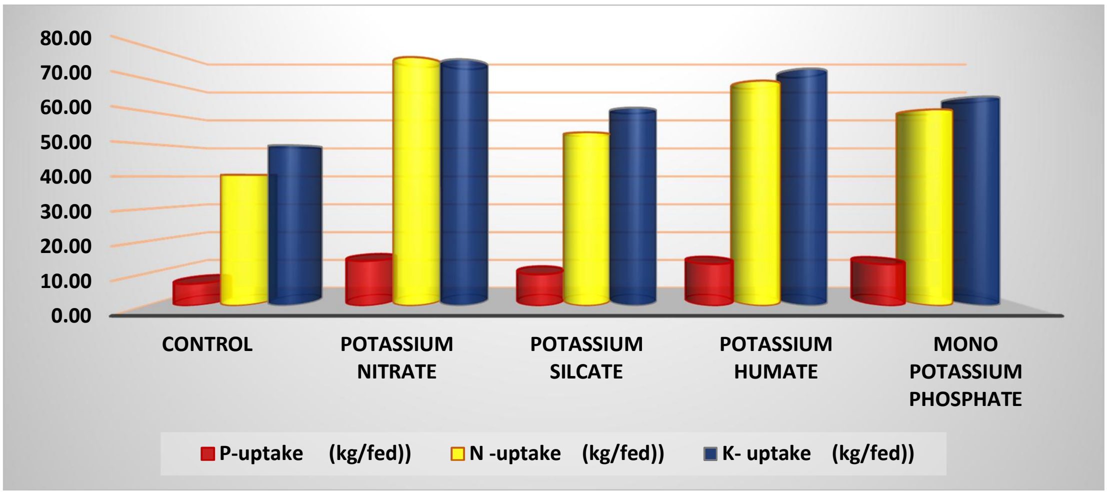

Fig. 1: Effect of foliar application of different sources of potassium on N, P and K uptake of potato tubers

The maximum value of phosphorus concentration was recorded by mono potassium phosphate and potassium humate treatments. The influence of the foliar application of mono potassium phosphate on phosphorus concentration was statistically significant. Mon potassium Phosphate and potassium silicate treatments showed a good performance in increasing P and K contents. Mon potassium Phosphate (MKP) is a cost effective and readily available fertilizer. Among the potassium and phosphate fertilizers used in foliar applications, MKP is the formulation with the lowest salt index and thus the foliar fertilizer of choice for many crops (Ankorion, 1998). It is an excellent and fast source of P and K when applied as a foliar fertilizer. All treatments showed a significant increase in potassium concentration in potato tubers as compared to control. Potassium silicate treatments recorded more potassium percent compared to the control as it contained potassium along with silicon. This may be due to the important role of Si in keeping the mineral balance in plants as in potato so it can increase the levels of some nutrients. Also, using potassium silicate affect the absorption and translocation of several macronutrients (Das *et al.,* 2017), may positively influence the osmotic adjustment, antioxidant enzyme (CAT and/or SOD) activities and photosynthetic apparatus maintenance as well as decreased H_2O_2 concentration in leaves of water stressed potato plants (Pilon *et al.,* 2014).This result may be attributed to the potassium role in increasing the activities of enzyme which could be explained by that potassium neutralizes various organic anions and other compounds within the plant which helping in stabilizing the pH value between 7 and 8, the optimum pH for most enzyme reactions. 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 photosynthesis, control of ionic balance, regulation of plant stomata and transpiration, activation of plant enzymes and many other processes Thompson, (2010). Potassium also enhances N uptake and protein synthesis resulting in better foliage growth Marschner, (1995). 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. All treatments showed increase in N, P and K concentration in potato tuber as compared to control but mono potassium phosphate (MPK) and potassium nitrate (KNO_3) treatments caused a significant increase. Foliar application of potassium nitrate has a positive effect on plant metabolism and thus also promotes yields in crops. Foliar application of different nutrients like potassium nitrate (KNO_3) and mono potassium phosphate may be beneficial in increasing yield of different crops. The beneficial effect of NO_3^- in delaying synthesis of ascorbic acid and promoting cytokine activity (Sarkar and Pal, 2006) and K on photosynthesis, carbohydrates distribution and starch synthesis in storage organs are presumed to be responsible for higher tuber yield (Imas and Magen, 2007).

Effect of foliar application of boron on nutrient uptake by potato plants

Boron foliar application significantly increased (N, P and K) uptake over that of control treatment(without B) Table (3) and fig (2).The control treatment exhibited least N, P and K uptake because of lower tuber yield and reduced concentration of those nutrients in potato tubers. Increased N-uptake in tuber with B application may be attributed to the role of B in synthesis of amino acids and proteins (El-Dissoky and Abdel- Kadar 2013). In addition, the effect of B application on increased K uptake may be related to synergistic relationship between K and B at sugar and carbohydrate transport (Mengel and Kirkby 1978).They further opined that plants that are large consumers of K require greater B levels (>20 ppm) in the tissue. Also, heavy users of K in the tuber bulking stage will require B levels 60¡80 ppm in the tissue in order to take up K they require (El-Dissoky and Abdel Kadar 2013). Meanwhile, Canda (2002) explained higher P content due to the influence of boron on membrane-bound ATPase activity.

The interaction effect between potassium sources and boron on nutrient uptake by potato plants

The combination effects between potassium sources and boron as foliar sprays resulted in no significant effects on N, P and K uptake of tuber yield Table (3) and fig (3).

Concentration and Uptake of B in tubers (ppm)

Foliar application of boron had significant effect on boron content and uptake in potato tuber(Table 4) and fig. (4).The spraying of100ppm boron in conjunction with potassium humate, potassium nitrate, mono potassium phosphate and potassium silicate increased in B uptake in potato tuber(103.16, 70.34, 47.23 and 40.83%more than control, respectively. Increased boron rates in combination with potassium sources increased boron content in tubers compared with control treatment. At the same time, interaction between potassium sources and boron rates had significant effect on boron concentration in potato tubers except for boron uptake in tuber which was not significantly.

Middle East J. Appl. Sci., 10(1): 120-137, 2020
EISSN: 2706 -7947 ISSN: 2077- 4613 *DOI: 10.36632/mejas/2020.10.1.15*

Table 2: Effect of foliar application of boron and different sources of potassium on yield components of potato plants

Parameters	No of tubers /plant				Average tuber weight (g)				Yield tuber (ton/fed.)			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	6.67	7.33	7.67	**7.00**	97.33	103.56	107.67	**102.85**	10.37	11.72	12.59	**11.56**
Potassium nitrate	11.00	11.67	12.67	**12.00**	142.67	149.00	154.67	**148.78**	12.99	14.03	16.77	**14.60**
Potassium silcate	8.00	8.33	9.33	**9.00**	110.33	113.17	116.67	**113.39**	11.57	11.91	12.92	**12.13**
Potassium humate	11.33	12.00	13.00	**12.00**	132.00	140.00	144.00	**138.67**	12.76	13.22	15.19	**13.73**
Mono potassium phosphate	9.67	10.00	11.33	**10.00**	121.00	123.33	129.33	**124.56**	12.38	12.95	13.96	**13.10**
Mean	**9.00**	**10.00**	**11.00**		**120.67**	**125.81**	**130.47**		**12.02**	**12.77**	**14.29**	
LSD 5% (A)	0.77				4.66				1.94			
LSD 5% (B)	0.49				4.43				1.08			
AXB	ns				ns				ns			

Table 3: Effect of foliar application of boron and different sources of potassium on N, Pand Kuptake (kg/fed) of potato tubers

Parameters	N uptake in tuber yield (kg/fed)				P uptake in tuber yield (kg/fed)				K uptake in tuber yield (kg/fed)			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	40.47	47.99	52.62	**47.03**	6.73	8.06	9.45	**8.08**	49.59	58.11	63.43	**57.04**
Potassium nitrate	76.65	84.39	103.56	**88.20**	13.89	15.21	19.88	**16.32**	75.99	81.54	100.01	**85.85**
Potassium silcate	53.53	55.97	65.29	**58.26**	9.71	10.77	12.45	**10.98**	61.11	64.64	74.70	**66.81**
Potassium humate	69.41	75.34	94.90	**79.88**	12.95	15.48	20.79	**16.41**	73.14	79.36	97.99	**83.49**
Mono potassium phosphate	60.60	68.44	74.68	**67.91**	12.84	14.71	18.34	**15.30**	64.53	72.14	80.69	**72.46**
Mean	**60.13**	**66.43**	**78.21**		**11.22**	**12.85**	**16.18**		**64.87**	**71.16**	**83.36**	
LSD 5% (A)	15.76				3.7				16.1			
LSD 5% (B)	8.57				2.32				8.5			
AXB	ns				ns				ns			

Table 4: Effect of foliar application of boron and different sources of potassium on boron content and uptake of potato tubers

Parameters	B(ppm) in tuber yield				B(g) in tuber yield			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	18.47	30.37	33.53	**27.46**	37.69	72.03	85.65	**65.12**
Potassium nitrate	19.87	35.23	39.63	**31.58**	56.68	107.34	145.90	**103.31**
Potassium silcate	21.57	38.50	43.60	**34.56**	51.08	93.55	120.62	**88.42**
Potassium humate	24.67	47.37	48.83	**40.29**	68.94	139.21	174.01	**127.39**
Mono potassium phosphate	24.43	36.73	41.93	**34.37**	62.74	101.93	126.10	**96.92**
Mean	**21.80**	**37.64**	**41.51**		**55.43**	**102.81**	**130.45**	
LSD 5% (A)	0.69				23.73			
LSD 5% (B)	0.54				12.35			
AXB	0.99				ns			

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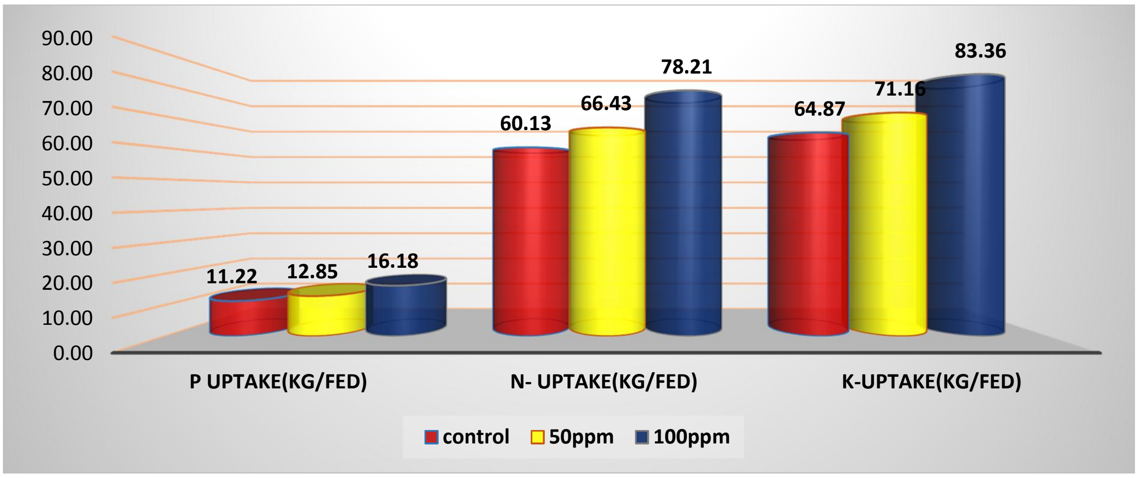

Fig. 2: Effect of foliar application of boron on N, P and K uptake of potato tubers

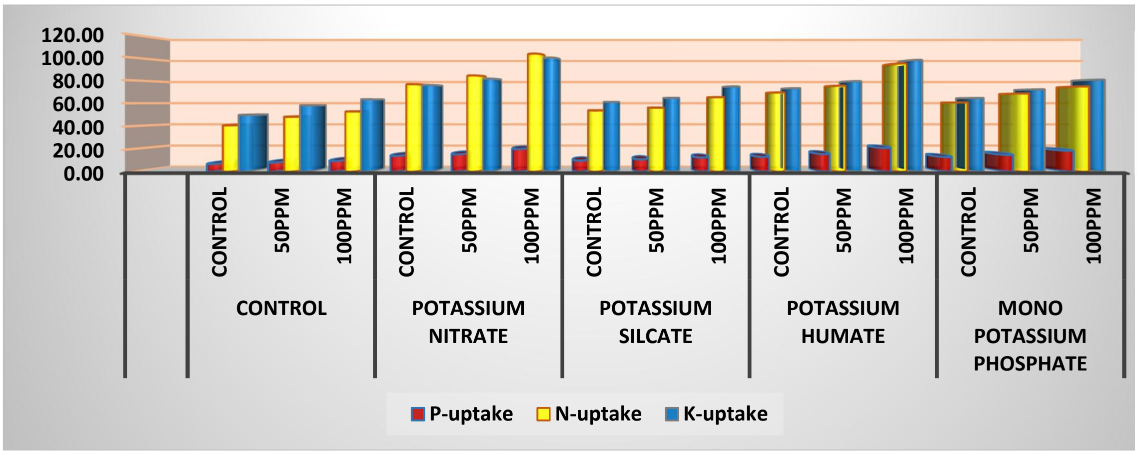

Fig. 3: The interaction effect between potassium sources and boron on N, P and K uptake by Tuber yield at harvest

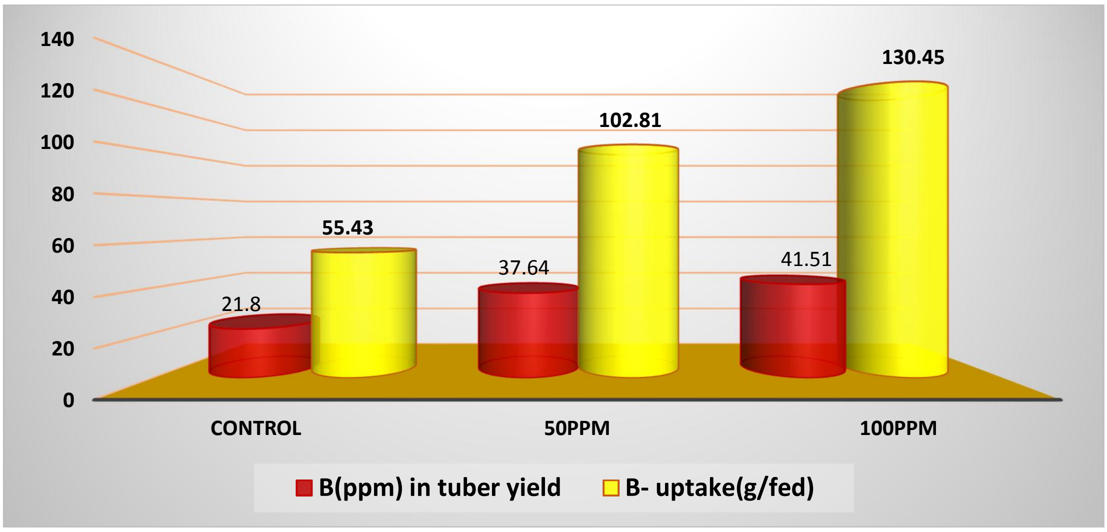

Fig. 4: Effect of foliar application of boron on boron content and uptake of potato tubers

Quality parameters of potato tubers

Effect of foliar application of potassium sources on specific gravity, starch and dry matter percentage

Specific gravity (SG), which is an expression of density, is the most widely accepted measurement of potato quality (Table 5) and fig (5).There is a very high correlation between the specific gravity of the tuber and the starch content and also the percentage of dry matter or total solids. Many factors such as potato variety, location, growing temperature, etc. are responsible for specific gravity of potato (Malik 1995).K fertilization plays greater role in determining the specific gravity of potato tuber. Not only K fertilizer dose but also source affects the specific gravity in potato tuber. The specific gravity was found to be more in potato tubers treated with potassium nitrate (KNO_3), potassium humate and mono potassium phosphate. The specific gravity is positively correlated with P as well as K fertilization. Higher the specific gravity the higher will be the quantity of dry matter and the greater the yield of produce. Potatoes with high specific gravity are preferred for preparation of chips and French fries. Potatoes with low specific gravity are used for canning. However, potatoes with very high specific gravity (1.10) may not be suitable for French fries production because they become hard or biscuit like. So purpose of growing potato should be kept in mind. Specific gravity values ranged from 1.052 g cm^{-3} to 1.089 g cm^{-3}.Dry matter content varies considerably between varieties and is a strongly inherited characteristic. Irrespective of cultural conditions that can affect dry matter certain varieties are consistently high in dry matter, while others are consistently low. The dry matter was higher in potato harvest from the plots treated with foliar application of potassium sources than those of control. A large increase in tuber starch was recorded with foliar application of potassium nitrate (KNO_3) and potassium humate. The applied K enhanced starch synthesis as it is involved in the activation of the enzyme called starch synthase, responsible for starch synthesis. It is the most efficient cation stimulating the activity of this enzyme that catalyzes the incorporation of glucose into long-chain starch molecules (Mengel and Kirkby, 1987).Also, potassium is considered as major osmotically active cation of plant cell where it enhances water uptake and root permeability and acts as guard cell controller, beside its role in increasing water use efficiency (Mengel and Kirkby, 1987). Moreover, the crucial importance of potassium in quality formation is related to its role in promoting synthesis of photosynthates in potato leaves and their transport to the tubers and to enhance their conversion into starch, protein and vitamins, hence overall tuber bulking and tuber composition depend on K nutrition (Bansal and Trehan 2011).

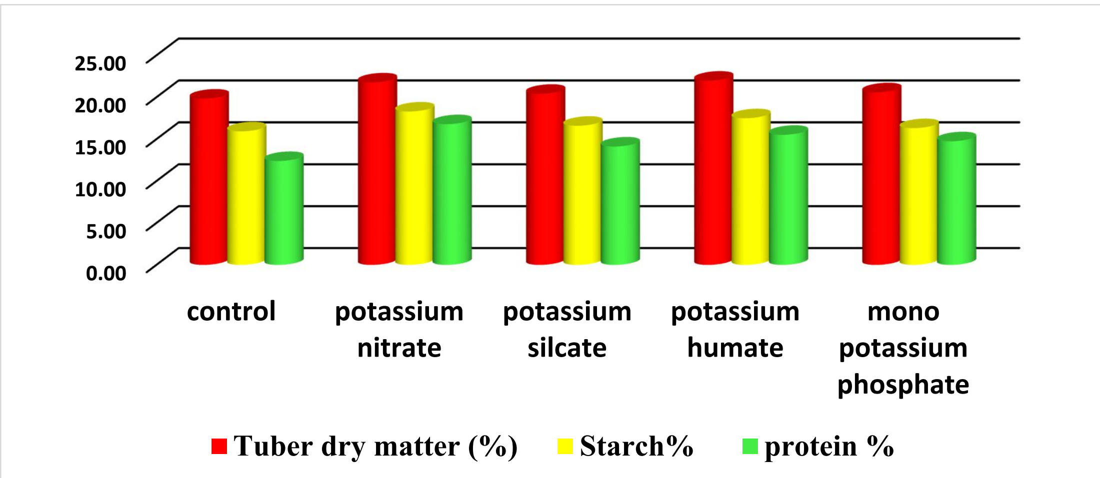

Fig. 5: Effect of foliar application of different sources of potassium on dry matter, starch and protein percentage of potato tuber

Effect of foliar application of boron on specific gravity, starch and dry matter percentage

In this study, foliar application of boron significantly affected quality parameters like specific gravity, dry matter and starch % in tubers Table (5) and fig.(6). Momentous increase recorded in quality parameters indices of potato plants might be due to boron plays a key role in a diverse range of plant

Middle East J. Appl. Sci., 10(1): 120-137, 2020
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functions including cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar or energy into growing parts of plants .The enhanced dry matter production may be attributed to greater accumulation of photosynthesis products by vegetative parts. These effects of boron foliar spray on the previous parameters of potato quality may be attributed to role of boron on sugar transport to parts of storage (tubers), also to its role in synthesis of proteins and regulation of carbohydrate metabolism. These results are in accordance with that obtained by Bari *et al.* (2001) and El-Banna and Abd El-Salsm (2005).

The interaction effect between potassium sources and boron on specific gravity, starch and dry matter percentage

Data in Table (5) clearly demonstrated that combined influence of potassium sourcesand boron showed the highest value of starch (18.82%) comparing with control (16.27%). Also, specific gravity and dry matter were improved by potassium sources and boron combination but these increases were not significant. The positive effect of potassium sources and boron combination treatment on starch could be interpreted by multiple physiological functions of both elements. The ability of potassium to improve dry matter and specific gravity was reported by Kumar *et al.,* (2007). Potassium sources could have an important role in promoting photosynthesis and increasing transport its products to the tubers, and to enhance their conversion into starch, protein and vitamins (Mengel and Kirkby, 1987). Boron increased the rate of photosynthesis by affecting photophosphorylation process inside chloroplasts and shift the hormonal balance in leaves and tubers especially IAA which is important for tuber growth after the onset of tuberization (Puzina, 2004).

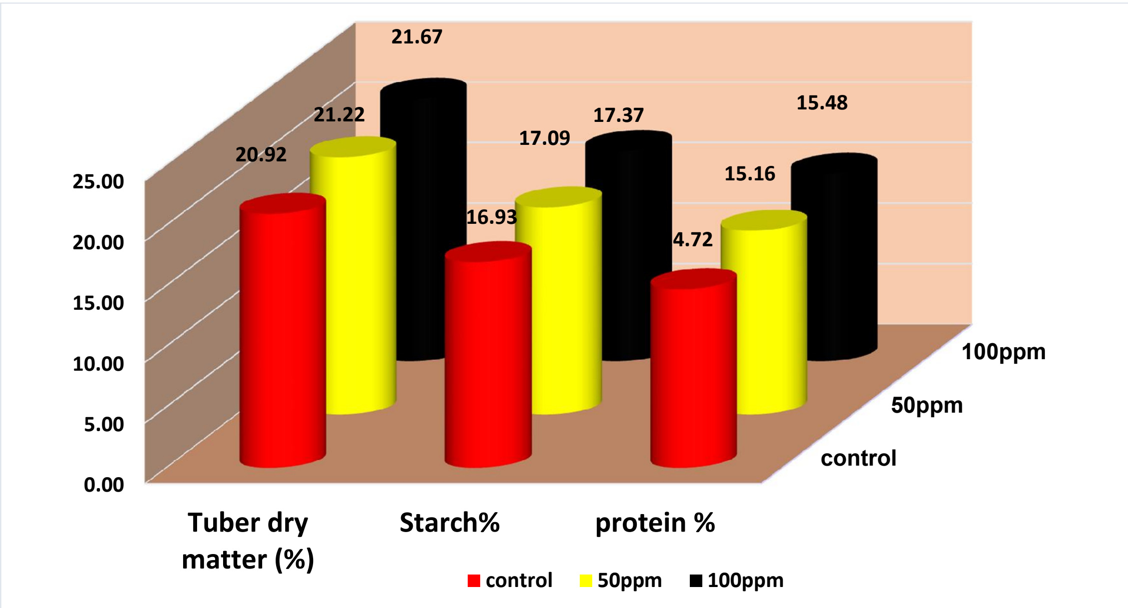

Fig. 6: Effect of foliar application of Boron on dry matter, starch and protein percentage of potato tuber

Effect of foliar application of potassium sources on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed

Data in Table (6) showed that the quality parameters of potato tubers like carbohydrate, reducing sugar content (%) and carbohydrate yield / fed. were significantly affected by foliar application of potassium sources. Potassium (K) plays significant role in quality as well as yield attributes of potato such as content of carbohydrate, reducing sugar content (%) and carbohydrate yield fed^{-1}. Its application activates number of enzymes involved in photosynthesis, carbohydrate metabolism and proteins synthesis and assists in the translocation of carbohydrates from leaves to tubers (Patricia and Bansal, 1999) .The higher yield quality in case of using of potassium sources may be also attributed to the role of potassium in translocation of produced photosynthetic assimilates and its accumulation in storage tubers and in turn increase the tuber weight, which consequently affect positively yield quality. Similar results reported by Bansal and Trehan (2011).According to Johnson (2003), potassium has two roles in the functioning of plant cells. First, it has an irreplaceable part to play in the activation of enzymes which are fundamental to metabolic processes, especially the production of proteins and sugars. Thereafter, it has a vital role in a process called carbohydrate metabolism. This process converts simple sugar to more complex sugar and starch. Second, potassium is the "plant-preferred" ion for maintaining the water content in plant cells as it creates conditions that cause water to move into the cell (osmosis) through the porous cell wall. These two important functions are responsible for increasing tubers size and its starch content. Sugar contents of potato tubers were also affected with potassium sources application. Sugar content was relatively higher in tubers treated with potassium sources as compared to control treatment.

Effect of foliar application of boron on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed

As regard to the effect of boron foliar spray on the content of carbohydrate, reducing sugar content and carbohydrate yield / fed in the potato tubers, data in Table (6) indicate that boron foliar spray application caused the highest significant increase in the content of carbohydrate, reducing sugar content and carbohydrate yield / fed in the tubers compared with the untreated control. Boron nutrition regulates water absorption and carbohydrate metabolism (Haque *et al.,* 2011). In the plant, boron plays a major role in the production and translocation of sugars. In the presence of boron, simple organic sugars (Glucose 1-P) will form complex sugar molecules and carbohydrates. In the absence of boron these simple sugars will form phenols (Quinone phenols), which will accumulate and attract insects and increase disease pressure. When boron is deficient in tissue cambial cells cease to divide but cell elongation continues in growing zones, and as a result xylem and phloem cells are displaced from their original position which leads to inactivation of vascular tissue. Inactivation of phloem cells leads to a failure of translocation of carbohydrates and sugars to tubers.

Effect of interaction between potassium sources and boron on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed

The interaction between foliar application of potassium sources and boron levels increased content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed (Table 6).The favorable effect of potassium sources and boron in quality formation is related to its role in promoting synthesis of photosynthesis in leaves and their transport to the tubers and to improve their conversion into starch, vitamins and protein. Also, foliar application of potassium sources and boron enhanced the dry matter content of tubers, which is highly essential for processing into chips and fries as stated by Feltran *et al.,* (2004) & Bansal and Trehan (2011). In this connection, El-Zohiri and Asfour (2009) showed that using potassium sources plus boron as foliar spray produced the highest values of starch and total sugars percentage in potato tubers.

Effect offoliar application of potassium sources on protein content and yield of potato tubers

Data showed that protein content and yield of potato tubers were significantly affected under potassium sources treatments in potato tubers (Table 7). All potassium sources as foliar spray exhibited greater protein content and yield than control. Potassium sources foliar application had a positive significant effect on total soluble protein content. This result may be attributed to the potassium role in increasing the activities of enzyme which could be explained by that potassium neutralizes various organic anions and other compounds within the plant which helping in stabilizing the pH value between 7 and 8 the optimum pH for most enzyme reactions. Foliar application of *potassium sources* caused a significance increasing the efficiency of the plant in the absorption of nitrogen, which plays a role in protein synthesis, transforms to the amino acids that move later places of manufacturing in the leaves to the storage places in the tubers to form protein, as well as the role of potassium in the process of protein synthesis Bansal and Trehan (2011).

Effect of foliar application of boron on protein content and yield of potato tubers

The quality parameters namely protein content and yield of potato tubers were significantly affected with boron as foliar application (Table 7).The potato tubers obtained from the plants treated

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Table 5: Effect of foliar application of boron and different sources of potassium on specific gravity, starch and dry matter percentage

Parameters	Tuber dry matter (%)				Specific gravity of tuber (g cm^{-3})				Starch (%)			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	19.84	20.22	20.29	**20.12**	1.044	1.051	1.060	**1.052**	15.93	16.08	16.27	**16.09**
Potassium nitrate	21.77	21.81	22.02	**21.87**	1.086	1.089	1.090	**1.089**	18.30	18.48	18.82	**18.53**
Potassium silcate	20.42	20.44	21.34	**20.73**	1.061	1.067	1.071	**1.066**	16.60	16.73	17.15	**16.83**
Potassium humate	21.98	22.16	23.15	**22.43**	1.075	1.082	1.086	**1.081**	17.50	17.75	18.10	**17.78**
Mono potassium phosphate	20.59	21.49	21.57	**21.22**	1.072	1.074	1.079	**1.075**	16.32	16.38	16.52	**16.41**
Mean	**20.92**	**21.22**	**21.67**		**1.068**	**1.073**	**1.077**		**16.93**	**17.09**	**17.37**	
LSD 5% (A)	2.95				0.015				0.86			
LSD 5% (B)	1.66				0.01				0.63			
LSD 5% AXB	ns				ns				ns			

Table 6: Effect of foliar application of boron and different sources of potassium on the content of carbohydrate %, reducing sugar content (%) and carbohydrate yield / fed.

Parameters	Total carbohydrate (%)				Total carbohydrate yield				Reducing sugars (%)			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	24.87	25.43	27.75	**26.02**	507.47	603.25	708.79	**606.50**	1.84	1.87	2.15	**1.95**
Potassium nitrate	29.90	35.23	37.80	**34.31**	853.08	1073.36	1391.49	**1105.98**	2.73	2.9	3.45	**3.03**
Potassium silcate	26.47	29.87	31.10	**29.14**	626.87	725.74	860.39	**737.67**	2.39	2.81	3.18	**2.79**
Potassium humate	29.87	32.60	34.57	**32.34**	834.79	958.14	1231.70	**1008.21**	2.61	3.51	3.23	**3.12**
Mono potassium phosphate	28.00	29.70	32.33	**30.01**	718.94	824.11	972.28	**838.44**	2.61	2.69	3.2	**2.83**
Mean	**27.82**	**30.57**	**32.71**		**708.23**	**836.92**	**1032.93**		**2.44**	**2.76**	**3.04**	
LSD 5% (A)	2.32				207.39				0.35			
LSD 5% (B)	1.7				102.47				0.15			
LSD 5% AXB	ns				ns				ns			

Table 7: Effect of foliar application of boron and different sources of potassium on protein content and yield of potato tubers

Parameters	Protein %				Tuber protein Yield (Kgfed^{-1})			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	12.40	12.65	12.88	**12.64**	252.97	299.95	328.85	**293.92**
Potassium nitrate	16.79	17.31	17.58	**17.23**	479.09	527.42	647.27	**551.26**
Potassium silcate	14.13	14.40	14.75	**14.42**	334.55	349.81	408.06	**364.14**
Potassium humate	15.52	16.02	16.65	**16.06**	433.82	470.86	593.14	**499.27**
Mono potassium phosphate	14.75	15.42	15.52	**15.23**	378.73	427.78	466.72	**424.41**
Mean	**14.72**	**15.16**	**15.48**		**375.83**	**415.16**	**488.81**	
LSD 5% (A)	0.72				98.49			
LSD 5% (B)	0.56				53.54			
LSD 5% AXB	ns				ns			

with foliar boron had higher quality attributes than those harvested from the plants treated with control. Tubers harvested from the plants treated with higher rate of Bexhibited significantly higher protein content and yield of potato tubers more than the potatoes harvested from control plots. According to Sathya (2009), boron improves photosynthetic activity, enhances activity of enzymes and plays a significant role in protein and nucleic acid metabolism. Foliar fertilization to potato with boron has significant impact on the amino acid content, especially increased methionine content in tuber (Kozera *et al.,* 2003). Boron exerts positive effect on improving frying quality of potato by reduction of reducing sugar and total phenol content (Lora Silva *et al.,* 2008).

Effect of interaction between potassium sources and boron on protein content and yield of potato tubers

Results in Table (7) revealed that the interaction effect between foliar application of potassium sources and boron were no significant on protein content and yield of potato tubers.

Effect of foliar application of potassium sources on Large, Medium and Small-Sized Tuber Yield (%)

Application of potassium sources significantly increased the yield of large and medium grade tubers and decrease proportionately small tubers (Table 8) and Fig (7).The weight of large size tuber increases with foliar spray of potassium humate or potassium silicate. Potassium application improved the tuber yield by increasing the large grade tuber yield and decreasing the small grade tuber yield. Interaction value shows that the maximum weight of medium size tubers % (35.37) were recorded with mono potassium phosphateat, while the minimum weight of medium size tuber % (24.85) was recorded with control treatment. Partricia and Bansal (1999) showed that foliar spray of potassium humate or potassium silicate decreased the yield of small grade tubers and increased the proportion of large marketable tubers. Increase in total yield and the yield of large tubers due to K large molecular weight substances with in storage fertilization may be due to the stimulating effect of potassium on photosynthesis, phloem loading and translocation as well as synthesis of organs contributing to the rapid bulking of the tubers (Singh, 1999).

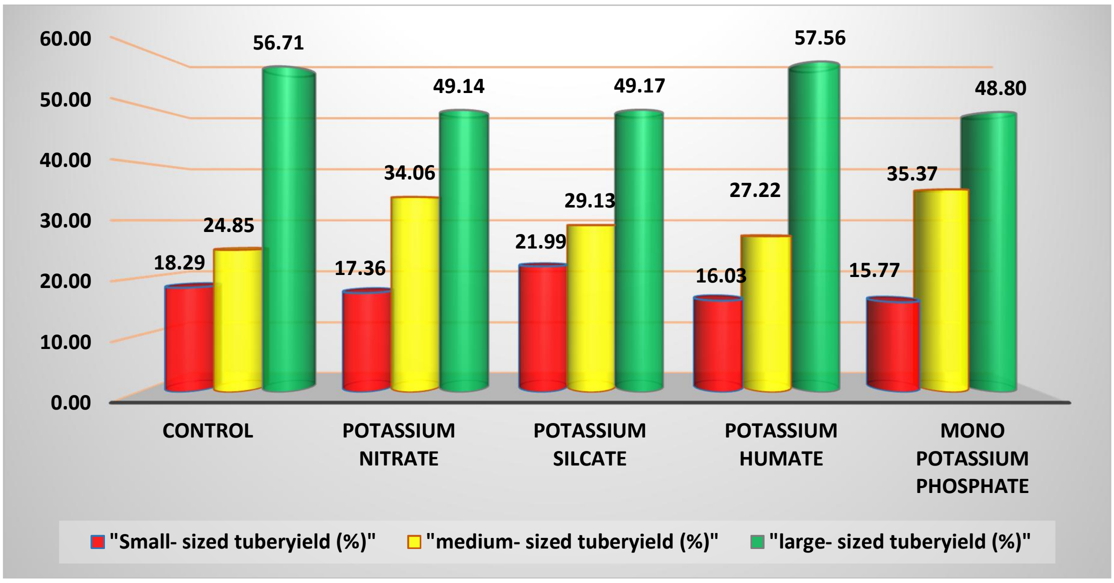

Fig. 7: Effect of foliar application ofdifferent sources of potassium onLarge, Medium and Small-Sized Tuber Yield (%)

Effect of foliar application of boron on Large, Medium and Small-Sized Tuber Yield (%)

Data in Table (8) showed that foliar application of boron was significantly affected on large, medium and small-sized tuber yield (%).Increase in tuber size was may be due to improved physiological activity like photosynthesis and translocation of food materials. Foliar application of boron helped in increasing the average weight of individual tuber thereby transferring the tubers from small to medium grade and medium to large grade.

Effect of interaction between Potassium sources and Boron on Large, Medium and Small-Sized Tuber Yield (%)

Data in Table (8) clearly showed that large, medium and small-sized tuber yield (%) was significantly affected by the interaction between foliar application of potassium sources and boron.

Effect of foliar application of different potassium sources and boron on total tuber yield (ton/fed) and marketable tuber yield (ton/fed) for potato tuber

Regarding the total yield and marketable tuber yield data in Table (9) and fig. (8) revealed that foliar application of potassium sources significantly increased the marketable potato tuber yield compared to control. The mean values of marketable yield per fed increased from 8.46, 9.06, 10.42.10.81 and10.82 ton/fed for control, Ksi, MPK, KN and KH respectively. In this concern, the highest total yield and marketable potato tuber yield were recorded when treated plants with boron at 100 ppm as foliar application while control treatment recorded the lowest marketable yield per fed. These increases may be ascribed to the role of foliar spray with potassium on increasing photosynthetic activity which accounts much for high translocation of photo assimilates from leaves to the tuber (Marschner, 1995).Boron increased the rate of photosynthesis by affecting photophosphorylation process into chloroplasts and shift the hormonal balance in leaves and tubers especially IAA which is important for tuber growth after the onset of tuberization (Puzina, 2004), Also, it has roles in cell elongation and nucleic acid synthesis.

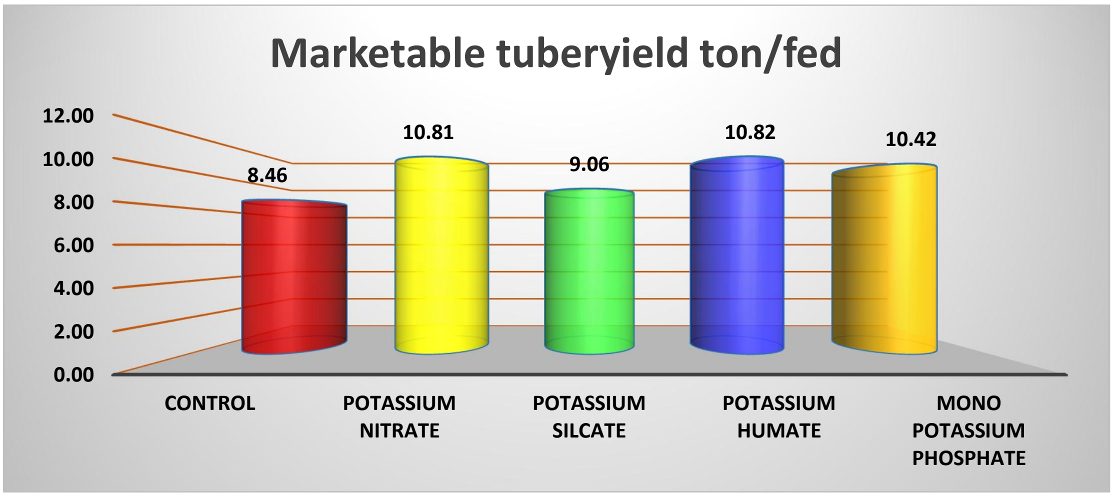

Fig. 8: Effect of foliar application of different potassium sources on marketable tuber yield (ton/fed) for potato tuber

Conclusion

Foliar spray with potassium nitrate, potassium silicate, potassium humate and mono potassium phosphate at the rate 1000 ppm led to increasing yield and enhancing some biochemical constituents of potato tuber compared to the control treatment. 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, tuber mineral composition and tuber quality. Spraying potato plants by potassium nitrate or potassium humate gave the highest values of the most of growth parameters, yield components and minerals concentration in potato plants. Spraying potato plants by boron at 100 ppm gave the highest values of the most of yield components and minerals uptake in potato plants.

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EISSN: 2706 -7947 ISSN: 2077- 4613 *DOI: 10.36632/mejas/2020.10.1.15*

Table 8: Effect of foliar application of boron and different sources of potassium on Large, Medium and Small-Sized Tuber Yield (%)

Parameters	Small- sized tuber yield (%)				Medium- sized tuber yield (%)				Large- sized tuber yield (%)			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	18.29	19.06	14.61	**17.32**	24.85	35.48	39.00	**33.11**	56.71	45.86	45.24	**49.27**
Potassium nitrate	17.36	13.25	20.65	**17.09**	34.06	38.84	39.48	**37.46**	49.14	48.05	40.16	**45.79**
Potassium silcate	21.99	11.76	13.38	**15.71**	29.13	36.67	22.65	**29.48**	49.17	52.40	64.10	**55.22**
Potassium humate	16.03	8.83	12.47	**12.44**	27.22	34.39	33.33	**31.65**	57.56	57.05	54.51	**56.37**
Mono potassium phosphate	15.77	12.57	13.39	**13.91**	35.37	26.76	32.84	**31.66**	48.80	60.49	53.74	**54.34**
Mean	**17.89**	**13.09**	**14.90**	**15.29**	**30.13**	**34.43**	**33.46**		**52.28**	**52.77**	**51.55**	
LSD 5% (A)	0.1				0.194				0.38			
LSD 5% (B)	0.15				0.13				0.32			
LSD 5% AXB	0.92				0.15				0.45			

Table 9: Effect of foliar application of different potassium sources and boron on total tuber yield (ton/fed) and marketable tuber yield ton/fed) for potato tuber

Parameters	Small--sized tuber yield ton/fed.				Medium-sized tuber yield ton/fed.				Large-sized tuber yield ton/fed.				Marketable tuber yield ton/fed.			
Source of potassium	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**	**B0**	**B50**	**B100**	**Mean**
Control	1.90	2.23	1.84	**1.99**	2.58	4.16	4.91	**3.88**	5.88	5.37	5.69	**5.65**	8.46	9.53	10.60	**9.53**
Potassium nitrate	2.26	1.86	3.46	**2.53**	4.42	5.45	6.62	**5.50**	6.38	6.74	6.74	**6.62**	10.81	12.19	13.36	**12.12**
Potassium silcate	2.54	1.40	1.73	**1.89**	3.37	4.37	2.93	**3.55**	5.69	6.24	8.28	**6.74**	9.06	10.61	11.21	**10.29**
Potassium humate	2.05	1.17	1.89	**1.70**	3.47	4.55	5.06	**4.36**	7.35	7.54	8.28	**7.72**	10.82	12.09	13.35	**12.08**
Mono potassium phosphate	1.95	1.63	1.87	**1.82**	4.38	3.47	4.58	**4.14**	6.04	7.84	7.50	**7.13**	10.42	11.30	12.08	**11.27**
Mean	**2.14**	**1.66**	**2.16**		**3.65**	**4.40**	**4.82**		**6.27**	**6.75**	**7.30**		**9.91**	**11.14**	**12.12**	
LSD 5% (A)	0.11				0.12				0.17				0.14			
LSD 5% (B)	0.072				0.12				0.16				0.27			
LSD 5% AXB	0.12				0.19				0.28				0.29			

References

Adiloglu, A. and S. Adiloglu, 2006. The effect of boron (B) application on the growth and nutrient contents of maize in zinc (Zn) deficient soils. Bulgarian J. of Agric. Sci., 12: 387-392.

Ankorion, J., 1998. MKP (Monopotassium Phosphate) for foliar fertilization. In: Proceedings of the Symposium on Foliar Fertilization: A Technique to Improve Production and Decrease Pollution, Cairo, Egypt, 10-14 December, Pp: 71-84

A.O.A.C. (Association of Official Analytical Chemist), 1990). "Official Method of Analysis". 15th ed. Association of Official Analytical Chemists, Washington. D. C., USA.

A.O.A.C., 1994. (Association of Official Analytical Chemist) Official Method of Analysis. 12th Ed. Washington, DC.

A.O.A.C., 1995. 'Official methods of Analysis'. Association of official analytical chemist. 16th edition, Washington DC.

Arslanoglu, F.S. Aytac and E.K. Oner, 2011. Morphological characterization of the local potato (*Solanum tuberosum* L.) genotypes collected from Eastern Black Sea region of Turkey. Department of Field Crops, Fac. of Agric., Ondokuz Mayıs University, Samsun, Turkey.

Bansali, S. and S. Trehan, 2011. Effect of potassium on yield and processing quality attributes of potato. Karnataka J. of Agric., 24(1): 48-54.

Barakat, M.A.S., A.S. Osman, W.M. Semida and M.A.H. Gyushi, 2015. Influence of potassium humate and ascorbic acid on growth, yield and chemical composition of common bean (*Phaseolus vulgaris* L.) grown under reclaimed soil conditions. Int. J. Acad. Res., 1: 192-199.

Bari, M.S., M.G. Rabbani, M.S.Q. Rahman, M.J. Islam and A.T.M.R Hoque. 2001. Effect of zinc, boron, sulphur and magnesium on the growth and yield of potato. Pakistan J. of Biological Sci., 4(9): 1090-1093.

Bednarz, C.W. and D.M. Oosterhuis, 1999. Physiological changes associated with potassium deficiency in cotton. J. Plant Nutr., 22: 303-313.

Berga L., W. Gebremedhin, J .Terrisa, T.T. Bereke and H. Yaynu , 1994. Potato improvement research. In: Edward, H., and Lemma, D (eds). Proceedings of the Second National Horticultural Workshop of Ethiopia held in Addis Ababa, Ethiopia.

Brown, P. H., N. Bellaloui, M. A. Wimmer, E. S. Bassil, J. Ruiz, H. Hu, H. Pfeffer, F. Dannel, and V. Romheld, 2002. Boron in plant biology. Plant Biology 4:205–23. Doi: 10.1055/s-2002-25740

Cakmak, I., 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. J. Plant Nutr. Soil Sci., 168: 521– 530.

Canada, A.L., 2002. "Fact Sheet No. 90": Boron as a Plant Nutrient. A & L Canada Laboratories, 2136 Jetstream Rd., London, ON N5V 3P5, 519-457-2575. (C.F. www.alcanada.com).

Chapman, H.D. and P.F. Pratt, 1982. Methods of Plant Analysis, I. Methods of Analysis for Soil, Plant and Water. Chapman Publishers, Riverside, California, USA.

Cottenie, A., M. Verloo, L. Kickens, G. Velghe and R. Camerlynck, 1982. Chemical analysis of plants and soils". Lab. Analytical and Agrochem; State Univ., Ghent- Belgium, P. 63.

Das, K.K., G.S. Swamy, D. Biswas and K.K. Chnaniya, 2017. Response of soil application of diatomaceous earth as a source of silicon on leaf nutrient status of guava. Int. J. Curr. Microbiol. App. Sci., 6(4): 1394-1399.

Dubois M., K.A. Gilles, J.K. Hamilton, P.A. Rebers and F. Smith, 1956. Colorimetric Method for Determination of Sugars and related Substances, Anal. Chem., 28, 350-356.

El-Dissoky, R.A. and A.E.S. Abdel Kadar, 2013. Effect of boron as a foliar application on some potatoes cultivars under Egyptian alluvial soil conditions. Res. J. Agri. Biol. Sci., 232–240.

El-Zohiri, S.S.M and H.E. Asfour , 2009.Effects of foliar sprays of potassium, magnesium and calcium on yield, quality and storage ability of potato. The Fifth Inter. Conf. of Suastain. Agric. Devlop. Fac. of Agric., Fayoum Univ., 21-23.

FAO. , 2008. International year of the Potato.www.potato2008.org

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Ed., John Wiley and Sons, New York, USA.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson, 2005. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7th Edition, Pearson Educational, Inc., Upper Saddle River, New Jersey.

Imas, P. and H. Magen, 2007. Management of potassium nutrition in balanced fertilization for soybean yield and quality – Global perspective. In: Proceedings of Regional Seminar on Recent Advances in Soybean-based cropping system. National Research Centre for Soybean, Indore. 28-29 September, 2007. Pp.1-20

Kabir, J.N. and B. Lemaga, 2003. Potato processing; Quality evaluation procedures for researchand food industry applications in East and Central Africa. Kenya Agricultural ResearchInstitute, Nairobi, Kenya.

Kirkman, M.A., 2007. Global markets for processed potato products. In: Vreugdenhil, D. (ed.) Potato biology and biotechnology advances and perspectives. Elsevier, Oxford, pp. 27–44.

Kozera, W., K. Nowak and W. Cwojdzinski, 2003. Effect of fertilization withs ome microelements on the content and quality of potato tuber protein. Acta Sci. Polonorum. Agricultura (Poland), 22, 73–82.

Kumar, P., S. Pandey, B. Singh, S. Singh, and D. Kumar, 2007. Influence of source and time of potassium application on potato growth, yield, economics and crisp quality. Pot. Res. 50(1): 1-13.

Lora Silva, R., A.P. LópezAlayón, R. Gómez and H. Bernal, 2008. Effect of doses of Fe, Cu, Mn, Zn, B and Mo on reduced and total sugars and on fried quality on creole potato(*Solanum phureja*) RevUDCAA ctualidad and Divulgation Scientific, 11,63–73

Lung'aho, C., B. Lemaga, M. Nyongesa, P. Gildermacher, P. Kinyale, P. Demo and J. Kabira, 2007. Commercial seed potato production in eastern and central Africa. Kenya Agricultural Institute. p.140.

Malik, N., 1995. Potatoes in Pakistan: A Hand Book. Islamabad: Pakistan Swiss Potato Development Project, Pakistan Agricultural Research Council.

Marschner, H., 1995. Mineral Nutrition of Higher Plants. 2nd Ed. Academic Press, Harcourt Brace and Company, Publishers. London, New York, Tokyo, pp 864

Mehdi, S. M., M. Sarfraz and M. Hafeez, 2007. Response of rice advance line PB-95 to potassium application in saline sodic soil. Pak. J. Biol. Sci., 10:2935-2939.

Meng, M.L., M.F., Yic, Y.Jun and Y.Z. Lin, 2004 .Research Progress on cultivation Physiology of potato in China 5th world Potato Congress, August, pp. 16

Mengel, K. and E.A. Kirkby, 1978. "Principles of Plant Nutrition", International Potash Institute, Bern, Switzerland.

Mengel, K. and E. Kirkby, 1987. Principles of plant nutrition, 4th ed. International Potash Institute. Bern.

Nardi, S., D. Pizzeghello, A. Muscolo and A. Vianello, 2002. Physiological effects of humic substances in plant growth. Soil Biol. Biochem., 34: 1527-1536.

Page, A.I., R.H. Miller and D. R. Keency, 1982. Methods of Soil Analysis part II. Chemical and Microbiological Methods. 2nd Ed. Am. Soc. Agron., Madison, Wisconsin U.S.A.

Partricia I. and S. K. Bansal, 1999. Potassium and integrated nutrient management in potato. Global Conference on Potato, 6-11 December, New Delhi, India.

Pilon, C., R.P. Soratto, F. Broetto and A.M. Fernandes, 2014. Foliar or soil applications of silicon alleviate water-deficit stress of potato plants. Crop Ecology & Physiology, 106(6): 2325- 2334.

Prakash, P., P. RajaKumari, V. Aishwarya, A.P.V. Thanuja Polani and A. Thirumurugan, 2012. The influence of potassium humate on Stevia rebaudiana. Int. J. Agric. Food Sci., 2: 30-31.

Puzina, T.I., 2004. Effect of zinc sulphate and boric acid on the hormonal status of potato plants in relation to tuberization. Russian J. Plant Philip, 51(2): 209-215.

Ryan, J., S. Garabet, K. Harmsen and A. Rashid, 1996. Soil and Plant Analysis. Manual Adapted for the west Asia and North Africa Region. ICARDA, Aleppo, Syria. 140pp.

Selim, E. M., A. S. El-Neklawy and S. M. El-Ashry, 2009. Beneficial effects of humic substances fertigation on soil fertility to potato grown on sandy soil. Aust. J. Basic and Appl. Sci. (4):4351-4358.

Salami, M. and S. Sadat, 2013. Study of potassium and nitrogen fertilizer levels on the yield of sugar beet injolge cultivar. J. of Novel Applied Sciences, 2(4): 94–100

Sarkar, R. K. and P. K. Pal, 2006. Effect of pre- sowing seed treatment and foliar spray nitrate salts on growth and yield of green gram (*Vigna radiata*). Indian Journal of Agricultural Sciences, 76 (1): 62-65

Sangakkara, U.R., M. Frehner and J. Nosberger, 2000. Effect of soil moisture and potassium fertilizer on shoot water potential, photosynthesis and partitioning of carbon in mungbean and cowpea. J. Agron. Crop Sci., 185: 201-207.

Sathya, S., G.J. Pitchai and R. Indirani , 2009. Boron nutrition of crops in relation to yield and quality– a review Agric. Reviews, 30,139-144.

Singh, J.P., 1999. Potassium fertilization of potatoes in north India. In: Proceedings of IPI Workshop on Essential Role of potatoes in Diverse Cropping Systems, held at the 16th World Congress of Soil Science, Montpellier, France, 20-29 August. Intl. Potash Inst. Basel, Switzerland. Pp.123-127.

Singh, J. and S.K. Bansal, 2000. Relative effect of two sources of potassium on yield and economics of potato production in an Inceptisol of western UP. Journal of Potassium Research, 16: 52-54.

Singh, S., D. Kumar, B. S. Chandel and V. Singh, 2014. Effect of balanced fertilization on yield, nutrients uptake and economics of potato in alluvial soil. Indian J. Agron, 59, 451–454

Tanaka, M. and T. Fujiwara, 2008. Physiological roles and transport mechanism of boron: perspective from plants. Euro. J. of Physi., 456: 671- 677.

Tariq, M. and C.J.B. Mott, 2007. The significance of boron in plant nutrition and environment-a review. J. Agron., 6(1): 1-10.

Teich, A., and J. Menzies, 1964. NPK on specific gravity, ascorbic acid and chipping quality of potato tubers. American Potato J., 41, 169-173.

Thompson, B., 2010. Efficient fertilizer Use-Potassium (1st edition Ed.). New York: John Willy and sons.

Umar, S. and S.K. Bansal, 1995. Potassium requirement of mustard (*Brassica juncea* L.) under moisture stress conditions. Plant Physiol & Biochem, New Delhi, 22(2):130-135.

Wang, M., Q. Zheng, Q. Shen and S. Guo, 2013. The critical role of potassium in plant stress response. International journal of molecular sciences, 14(4):7370–7390.

Weng, X.Y., C.J. Zheng, H.X. Xu and J.Y. Sun., 2007. Characteristics of photosynthesis and functions of the water-water cycle in rice (*Oryza sativa* L.) leaves in response to potassium deficiency. Physiol. Plant. 131:614–621.

Wolf, B., 1971. The determination of boron in soil extracts, plant materials, composts, manures, waters and nutrient solutions. Comm. Soil Sci. and Plant Anal., 2: 363.

Yang, C.M., M.H. Wang, Y.F. Lu, I.F. Chang and C.H. Chou, 2004. Humic substances affect the activity of chlorophyllase. J. Chem. Ecol., 30: 1057-1065.

Zekri, M. and T.A. Obreza, 2009. Plant nutrients for citrus trees. SL, 200, UF\IFAS Extension Service, Institute of Food and Agricultural Sciences, University of Florida.