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Impact of Foliar Spraying of some Potassium Sources and Boron Levels on Sugar Beet Quantity and Quality

Ibrahim, M. E. M.[1]; Riham M. N. Faiyad[2*] and I. S. H. El-Gamal[1]

[1]Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt.
[2]Soil Fertility and Plant Nutrition Research Department; Soils, Water and Environment Research Institute; Agricultural Research Center, Giza, Egypt.

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ABSTRACT

Two field experiments were conducted during the two successive winter seasons of 2017/2018 and 2018/2019 at Tag Al-Ezz Agricultural Research Station, Agricultural Research Center, Dakahlia Governorate, Egypt to study the effect of foliar spraying of some potassium sources *i.e.* potassium silicate at 4ml L^{-1}, potassium humate at 4ml L^{-1} and a mixture of them as main plots and foliar spraying with four levels of boron (0.0, 100, 150 and 200 mgL^{-1}) as sub plots as well as their interactions on nutrients concentrations, yield components, quality characters and yield of sugar beet (*Beta valgaris* var. *saccharifera* L. Faten variety). The experimental design was split-plot design system. Spraying sugar beet plants with a mixture of K-Silicate and K-Humate produced the highest values of all studied parameters *i.e.* NPK concentrations, yield components, quality characteristics and yields followed by spraying with K- Humate, then spraying with K- Silicate and control in a descending order, with exception juice purity that had inverse trend in both seasons. Spraying sugar beet plants with a solution of boron at a rate of 100 mgL^{-1} was more effective than other studied boron levels in increasing nutrients concentrations, yield components, quality characters and yields and gave the highest values of them during both seasons. It can be concluded that maximum sugar beet nutrients concentrations, yield components, quality characters and yields were significantly affected by the interactions between the foliar spraying of K-Silicate+K-Humate mixture and boron at a rate of 100 mgL^{-1} under the environmental conditions of Dakahlia Governorate, Egypt.

Keywords: Sugar beet, Potassium silicate, Potassium humate, Boron, Foliar spraying.

INTRODUCTION

Sugar beet (*Beta valgaris*, L.) is one of the main sugar crops in Egypt as well as many countries all over the world besides sugar cane (*Sacchurum officinarum* L.). The importance of sugar beet to agriculture is not only confined to sugar production but also, used to produce many products. Recently, the sugar beet crop has an important position in Egyptian crop rotation as a winter crop not only in the fertile soils but also in poor, saline, alkaline and calcareous soils. Thus, in Egypt, sugar beet has become an important crop for sugar production, hence the total cultivated area in the 2018 season reached about 521427 feddan and the total production exceeded 11.223 million ton roots with an average of 21.523 ton fed^{-1} (FAO, 2020).

Potassium is a major plant nutrient and plays an essential role in a variety of physiological processes *i.e.* photosynthesis, protein synthesis, control of ionic balance, regulation of plant stomata and water use, enzyme activation and osmoregulation (Mengel, 2007 and Marschner, 2012). Also, potassium enhances the ability of plants to counterattack stress such as diseases, pests, cold and drought. Potassium performs these roles in all crops and in sugar beet, therefore it is considered an important plant nutrient to sustain high productivity and quality, with equilibrium with other essential plant nutrients (Yu-ying and Hong, 1997). Also, it influences synthesis, transformation, and storage of carbohydrates as well as potato tuber quality (Ebert, 2009 and Dkhil *et al.*, 2011). Thus, application of suitable potassium fertilizer source may increase the production of sugar beet (Abdel-Mawly and Zanouny, 2004).

Among all the micronutrients assimilated by plants, silicon (Si) alone is consistently present at concentrations similar to those of the macronutrients (Epstein, 1999). One of the most important facts is that silicon in the soil helps plants survive in the conditions of water shortage, decreasing transpiration in cells, reduces micronutrient and metal toxicity, as well as resistance against pathogens *i.e.* fungi or herbivorous insects (Reynolds *et al.*, 2009). Silicon is reported that reduces multiple stresses including biotic and abiotic stresses in plants by maintaining plant water potential, photosynthetic activity, stomata conductance, and leaf erectness under high transpiration rates (Shaaban and Abou El- Nour, 2014 and Das *et al.*, 2017). Many studies have suggested the positive growth effects of silicon, including increasing dry weight and yield and most commonly increasing disease resistance (Rodrigues *et al.*, 2004). Potassium silicate is a source of highly soluble potassium and silicon so it is used in agricultural production systems primarily as a silicon amendment source and has utilized of supplying small amounts of potassium help to improve the quality of yield (Tarabih *et al.*, 2014). Potassium silicate contains no volatile organic compounds and applications will not result in the release of any hazardous or environmentally

*** Corresponding author.**
E-mail address: reham.nageb@yahoo.com
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persistent by products (Blumberg, 2001). Ibrahim, Hoda *et al.* (2015) showed that application of potassium silicate had a positive effect on seed yield and quality of Egyptian clover as well as soil pH.

Potassium humate is a product that contains many elements necessary for the development of a plant (Abdel-Razzak and EI-Sharkawy, 2013 and Faiyad, Riham *et al.* 2019). Foliar application of Humic substances is increasingly used in agricultural practice, the mechanism of possible growth-promoting effect, usually attributed to hormone-like impact, activation of photosynthesis, accelerate cell division, increase the permeability of plant cell membranes, improve nutrient uptake, reduce the uptake of toxic elements and improve the plant response to salinity (Verlinden *et al.*, 2009). Also, potassium humate can be used as a non-expensive source for potassium and it could be used as a soil dressing, drenching, or foliar application. In addition, Humic acid (HA) is one of the major components of humus. In addition, potassium humate application led to improving plant growth parameters, yield, and quality of sweet pepper plant (El - Bassiony *et al.,* 2010).

Boron (B) is necessary for plant growth. It plays an important role in cell wall synthesis, cell division, cell development, auxin and indole acetic acid (IAA) metabolism, hormones development, synthesis of amino acids and proteins, regulation of carbohydrate metabolism, sugar transport, RNA metabolism and respiration. Boron is also probably more important than any other micronutrient in obtaining high quality and crop yields (Marschner, 1995 and BARI, 2006). Although, boron is a trace element, sugar beet has a higher requirement for boron more than other many crops. Where, an adequate boron supply severely increased yield and quality of roots. Moreover, boron is essential for the formation of new cells in meristems and translocation of sugar to roots (Loomis and Durst, 1992). Foliar spraying sugar beet plants with boron at a suitable rate depended on soil pH and boron content, significantly increased root length, root diameter, sucrose and juice purity percentages, root, top and sugar yields, however, Na, K, α-amino N, harvest index and loss sugar yield were decreased. Seeing as roots absorbed boric acid and the role of boron in chloroplast formation, sink limitations and changes in the cell wall, which lead to secondary effects in plant metabolism, development, growth and yield with good quality (Armin and Asgharipour, 2012; Abd El-Azez, 2014; El-Sheref, Amina, 2014; Abo-Steet, Seham *et al.*, 2015; Abdel-Nasser and Ben-Abdalla, 2019 and Kandil *et al.*, 2020).

Therefore, the aim of this research intended to study the effect of foliar spraying with different potassium sources and boron levels and their interactions on improving growth, chemical constituents, yield components, quantity and quality of sugar beet plants as a strategic crop in Egypt.

MATERIALS AND METHODS

Two field experiments were carried out at Tag Al-Ezz, Agricultural Research Station, Agricultural Research Center, Dakahlia Governorate, Egypt (31°31' 47.64" N latitude and 30°56' 12.88" E longitude), during 2017/2018 and 2018/2019 successive winter seasons to study the impact of foliar spraying of some potassium sources and boron levels on sugar beet (*Beta vulgaris* L.) Faten variety chemical constituents, yield components, quality and yield.

The experimental design was a split plot design with three replicates for each treatment. Therefore, this study including 48 experimental plots. The main plots were included four potassium fertilizer sources as foliar application: 1- Without spraying (control treatment). 2- Spraying with potassium silicate solution (K- Silicate) at a rate of 4 ml L^{-1}. 3- Spraying with potassium humate solution (K- Humate) at a rate of 4 ml L^{-1}. 4. Spraying with a mixture of K- Silicate+ K- Humate at the same previous rates for each. The sub plots were assigned to four levels of boron foliar spraying (0.0, 100, 150 and 200 mg B L^{-1}) in the form of boric acid. The chemical composition of potassium silicate is 10 % K_2O and 25 % SiO_2. The used potassium humate "KH" was purchased from the agricultural commercial market. The chemical composition of potassium humate is 0.45% N, 1.1 % P_2O_5, 10 % K_2O and pH 8.5. The foliar solution volume was 300 L fed^{-1} and spraying was done by hand sprayer (for experimental plots) until saturation point twice i.e. at 60 and 90 days after sowing (DAS) for potassium fertilizer sources and at 90 and 110 days after sawing for boron foliar application.

Each experimental basic unit included 5 ridges, each of 60 cm apart and 4 m long, comprising an area of 12 m^2 (1/350 fed). The preceding summer crop was rice (*Oryza sativa* L.) in both seasons.

For the two seasons, soils were clay in texture. Their physical and chemical analyses were estimated according to the standard methods of Page *et al*., 1982 and Klute, 1986 and the corresponding data are presented in Table 1.

Table 1. Physical and chemical properties of the soils under investigation during 2017/2018 and 2018/2019 seasons.

Physical properties									
Properties Seasons	**Coarse sand (%)**	**Fine sand (%)**	**Silt (%)**	**Clay (%)**	**Soil texture**	**$CaCO_3$ (%)**	**Water table (cm)**	**Field capacity (%)**	**Real density (g/cm^3)**
1st season	3.5	13.8	35.8	46.9	Clay	4.66	97	40.6	2.67
2nd season	4.2	14.9	34.4	46.5	Clay	4.74	100	39.9	2.65

Chemical properties						
Properties Seasons	pH*	EC** dS m^{-1}	Organic matter (%)	Available nutrients (mg kg^{-1}) N	P	K
1st season	7.8	4.2	1.77	44.4	8.1	232
2nd season	7.9	4.1	1.86	46.3	8.9	223

*** Soil pH was determined in soil suspension (1: 2.5).**
**** Soil Electrical Conductivity (EC) was determined in saturated soil paste extract.**

The experimental field well prepared by two ploughing, leveling, compaction, division and then divided to the experimental units. Mono calcium phosphate (15.5 % P_2O_5) was applied during soil preparation at the level of 150 kg fed^{-1}. Sugar beet balls (3-4 balls/hill) were hand sown using dry sowing method on one side of the ridge in hills 20 cm apart on the 22nd and 23rd of October for the first and second seasons, respectively. The plots were irrigated immediately after sowing. Sugar beet plants were thinned twice to one plant/hill (35000 plants fed^{-1}) at the age of 30 and 45 days from sowing. Nitrogen fertilizer in the form of urea (46.5% N) at a level of 80 kg N fed^{-1} was applied in two equal doses, the first, after thinning and before the second irrigation however, the second one was applied before the third irrigation. Potassium fertilizer in the form of potassium sulphate (48 % K_2O) at a rate of 50 kg fed^{-1} was applied before the second irrigation as a soil application. All other recommended agricultural practices for growing sugar beet were followed according to the recommendations of Sugar Crops Research Institute, Agricultural Research Center.

Studied characters:

For the two seasons, at 120 days of sowing, plant samples were successively taken randomly from three replicates of every treatment to determine N, P and K percentages in foliage according to Jones *et al.* (1991).

At harvest (190 DAS), five plants were randomly chosen from the outer ridges of each plot to determine the following characters:

1. Foliage fresh weight (g plant^{-1}).
2. Foliage dry weight (g plant^{-1}).
3. Root fresh weight (g plant^{-1}).
4. Root dry weight (g plant^{-1}).
5. Root length (cm).
6. Root diameter (cm).

Root quality characters were determined in Dakahlia Sugar Company Laboratories at Bilkas District, Dakahlia Governorate. All studied quality parameters were as follows:

1. Sodium (Na %) in sugar beet roots was determined according to Peters *et al.* (2003).
2. Alfa amino nitrogen (α- amino-N %) in sugar beet roots was determined by the fluorometric OPA-method (Burba and Georgi, 1976).
3. Impurity (%) in sugar beet roots was determined according to Carruthers and Oldfield, (1962).

Impurity (%) = K + Na + α-amino N

4. Total soluble solids (TSS %) in roots were measured in juice of fresh roots by using Hand Refractometer.
5. Sugar content (%) was determined Polarimetrically on a lead acetate extract of fresh macerated roots according to the method of Carruthers and Oldfield (1961).
6. Juice purity (%) of sugar beet root is the ratio of sugar to total soluble solids as described by Andersen and Smed (1963).
7. Extractable white sugar (%). Correct sugar content (white sugar) of beet roots was calculated by linking the beet non-sugar, K, Na and α-amino nitrogen (meq 100g^{-1} of beet) according to Harvey and Dutton (1993) using the following equation:

Extractable white sugar (%) = Sugar content (%)- [0.343(K+ Na) +0.094 α-AmN+0.29]

At harvest, plants produced from the two inner ridges of each plot were collected and cleaned. Roots and tops were separated and weighted in kg, then converted to estimate:

1- Root yield (ton fed^{-1}).
2- Top yield (ton fed^{-1}).
3- Extracted sugar yield (ton fed^{-1}) was calculated by multiplying root yield (ton fed^{-1}) by extracted white sugar percentage.
4- Roots N, P and K % were determined according to Jones *et al*. (1991). Also, boron (B mg kg^{-1}) was determined as described by Wolf (1971).

Statistical analysis:

All obtained data were statistically analyzed according to Gomez and Gomez (1984). Least significant difference (LSD) method was used to test the differences among means of treatments at 5 % level of probability as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Results

Foliage chemical content at 120 days after sowing:

Data in Table 2 revealed that foliar spraying of potassium sources *i.e.* potassium silicate (K- silicate), potassium humate (K- humate) and their mixture, boron at levels of 100, 150 and 200 mg L^{-1} as well as their interactions gave significant effects on foliage NPK percentages as compared with control treatment in the two seasons.

It is clear that foliar spraying of sugar beet plants with the mixture of K- silicate + K- humate produced the highest values of N, P and K percentages followed by K- humate, K- silicate and control in a descending order.

Regarding the individual influence of boron levels (0, 100, 150 and 200 mg L^{-1}), it can be observed that foliar spraying of sugar beet plants with boron at a rate of 100 mg L^{-1} was more effective than the other studied boron levels (0, 150 and 200 mg L^{-1}) in increasing NPK percentages and gave the highest values of them during both seasons. Foliar spraying sugar beet plants with boron at the rate of 150 mg L^{-1} came in the second- order followed by plants untreated (without B) and lately spraying sugar beet plants with boron at a rate of 200 mg L^{-1}.

Concerning the interaction effect between the treatments under investigation, it could be noticed that the values of NPK percentages were significantly affected by the application of K and B simultaneously. In this respect, spraying sugar beet plants with the mixture of K- silicate + K- humate and with boron at a rate of 100 mg L^{-1} gave the highest values of foliage NPK concentrations at 120 days after sowing. The second best interaction treatment was spraying with the K- silicate +K- humate and boron at a rate of 150 mg L^{-1}. On the other hand, the lowest values of NPK concentrations (%) were realized with plants unsprayed with K and sprayed with B at a rate of 200 mg L^{-1}. This trend was found in both seasons.

Table 2. Nitrogen (N), phosphorus (P) and potassium (K) (%) in sugar beet foliage at 120 days after sowing as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		N (%)		P (%)		K (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:							
Without (control)		1.542	1.556	0.210	0.212	2.424	2.446
K- Silicate		2.240	2.261	0.278	0.280	3.578	3.613
K- Humate		2.360	2.383	0.287	0.290	3.764	3.800
K- Silicate +K- Humate		2.794	2.821	0.322	0.325	4.372	4.416
LSD at 5%		0.018	0.019	0.002	0.004	0.029	0.037
B- Boron levels:							
0 mg L^{-1}		2.197	2.217	0.271	0.274	3.481	3.514
100 mg L^{-1}		2.573	2.599	0.302	0.305	4.035	4.074
150 mg L^{-1}		2.386	2.408	0.286	0.289	3.773	3.810
200 mg L^{-1}		1.781	1.797	0.238	0.240	2.849	2.876
LSD at 5%		0.019	0.025	0.002	0.002	0.019	0.025
C- Interactions:							
Without	0 mg L^{-1}	1.493	1.506	0.205	0.207	2.337	2.357
	100 mg L^{-1}	1.703	1.719	0.226	0.228	2.713	2.739
	150 mg L^{-1}	1.587	1.601	0.215	0.217	2.537	2.560
	200 mg L^{-1}	1.387	1.399	0.195	0.197	2.110	2.129
K- Silicate	0 mg L^{-1}	2.140	2.160	0.271	0.274	3.430	3.464
	100 mg L^{-1}	2.640	2.664	0.311	0.314	4.150	4.190
	150 mg L^{-1}	2.367	2.389	0.287	0.290	3.817	3.853
	200 mg L^{-1}	1.813	1.830	0.242	0.244	2.917	2.943
K- Humate	0 mg L^{-1}	2.237	2.257	0.277	0.280	3.603	3.639
	100 mg L^{-1}	2.773	2.803	0.321	0.324	4.363	4.406
	150 mg L^{-1}	2.520	2.544	0.299	0.302	3.977	4.014
	200 mg L^{-1}	1.910	1.928	0.251	0.254	3.113	3.143
K- Silicate + K- Humate	0 mg L^{-1}	2.917	2.944	0.331	0.334	4.553	4.598
	100 mg L^{-1}	3.177	3.208	0.351	0.354	4.913	4.962
	150 mg L^{-1}	3.070	3.100	0.342	0.345	4.763	4.814
	200 mg L^{-1}	2.013	2.032	0.263	0.266	3.257	3.288
LSD at 5%		0.039	0.051	0.006	0.006	0.047	0.054

Yield components:

Data presented in Tables 3, 4 and 5 indicated the effect of foliar applications of potassium sources (K- silicate, K- humate and the mixture of them) and foliar application of boron levels (0, 100, 150 and 200 mg L^{-1}) as well as their interactions on yield components characters[*i.e.* the fresh and dry weights of foliage and root (g $plant^{-1}$), root length (cm), root diameter (cm)] and yield characters[*i.e.* root yield, top yield and extracted sugar yield (ton fed^{-1})] of sugar beet as compared to untreated plants in both seasons.

Table 3. Foliage fresh and dry weights (g $plant^{-1}$) of sugar beet as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		Foliage weight (g $plant^{-1}$)			
		Fresh		Dry	
		1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:					
Without (control)		386.2	390.6	37.77	38.22
K- Silicate		440.1	445.6	44.15	44.74
K- Humate		484.3	488.4	47.71	48.17
K- Silicate + K- Humate		563.2	571.6	55.71	56.51
LSD at 5%		60.8	68.5	4.70	5.02
B- Boron levels:					
0 mg L^{-1}		437.5	443.5	43.16	43.75
100 mg L^{-1}		539.1	545.5	53.38	54.03
150 mg L^{-1}		487.8	493.3	48.57	49.16
200 mg L^{-1}		409.5	414.0	40.22	40.70
LSD at 5%		22.6	21.5	1.32	1.39
C- Interactions:					
Without	0 mg L^{-1}	362.5	367.0	35.75	36.13
	100 mg L^{-1}	440.0	442.6	43.60	43.90
	150 mg L^{-1}	397.5	403.8	39.65	40.40
	200 mg L^{-1}	345.0	349.2	32.10	32.45
K- Silicate	0 mg L^{-1}	405.0	410.1	41.45	41.95
	100 mg L^{-1}	498.5	504.1	49.90	50.53
	150 mg L^{-1}	469.5	474.8	46.90	47.50
	200 mg L^{-1}	387.5	393.5	38.35	38.99
K- Humate	0 mg L^{-1}	452.5	455.1	45.00	45.35
	100 mg L^{-1}	535.0	541.1	51.70	52.33
	150 mg L^{-1}	507.0	511.8	49.95	50.43
	200 mg L^{-1}	443.0	445.7	44.20	44.57
K- Silicate + K- Humate	0 mg L^{-1}	530.0	541.8	50.45	51.55
	100 mg L^{-1}	683.0	694.1	68.35	69.37
	150 mg L^{-1}	577.5	583.0	57.80	58.30
	200 mg L^{-1}	462.5	467.6	46.25	46.81
LSD at 5%		NS	NS	NS	NS

Table 4. Root fresh and dry weights (g plant^{-1}), root length and diameter (cm) of sugar beet as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		Root weight (g plant^{-1}) Fresh		Root weight (g plant^{-1}) Dry		Root length (cm)		Root diameter (cm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:									
Without (control)		1206.8	1217.7	257.8	260.3	29.00	29.37	10.86	10.95
K- Silicate		1369.3	1386.0	286.5	290.0	31.87	32.20	11.67	11.78
K- Humate		1418.1	1429.1	296.2	298.3	33.87	34.19	12.03	12.14
K- Silicate +K- Humate		1522.5	1540.1	321.3	325.1	36.75	37.17	12.88	13.01
LSD at 5%		127.3	133.1	30.6	32.2	2.06	2.00	0.22	0.24
B- Boron levels:									
0 mg L^{-1}		1324.3	1338.2	276.1	279.0	31.37	31.65	11.46	11.55
100 mg L^{-1}		1516.2	1530.3	324.3	327.4	38.25	38.64	12.86	12.97
150 mg L^{-1}		1435.0	1450.6	303.4	306.7	34.25	34.63	12.27	12.42
200 mg L^{-1}		1241.2	1253.8	257.9	260.5	27.62	28.01	10.86	10.95
LSD at 5%		36.0	39.6	7.1	6.8	2.65	2.53	0.95	1.03
C- Interactions:									
Without	0 mg L^{-1}	1147.5	1156.0	241.9	243.9	28.50	28.77	10.50	10.56
	100 mg L^{-1}	1337.5	1347.7	296.0	298.8	33.50	33.96	11.80	11.90
	150 mg L^{-1}	1285.0	1293.8	271.2	273.3	30.00	30.44	11.45	11.62
	200 mg L^{-1}	1057.5	1073.4	222.0	225.2	24.00	24.34	9.70	9.74
K- Silicate	0 mg L^{-1}	1322.5	1334.7	269.7	272.5	30.50	30.73	11.35	11.45
	100 mg L^{-1}	1487.5	1504.2	317.1	320.5	36.50	36.94	12.30	12.44
	150 mg L^{-1}	1390.0	1417.2	295.5	301.2	33.50	33.77	12.05	12.16
	200 mg L^{-1}	1277.5	1288.0	263.7	266.0	27.00	27.37	11.00	11.08
K- Humate	0 mg L^{-1}	1327.5	1342.6	273.0	275.2	32.00	32.37	11.60	11.70
	100 mg L^{-1}	1550.0	1561.8	327.9	330.3	39.50	39.78	13.00	13.09
	150 mg L^{-1}	1485.0	1497.5	314.3	316.7	35.00	35.21	12.25	12.39
	200 mg L^{-1}	1310.0	1314.7	269.7	271.0	29.00	29.39	11.30	11.40
K- Silicate + K- Humate	0 mg L^{-1}	1500.0	1519.5	320.1	324.4	34.50	34.73	12.40	12.49
	100 mg L^{-1}	1690.0	1707.7	356.3	360.1	43.50	43.87	14.35	14.46
	150 mg L^{-1}	1580.0	1593.9	332.7	335.8	38.50	39.10	13.35	13.50
	200 mg L^{-1}	1320.0	1339.2	276.1	279.9	30.50	30.97	11.45	11.57
LSD at 5%		204.2	206.3	32.2	35.7	4.00	4.10	1.01	1.05

Table 5. Root, top and extracted sugar yields of sugar beet (ton fed^{-1}) as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		Yield (ton fed^{-1}) Root		Top		Extracted sugar	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:							
Without (control)		25.428	25.673	10.694	10.804	3.795	3.830
K- Silicate		26.135	26.419	11.273	11.406	3.951	3.993
K- Humate		27.229	27.514	11.765	11.917	4.185	4.227
K- Silicate +K- Humate		27.998	28.271	12.047	12.161	4.365	4.407
LSD at 5%		0.622	0.649	0.744	0.695	0.109	0.112
B- Boron levels:							
0 mg L^{-1}		26.083	26.373	11.267	11.429	3.944	3.981
100 mg L^{-1}		28.473	28.787	11.856	11.996	4.240	4.287
150 mg L^{-1}		27.478	27.736	11.578	11.689	4.237	4.273
200 mg L^{-1}		24.755	24.981	11.078	11.173	3.875	3.917
LSD at 5%		1.169	1.133	NS	NS	0.184	0.183
C- Interactions:							
Without	0 mg L^{-1}	25.237	25.509	10.650	10.805	3.767	3.801
	100 mg L^{-1}	26.547	26.825	10.980	11.113	3.867	3.904
	150 mg L^{-1}	25.997	26.239	10.820	10.909	3.880	3.914
	200 mg L^{-1}	23.930	24.120	10.327	10.389	3.665	3.700
K- Silicate	0 mg L^{-1}	25.687	25.984	11.130	11.296	3.849	3.886
	100 mg L^{-1}	27.677	27.984	11.607	11.748	4.048	4.088
	150 mg L^{-1}	26.847	27.151	11.337	11.461	4.121	4.165
	200 mg L^{-1}	24.330	24.555	11.020	11.118	3.786	3.835
K- Humate	0 mg L^{-1}	26.400	26.735	11.480	11.690	4.025	4.067
	100 mg L^{-1}	29.411	29.715	12.297	12.427	4.401	4.451
	150 mg L^{-1}	28.037	28.260	11.917	12.031	4.382	4.411
	200 mg L^{-1}	25.070	25.347	11.367	11.518	3.930	3.980
K- Silicate + K- Humate	0 mg L^{-1}	27.010	27.265	11.810	11.924	4.135	4.172
	100 mg L^{-1}	30.260	30.625	12.540	12.697	4.632	4.688
	150 mg L^{-1}	29.030	29.293	12.237	12.356	4.576	4.618
	200 mg L^{-1}	25.690	25.902	11.600	11.668	4.119	4.152
LSD at 5%		1.260	1.294	NS	NS	0.261	0.270

For both seasons, foliar application of K- silicate + K-humate gave the highest values of all above-mentioned traits. While the lowest values were recorded with the plants untreated with K (control treatment).

Also, data in Tables 3, 4 and 5 revealed that the foliar spraying sugar beet plants with boron at a rate of 100 mgL^{-1} produced the highest values of the foliage and root fresh and dry weights; root length; root diameter; root, top and extracted sugar yields in both seasons. At the same time the lowest values of all above-mentioned traits were observed with the addition of boron at a level of 200 mg L^{-1}. Data also indicated that the boron treatments had significant effects on all above-mentioned traits except top yield (ton fed^{-1}) values which were non-significant in both seasons.

Most studied parameters were also significantly affected by the interaction between foliar application of potassium sources and boron levels together. The highest values were recorded with K- silicate + K- humate mixture and spraying sugar beet plants with boron at a level of 100 mg L^{-1} while the lowest values of these characters were realized with plants unsprayed with K and sprayed with 200 mg L^{-1} B.

Juice quality and chemical constituents at maturity stage:

In Egypt, sugar beet quality and yield are essential issues for farmer's income. Recently, the major purpose to cultivate sugar beet plant is the production of a maximum amount of sugar. The sucrose percentage in sugar beet is the main factor affecting the sugar yield. The mentioned parameters could be considered as major factors affecting on quality of sugar beet root. Statistical analysis of the data presented in Tables 6, 7and 8 indicated the values of root quality characters [*i.e.* N, P, K, Na, B, α-amino N, impurity, TSS, sucrose, juice purity and extractable white sugar] of sugar beet plant as affected by the foliar spraying of different potassium sources and boron levels as well as their interactions at harvest during the seasons of 2017/ 2018 and 2018/ 2019.

It is quite obvious from the data presented in Tables 6, 7 and 8 that foliar application of potassium sources significantly affected all aforementioned traits in both seasons. Data in the same tables illustrated that, the highest values of all above-mentioned traits, except juice purity (%), were realized when sugar beet plants sprayed with the mixture of K- silicate + K-humate, while the control treatment gave the lowest values. On the contrary, spraying sugar beet plants with K- silicate + K-humate significantly reduced juice purity % (Table 8) as compared with the untreated plants.

Regarding the individual effect of boron foliar spraying, data in the same tables indicated that the values of all aforementioned traits were significantly affected by boron addition. the highest values of the most traits were connected with the plants treated with 100 mg L^{-1}, while the lowest one was associated with the treatment of 200 mg L^{-1}. However, B in roots (mg kg^{-1}) were gradually increased as increasing the rate of boron.

Table 6. Nitrogen (N), phosphorus (P), potassium (K) and sodium (Na) (%) in sugar beet roots as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		N		P		K		Na	
		In roots (%)							
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:									
Without (control)		0.938	0.947	0.156	0.157	3.793	3.824	1.642	1.653
K- Silicate		1.438	1.452	0.216	0.218	3.964	4.006	1.709	1.727
K- Humate		1.542	1.557	0.224	0.226	4.175	4.232	1.840	1.865
K- Silicate +K- Humate		1.798	1.818	0.261	0.264	4.426	4.475	1.924	1.940
LSD at 5%		0.049	0.053	0.003	0.005	0.024	0.027	0.228	0.231
B- Boron levels:									
0 mg L^{-1}		1.409	1.422	0.213	0.214	3.948	3.997	1.746	1.760
100 mg L^{-1}		1.657	1.674	0.244	0.246	4.603	4.657	1.933	1.958
150 mg L^{-1}		1.542	1.558	0.225	0.228	4.167	4.202	1.808	1.825
200 mg L^{-1}		1.109	1.121	0.176	0.178	3.641	3.681	1.627	1.642
LSD at 5%		0.047	0.055	0.004	0.003	0.021	0.023	0.156	0.165
C- Interactions:									
Without	0 mg L^{-1}	0.887	0.894	0.155	0.156	3.627	3.663	1.640	1.642
	100 mg L^{-1}	1.057	1.066	0.171	0.173	4.387	4.434	1.740	1.768
	150 mg L^{-1}	0.990	0.998	0.163	0.164	3.830	3.838	1.660	1.676
	200 mg L^{-1}	0.820	0.830	0.136	0.137	3.330	3.360	1.527	1.525
K- Silicate	0 mg L^{-1}	1.370	1.383	0.209	0.210	3.740	3.772	1.667	1.682
	100 mg L^{-1}	1.717	1.732	0.249	0.251	4.540	4.593	1.927	1.950
	150 mg L^{-1}	1.567	1.585	0.226	0.228	4.150	4.198	1.737	1.759
	200 mg L^{-1}	1.100	1.109	0.181	0.183	3.427	3.461	1.507	1.515
K- Humate	0 mg L^{-1}	1.490	1.503	0.216	0.218	4.007	4.064	1.807	1.827
	100 mg L^{-1}	1.827	1.848	0.259	0.261	4.620	4.674	1.960	1.983
	150 mg L^{-1}	1.630	1.644	0.235	0.237	4.237	4.295	1.827	1.847
	200 mg L^{-1}	1.220	1.234	0.188	0.190	3.837	3.896	1.767	1.805
K- Silicate + K- Humate	0 mg L^{-1}	1.890	1.907	0.271	0.273	4.417	4.488	1.870	1.887
	100 mg L^{-1}	2.027	2.049	0.297	0.300	4.867	4.928	2.107	2.131
	150 mg L^{-1}	1.980	2.004	0.279	0.282	4.450	4.478	2.010	2.019
	200 mg L^{-1}	1.297	1.313	0.199	0.201	3.970	4.008	1.710	1.724
LSD at 5%		0.077	0.083	0.010	0.011	0.042	0.044	NS	NS

Table 7. Boron (B) content (mg kg^{-1}), α-amino-nitrogen (α-amino-N), impurity and total soluble solids (TSS) (%) in sugar beet roots as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		Root B concentration (mg kg^{-1})		Root α-amino-N concentration (%)		Impurity (%)		TSS (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:									
Without (control)		17.25	17.42	2.616	2.638	8.05	8.11	23.00	23.25
K- Silicate		18.25	18.43	2.743	2.773	8.41	8.50	24.05	24.31
K- Humate		19.29	19.48	2.858	2.897	8.87	8.99	24.57	24.81
K- Silicate +K- Humate		20.16	20.36	2.971	2.997	9.32	9.41	25.15	25.39
LSD at 5%		0.10	0.14	0.255	0.261	0.85	0.91	0.62	0.59
B- Boron levels:									
0 mg L^{-1}		4.43	4.48	2.610	2.631	8.30	8.38	23.78	24.02
100 mg L^{-1}		19.01	19.20	3.114	3.151	9.65	9.76	25.33	25.60
150 mg L^{-1}		23.73	23.97	2.939	2.973	8.91	9.00	24.45	24.70
200 mg L^{-1}		27.77	28.05	2.525	2.549	7.79	7.87	23.21	23.44
LSD at 5%		0.12	0.15	0.206	0.214	0.38	0.41	0.39	0.41
C- Interactions:									
Without	0 mg L^{-1}	3.44	3.47	2.477	2.493	7.74	7.80	22.36	22.61
	100 mg L^{-1}	16.94	17.11	2.910	2.940	9.03	9.14	23.96	24.22
	150 mg L^{-1}	22.34	22.58	2.740	2.763	8.23	8.28	23.60	23.86
	200 mg L^{-1}	26.29	26.55	2.337	2.353	7.19	7.24	22.06	22.30
K- Silicate	0 mg L^{-1}	4.21	4.25	2.587	2.607	7.99	8.06	23.90	24.16
	100 mg L^{-1}	18.44	18.62	3.040	3.073	9.50	9.61	25.06	25.35
	150 mg L^{-1}	23.17	23.40	2.830	2.873	8.71	8.83	24.20	24.45
	200 mg L^{-1}	27.20	27.46	2.517	2.540	7.45	7.51	23.06	23.28
K- Humate	0 mg L^{-1}	4.81	4.87	2.657	2.687	8.47	8.58	24.16	24.40
	100 mg L^{-1}	19.85	20.05	3.157	3.197	9.73	9.85	25.80	26.10
	150 mg L^{-1}	24.19	24.43	3.050	3.100	9.11	9.24	24.66	24.90
	200 mg L^{-1}	28.29	28.57	2.570	2.603	8.17	8.30	23.66	23.85
K- Silicate + K- Humate	0 mg L^{-1}	5.28	5.33	2.720	2.737	9.00	9.11	24.70	24.92
	100 mg L^{-1}	20.81	21.02	3.350	3.393	10.32	10.45	26.50	26.73
	150 mg L^{-1}	25.23	25.48	3.137	3.157	9.59	9.65	25.36	25.59
	200 mg L^{-1}	29.31	29.60	2.677	2.700	8.35	8.43	24.06	24.32
LSD at 5%		0.14	0.15	NS	NS	NS	NS	0.88	0.94

Table 8. Sugar content, juice purity and extractable white sugar (%) of sugar beet as affected by foliar spraying of potassium sources and boron levels as well as their interactions during 2017/2018 and 2018/2019 seasons.

Treatments		Sugar content (%)		Juice purity (%)		Extractable white sugar (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
A- Potassium fertilizer sources:							
Without (control)		17.46	17.63	76.06	76.75	14.94	15.08
K- Silicate		17.72	17.90	73.79	74.52	15.13	15.28
K- Humate		18.05	18.24	73.60	74.39	15.37	15.53
K- Silicate +K- Humate		18.37	18.56	73.17	73.97	15.60	15.76
LSD at 5%		0.17	0.20	1.65	1.54	0.06	0.09
B- Boron levels:							
0 mg L^{-1}		17.71	17.89	73.31	74.05	14.86	15.01
100 mg L^{-1}		18.39	18.58	79.31	80.19	15.93	16.10
150 mg L^{-1}		18.09	18.26	74.00	74.71	15.41	15.56
200 mg L^{-1}		17.42	17.59	70.00	70.68	14.84	14.99
LSD at 5%		0.32	0.35	2.09	2.65	0.27	0.29
C- Interactions:							
Without	0 mg L^{-1}	17.32	17.48	74.06	74.67	14.56	14.70
	100 mg L^{-1}	18.09	18.29	81.97	82.83	15.75	15.92
	150 mg L^{-1}	17.47	17.63	75.96	76.57	14.92	15.06
	200 mg L^{-1}	16.98	17.13	72.85	73.64	14.52	14.65
K- Silicate	0 mg L^{-1}	17.45	17.61	72.08	72.86	14.73	14.90
	100 mg L^{-1}	18.21	18.39	78.96	79.85	15.82	15.98
	150 mg L^{-1}	18.02	18.19	74.46	75.16	15.35	15.50
	200 mg L^{-1}	17.23	17.42	69.65	70.23	14.63	14.76
K- Humate	0 mg L^{-1}	17.82	18.01	72.36	73.15	14.96	15.13
	100 mg L^{-1}	18.59	18.78	78.65	79.62	16.05	16.21
	150 mg L^{-1}	18.33	18.50	74.30	75.05	15.61	15.75
	200 mg L^{-1}	17.48	17.67	72.28	72.94	14.88	15.04
K- Silicate + K- Humate	0 mg L^{-1}	18.27	18.46	68.99	69.81	15.31	15.46
	100 mg L^{-1}	18.69	18.89	77.66	78.45	16.10	16.27
	150 mg L^{-1}	18.56	18.74	73.18	73.98	15.76	15.92
	200 mg L^{-1}	17.99	18.16	69.09	69.75	15.24	15.38
LSD at 5%		0.49	0.50	NS	NS	0.59	0.60

On the other hand, it appeared that foliar spraying of K- silicate + K-humate and 100 mg B L^{-1} simultaneously gave the highest values of most studied parameters as compared with the other investigated treatments.

Discussion

The superiority impact of foliar application of potassium silicate and potassium humate mixture may be due to the beneficial effects of potassium, silicon, and humic acid. Where, potassium had an imperative role in photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, enzyme activation and osmoregulation (Mengel, 2007). Also, silicon is an important micronutrient for plant development, healthy and competitive growth (Brunings et al., 2009). Ali et al. (2019) found that spraying sugar beet plants with K-silicate has the potential to alleviate the negative effects of drought stress and increase fertilizer use efficiency and hence can save fertilizers. Hamada, Maha (2019) concluded that foliar spraying twice with potassium silicate at a rate of 12.0 ml L^{-1} and fertilizing with 48 kg K_2O fed^{-1} improved sugar beet growth, yields and its components. These results are in concurrence with those stated by Artyszak et al. (2016) they found that the use of foliar application of silicon on sugar beet plants has a positive impact on fresh root mass and increases the root yield.

Besides, humic acid has been reported that it significantly enhances plant growth, moisture and nutrient uptake through its valuable effects either at the cell wall, membrane level or in the cytoplasm, including increasing photosynthesis and respiration rates in plants, protein synthesis and plant hormones like activity involved in plant growth stimulation, nutrient uptake and yield (Yilmaz, 2007). El-Hassanin et al. (2016) showed that foliar application with potassium humate at the level of 0.5% statistically improved sucrose, extractable sugar, purity, sugar lost to molasses, extractability percentages and yields fed^{-1}. El-Hamdi et al. (2018) revealed that K-humate addition had positive effects on fresh weights of foliages and roots, sugar yield (kg fed^{-1}), N %, K %, sucrose % and quality % in roots of sugar beet.

Generally, the range of boron deficiency and toxicity is narrow, so the performance of sugar beet plants at rates of 150 and 200 mg B L^{-1} declined may be due to boron toxicity. In the other words, foliar application of boron at the low rate (100 mgL^{-1}) was beneficial for sugar beet plants, while the toxicity of boron appeared at the high rates (150 and 200 MgL^{-1}) due to increasing free radicals in the plant with these rates of boron. These results agree with the findings of Abido (2012) who found that maximum sugar beet yield and root quality were recorded by treating the plants with 80 ppm boron as foliar application as compared to 40 and 120 ppm boron. Besides, Mekdad (2015) illustrated that sugar beet plants treated with 120 ppm B as foliar application gave root quality better than that treated with 150 ppm B. Increasing sugar beet chemical constituents, yield components, quality and yields by foliar spraying with boron may be attributed to the role of boron in cell division and elongation in meristematic tissues, nitrogen metabolism and hormonal action (BARI, 2006), also boron had a vital role in sugar translocation to roots, therefore improve growth, yields and quality of sugar beet. These findings agree with Abo-Steet et al. (2015) they found that CO and foliar application with Zinc and Boron enhanced the growth and yield productivity of sugar beet roots as well as nutrient contents and available N, P, K, Fe, Mn, Zn and B contents. Similar results were obtained by Abdel-Motagally (2015) who reported that foliar application with boron at a rate of 100 mg L^{-1} gave the highest sugar yield and the best technological quality. Also, these findings agree with those stated by Dewdar et al. (2015), Abdel-Nasser and Ben-Abdalla (2019) and Kandil et al. (2020).

CONCLUSION

It can be concluded that maximum sugar beet nutritive concentrations, yield components, quality and yields were resulted from spraying plants twice at 60 and 90 days after sowing with the mixture of K- silicate+ K- humate at a rate of 4 ml L^{-1} for each one in addition to spraying sugar beet plants twice at 90 and 110 days after sowing with boron at a rate of 100 mg L^{-1} under the environmental conditions of Dakahlia Governorate, Egypt. Boron is beneficial element for sugar beet plants at low concentration (100 B mg L^{-1}). Conversely, its toxicity starts to appear at the high concentration (150 and 200 mg L^{-1}).

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تأثير الرش الورقي ببعض مصادر البوتاسيوم ومستويات من البورون على المحصول الكمي و النوعي لبنجر السكر

محمد الغريب محمد إبراهيم[1] ، ريهام محمد نجيب فياض[2] وإبراهيم سليمان هلال الجمل[1]

[1]معهد بحوث المحاصيل السكرية - مركز البحوث الزراعية - الجيزة - مصر

[2]قسم خصوبة الأراضي و تغذية النبات - معهد بحوث الأراضي والمياه والبيئة - مركز البحوث الزراعية - الجيزة – مصر

أقيمت تجربتان حقليتان خلال موسمي 2018/2017 و 2019/2018 فى محطة البحوث الزراعية بتاج العز بمحافظة الدقهلية، مركز البحوث الزراعية، مصر، لدراسة تأثير الرش الورقي ببعض مصادر الأسمدة البوتاسية (بدون رش بالبوتاسيوم، الرش بسيليكات البوتاسيوم ، هيومات البوتاسيوم بمعدل 4 مل / لتر لكل سماد وخليط من سيليكات البوتاسيوم وهيومات البوتاسيوم بنفس المعدلات السابقة لكلا منهما) كمعاملات رئيسية ومستويات من البورون (بدون "معاملة المقارنة" ، 100 ، 150 و 200 جزء في المليون) كمعاملات منشقة كرش ورقى على المحتوي الغذائي للنباتات عند عمر 120 يوم ومكونات المحصول ومقياس الجودة والمحصول لبنجر السكر صنف فاتن تم تنفيذ التجارب فى تصميم القطع المنشقة مرة واحدة. أظهرت النتائج المتحصل عليها أن رش نباتات بنجر السكر بخليط من سيليكات البوتاسيوم وهيومات البوتاسيوم اعطي أعلى قيم لتركيزات العناصر الغذائية NPK عند عمر 120 يوم وكذلك مكونات المحصول وصفات الجودة والمحصول يليه الرش الورقي بهيومات البوتاسيوم ثم الرش الورقي بسيليكات البوتاسيوم، وأخيراً معاملة الكنترول ، باستثناء دليل الجودة والذي كان له اتجاه عكسي في كلا الموسمين، كذلك أدي رش نباتات بنجر السكر بمحلول البورون بتركيز 100 جزء في المليون إلي اعطاء أفضل القيم لجميع الصفات المدروسة مقارنة بباقي مستويات البورون الأخرى موضع الدراسة (بدون الرش بالبورون والرش بالبورون بتركيزين 150 و 200 جزء في المليون). توصى الدراسة إلي أن أعلى القيم لجميع الصفات الكمية و مقاييس الجودة لمحصول بنجر السكر صنف كوميرا نتجت من الرش الورقي للنباتات بخليط من سيليكات البوتاسيوم وهيومات البوتاسيوم بمعدل 4 مل / لتر لكل منهما و البورون بمعدل 100 جزء في المليون و ذلك تحت الظروف البيئية لمحافظة الدقهلية ، مصر.