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Impact of Applying Potassium Fulvate and Boron on Sugar Beet Yield and Quality

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ABSTRACT

Two field experiments were conducted out in a lysimeter at Sakha Agricultural Research Station, Kafr Elsheikh Governorate, Agricultural Research Center, Egypt, during winter seasons 2018 - 2019 and 2019 - 2020 to investigate the influence of four potassium fulvate treatments (without potassium fulvate, soil application of potassium fulvate, foliar application of potassium fulvate and soil+ foliar application of potassium fulvate) and foliar application with boron in three levels (without, 20 and 40 mg L^{-1}) and their interactions on growth, yield, its components and quality of sugar beet (triple cross Farida hybrid as multigerm variety). A strip-plot design with three replicates was used. The obtained results showed that soil application of potassium fulvate (4 Liters fed^{-1}) besides spraying twice with potassium fulvate (5 cm^3 L^{-1} water) gave the highest effective values of yield components, chemical constituents, quality and yields. Foliar application of boron (40 mgL^{-1}) was more effective than other treatments (without, 20 mg L^{-1}). It could be concluded that the interaction between foliar applications of boron (40 mgL^{-1}) after 50 and 70 days from sowing in the presence addition of soil application with potassium fulvate (4 Liters fed^{-1}) besides spraying twice along with potassium fulvate (5 cm^3 L^{-1} water) achieved the highest growth, yield and its components of the sugar beet under the conditions of Sakha, Kafr Elsheikh Governorate, Egypt.

Keywords: Sugar beet, potassium fulvate, Boron levels, Foliar application, Yield Quality.

INTRODUCTION

Sugar beet (Beta valgaris var. saccharifera L.) is quite possibly the main sugar crops in Egypt just as numerous nations everywhere on the world other than sugar stick (Sacchurum officinarum L.). The fundamental of sugar beet to farming isn't simply restricted to sugar creation yet additionally, used to deliver numerous items. As of late, the sugar beet crop has a significant situation in Egyptian harvest revolution as a colder time of year crop in the prolific soils as well as in poor, saline-basic, and calcareous soils. Consequently , in Egypt, sugar beet has turns into a significant harvest for sugar creation, henceforth the complete developed territory in the 2019 season came to about 493914.3 feddan and the all-out creation surpassed 10.525 million tons of roots with a normal of m 21.309 t/fed care of (FAO, 2021).

In view of its high efficiency, sugar beet requires prolific soils with high natural movement, plentiful in mineral and natural supplements, particularly when filled in antagonistic climate conditions (Grzebisz *et al*., 2005). Fulvic corrosive is a subgroup of different blends perceived as humic substances (Senesi and Loffredo, 2018). Prior examinations show that the use of humic substances (humic and fulvic acids) adds to the improvement of soil microbial movement, expansion in the length and weight of shoots and roots, the quantity of parallel roots, seedling development and germination (Ulukan, 2008) and impeccably influences the take-up of most supplements (Canellas and Olivares, 2014). They fundamentally affect the root development than flying pieces of plants (Nardi *et al.*, 2002), which proposes their specific significance in the development of root crops. (El-Hassanin *et al.*, 2016) Noted that fulvic acid exceeded the other humic substances in the content of sucrose, purity percentages, extractable sugar, yield and lowest juice impurities.(Mohamed and Afifi ,2017) concluded that foliar application of fulvic acid only or with boron improved sugar beet growth and yield quantity and quality as well as, fulvic acid is a promising effective factor and environmental friendly agent. (Wilczewski *et al.*, 2018) reported that both foliar and soil application of humic substances (humic and fulvic acids) in the form of Humistar improved the yield of sugar beet and resulting, increase the biological yield of sugar from storage roots. (Kandil *et al.*, 2020) indicate that the greatest values of diameter and root length, root weight, and root/shoot ratio of the sugar beet plants were obtained as a result of spraying with fulvic acid (FA) and NPK nanoparticles (NPK NPs).

(Marschner, 1995 and BARI, 2006) reported that among micronutrients, boron (B) is essential for plant growth. It assumes a significant part in cell wall cell division, synthesis, 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. Also, boron is plausibly more significant than any other micronutrient in obtaining high quality and crop yields Even though boron is a trace element, sugar beet has a higher prerequisite for boron more than other many crops. Where an adequate boron supply severely decreased yield and quality

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of roots. Furthermore, boron is essential for the formation of new cells in meristems and translocation sugar to roots (Loomis and Durst, 1992).Also, foliar application sugar beet plants with boron at a suitable rate determine on soil pH and soil boron content significantly increased root length, root diameter, sucrose and juice purity percentages, root, top and sugar yields, at the same time decreased Na, K, α-amino N, loss sugar percentages, harvest index and loss sugar yield, 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 (El-Hamdi *et al.*, 2018 ; Abdel-Nasser and Ben-Abdalla, 2019 and Kandil *et al.*, 2020).

Thus, this research planned to study the effect of potassium fulvate treatments and foliar spraying with boron levels on yield components, chemical constituents, quality, and yields of sugar beet under the environmental conditions of Sakha district, Kafr Elsheikh Governorate, Egypt.

MATERIALS AND METHODS

Two field experiments were carried out in lysimeter at Sakha Agricultural Research Station, Kafr Elsheikh Governorate, Agricultural Research Center, Egypt, during 2018 - 2019 and 2019 - 2020 winter seasons to investigate the influence of four potassium fulvate treatments (without potassium fulvate, soil application, foliar application and soil+ foliar application) and foliar application with boron in three levels (without, 20 and 40 mgL^{-1}) and their interactions on growth, yield and its components of sugar beet (triple cross Farida hybrid as multigerm variety).

Experiment description:

The experimental design was a strip-plot design system with three replications.

The experiments included 12 treatments which were the combinations of potassium fulvate treatments, boron (foliar application) and their interactions on growth, yield, its components and quality of sugar beet (triple cross Farida hybrid as multigerm variety). The vertical-plots were included four potassium fulvate treatments as follows:

1. Without application = spraying with water as control.
2. .Soil application of potassium fulvate at the rate of 4 Liters fed-1 .
3. .Spraying with potassium fulvate at the rate of 5 cm^3/liter water.
4. Soil application of potassium fulvate at the rate of 4 Liters fed-1 in addition to spraying with potassium fulvate at the rate of 5 cm^3/liter water. Liters fed^{-1}

The horizontal-plots were assigned to foliar spraying with three levels of boron as follows:

1- Without boron= spraying water as control.
2- 20 mg boron /liter water.
3- 40 mg boron /liter water.

The three boron rates were applied at the form of boric acid. The foliar solution volume for potassium fulvate or boron was 200 Liter fed^{-1} and spraying was done by hand sprayer (for experimental plots) until saturation point twice at the aforementioned levels after 50 and 70 days from sowing (DFS). Each experiment was carried out in Lyzimeters, each having the capacity dimensions of 80 × 80 × 80 cm *i.e.* experimental unit area was 0.80 × 0.80 m occupying an area of 0.64 m^2, which were filled with a sandy soil. Soil physical, chemical, and nutrients status of the experimental sites were determined according to (Page *et al*., 1982) as shown in Table 1.

Calcium superphosphate (15.5 % P_2O_5) was applied before sowing at a rate of 200 kg/fed. Sugar beet balls (3-5 balls/hill) were hand sewn using the dry sowing method in hills (20 × 40 cm apart *i.e.* 8 hills/Lyzimeter) on 25th and 27th September in the first and second seasons, respectively. The Lyzimeters were irrigated immediately after sowing. Sugar beet plants were thinned to one plant/hill at the age of 35 days from sowing. Nitrogen fertilizer in the form of ammonium nitrate (33.5% N) at a rate of 80 kg N/fed was applied in two equal doses. The first half was applied after thinning and before the second irrigation (35 days from sowing "DFS") and the second half was applied before the third irrigation (50 DFS). Potassium fertilizer in the form of potassium sulphate (48 % K_2O) at the rate of 50 kg/fed was applied before the second irrigation (35 DFS) as a soil application. All other recommended agricultural practices for growing sugar beet were followed according to Sugar Crops Research Institute, Agricultural Research Center recommendation.

Table 1.The average of physical and chemical soil properties of the Lyzimeters during two seasons 2018/19 and 2019/20 before planting.

Physical properties										
Properties	**Coarse sand (%)**	**Fine sand (%)**	**Silt (%)**	**Clay (%)**	**Soil texture**	**$CaCO_3$ (%)**	**Saturation point (%)**	**Field capacity (%)**		**Wilt point (%)**
Value	38.36	53.66	3.78	4.20	Sandy	1.00	13.4	9.95		3.20
Chemical properties										
Properties	pH *	EC** $dS\ m^{-1}$	Organic matter (%)	Soluble anions (meq/L) HCO_3^-	Cl^-	SO_4^{--}	Soluble Cations (meq/L) Ca^+	Mg^{++}	Na^+	K^+
Value	7.86	0.49	0.52	1.04	1.11	2.26	1.73	0.91	1.34	0.43

***in soil paste.** ****in soil paste extract.**

At harvest time (210 DFS), three plants were randomly chosen from each experimental plot to determine the following characters; shoot and root fresh and dry weights (g/plant), root length and diameter (cm). To determine the shoot and root dry weight of sugar beet plants, shoot and root were air-dried, then oven -dried at 70 °C till constant weight obtained.

At harvest, samples of sugar beet shoots and roots were ground using stainless steel equipment, then 0.2 g from each shoot and root sample was digested using a mixture of (H_2SO_4) and ($HClO_4$) as described by (Petrerburgski, 1968) to determine; Total nitrogen (N) percentage (%), which was determined by Kjeldahl method as mentioned by (Hesse, 1971). Total phosphorus (P) percentage (%), which was determined colorimetrically using a spectrophotometer at wavelength 640 nm as described by (Jackson, 1967). Total potassium was determined using a flame photometer as described by (Jackson, 1967). Boron (B) content ($mgKg^{-1}$), which was determined colorimetrically by Azomethine-H method at spectrophotometer as described by (Wolf, 1971).

At harvest, soil samples of the experimental plot were taken to determine:

-Available nitrogen (N $mgKg^{-1}$) was extracted using solution of KCl (2.0 M) according to (Hesse, 1971) and determined by micro-Kjeldahl apparatus.

- Available phosphorus (P $mgKg^{-1}$) was extract by $NaHCO_3$ solution (0.5 N at pH 8.5) and determined on spectrophotometer at wave length 640 nm with method of ammonium molybedate and stannous chloride (Jackson, 1967).

-Available potassium (K ppm) was extracted by ammonium acetate solution (1.0 N at pH 7) and determined on flame photometer according to (Hesse, 1971).

Root quality characters were determined in El-Delta Sugar Company Laboratories at El-Hamoul District, Kafr Elsheikh Governorate. The studied quality parameters were as follows;

1- Sodium (Na %) in sugar beet roots was determined using flame photometer according to (ICUMSA, 1994).

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 (α-amino N, Na and K contents in juice).

4- Gross sucrose (%) was determined polarimetrically on a lead acetate extract of fresh macerated roots according to the method of (Carruthers and Old Field 1960).

5- Juice quality index (QI % = Purity %) was calculated using the following equation of (Cooke and Scott 1993):

QI% = Extracted sugar% x 100 / pol%

6- 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 (expressed as a meq 100 g^{-1} of beet) according to (Harvey and Dutton 1993) using the following equation:

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

7- Sugar lost to molasses (SLM) percentage (%) was determined as follows;

SLM (%) = Gross sucrose percentage - Extractable white sugar percentage.

The other plants that produced from each experimental plot at harvesting time were collected and cleaned. Roots and tops were separated and weighted in kg, then converted to estimate;

1-Root and top yields (t/fed).

2- Extracted sugar yield (t/fed) was calculated by multiplying root yield by extracted white sugar percentage.

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the strip-plot design as published by (Gomez and Gomez 1984), using MSTAT statistical package developed by (Russel, 1986). Least significant difference (LSD) method was used to test the differences among treatment means at 5 % level of probability as described by (Snedcor and Cochran 1980).

RESULTS AND DISCUSSION

1.Effect of treatments on vegetative growth parameters:

A-Effect of K- fulvate on vegetative growth parameters

The average data tabulated in Table 2 showed the effect of soil application of potassium fulvate (4 Liters fed-1), spraying with potassium fulvate (5 cm3/liter water), and soil application of potassium fulvate (4 Liters fed-1) besides spraying with fulvic acid (5 cm3/liter water) as well as their interactions on vegetative growth parameters (shoot and root fresh and dry weights/plant, root length, and diameter). Information introduced in Table 2 showed that applications of K- fulvate as soil application and spraying with potassium fulvate individually and/or in combination caused significant increases in shoot and root fresh and dry weights/plant, root length, and diameter. The best appropriate treatment was mixtures of K- fulvate as soil application and spraying with potassium fulvate followed by K- fulvate as foliar application followed by soil application respectively, compared with untreated control. These results may be due to the fact that the application of K- fulvate has several positive effects on soil properties, one of which may be contributing towards cation exchange capacity of the soil (Malan, 2015 and Moradi et al., 2017). Also, (Lotfi et al., 2015) demonstrated that, K- fulvate when applied to the soil is converted into readily available humic substances which straightforwardly or in a roundabout way upgrade the plant growth.

B-Effect of boron levels on vegetative growth parameters

Results in the same Table showed that increasing boron fertilization rates from zero to 20 and 40 mg/liter water increased significantly the mean values of vegetative growth parameters (shoot and root fresh and dry weights/plant, root length, and diameter) during 2018/2019 and 2019/2020 seasons. In addition, the highest mean values of vegetative growth parameters (shoot and root fresh and dry weights/plant, root length, and diameter), were recorded when applying the 40 mg/liter water concentration of boron fertilization, whereas, the lowest mean values of vegetative growth parameters, were acquired by growing sugar beet plant under the control treatment (zero boron fertilization= water) during 2018/2019 and 2019/2020 seasons, respectively. The increment of growth attributes gained by increasing boron level may be as a result to its role in enzyme activity which facilitates carbohydrate transportation as well as protein synthesis. Similar results were obtained by (Abido, 2012) and (Hanan and Yasin 2013) showed that increasing the concentration of boron significantly increased root size. Such an effect of boron might be attributed to the increase in activities of certain enzymes very important for cell division and the regulation of potassium/ calcium ratio in plants. These results are in harmony with those obtained by (Ibrahim, 2006) and (Abido, 2012)

C-Effect of interaction

The tabulated results in Table 2 indicated that boron levels and K- fulvate had a significant effect on vegetative growth parameters of sugar beet during two growing seasons

Table 2. Shoot and root fresh and dry weights/plant, root length and diameter of sugar beet as affected by K-fulvate treatments and boron levels as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters Treatments Seasons	**Shoot fresh weight (g/plant)**		**Shoot dry weight (g/plant)**		**Root fresh weight (g/plant)**		**Root dry weight (g/plant)**		**Root length (cm)**		**Root diameter (cm)**	
	2018/ 2019	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**
A- K-fulvate treatments:												
Without K-fulvate	226.1	259.0	84.8	97.1	431.5	494.4	158.2	181.2	18.12	20.76	6.80	7.79
Soil application of K-fulvate	385.0	441.0	131.6	150.7	825.0	944.9	317.2	363.3	25.21	28.88	9.07	10.39
Spraying with K-fulvate	459.5	526.4	148.9	170.6	1023.6	1172.5	354.6	406.2	34.81	39.89	9.81	11.23
Soil application of K-fulvate + Spraying with K-fulvate	486.4	557.1	150.0	171.9	1027.4	1176.6	378.8	433.9	35.90	41.12	9.86	11.29
LSD at 5%	50.4	52.8	15.6	16.0	125.9	134.4	22.0	23.0	2.99	3.09	1.11	1.17
B- Boron (B) levels:												
Without	330.0	377.9	116.4	133.3	681.0	780.0	257.9	295.3	23.72	27.17	8.07	9.24
20 mg B/liter	380.4	435.7	123.4	141.4	791.3	906.4	287.4	329.2	27.52	31.53	8.88	10.16
40 mg B/liter	457.4	524.0	146.7	168.0	1008.3	1154.8	361.3	413.9	34.29	39.28	9.71	11.12
LSD at 5%	38.4	40.6	11.0	11.5	32.3	33.2	23.7	24.2	3.83	4.03	1.22	1.24
C- Interaction (F. test):												
A × B	*	*	*	*	*	*	*	*	*	*	*	*

2- Effect of treatments on nutrient concentration:

A-Effect of K- fulvate on Nutrient Concentration

Tables 3 and 4 demonstrated that the nutritional values of N, P, and K percentages, B content in shoots and roots, N, P, and K percentages in soil were influenced by the application of soil application of potassium fulvate, spraying with potassium fulvate, and soil application of potassium fulvate besides spraying with potassium fulvate. Soil application of fulvic acid (4 Liters fed^{-1}) besides spraying twice with potassium fulvate (5 cm^3/liter water) after 50 and 70 days from sowing produced the highest values of N, P, and K percentages, B content in shoots and roots, N, P and K percentages in soil. While spraying sugar beet plants twice with potassium fulvate (5 cm^3/liter water) came in the second rank, then soil application of potassium fulvate. On the other hand, sugar beet plants growing without K- fulvate application (control treatment) resulted in the lowest values of N, P, and K percentages, B content in shoots and roots, N, P, and K percentages in soil. K- fulvate enhanced the chemical properties of soils because it increased the number of soil microorganisms which enhanced nutrient cycling (Delfine *et al.*, 2005) and reduced soil pH thus, increasing the availability of mineral nutrients to be absorbed by plant roots.

B-Effect of boron levels on Nutrient Concentration

From achieved results of this research, the studied boron fertilizer levels (control, 20 and 40 mg/liter water) exhibited significant influence on nitrogen (N), phosphorus (P), and potassium (K) percentages in shoot and root, boron (B) content in shoots and roots, and K percentages in soil whilst, had insignificant effects on N and percentage in the soil. Foliar spraying sugar beet plants twice (50 and 70 days after sowing) with a solution of boron at the rate of 40 mg L^{-1} was more effective than other studied boron levels (without and 20 mg L^{-1}) in increasing growth and chemical constituents. This increase in growth and chemical constituents, of sugar beet 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).

C-Effect of interaction

The collected data in Tables 3 and 4 pointed out that using combination boron with potassium fulvate as soil application +foliar application significantly affected nitrogen (N), phosphorus (P), and potassium (K) percentages in shoot and root, boron (B) content in shoots and roots whilst, had insignificant effects on N, P and k percentage in the soil

Table 3. Nitrogen (N), phosphorus (P) and potassium (K) percentages in sugar beet shoots and roots as affected by K-fulvate treatments and boron levels as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters Treatments Seasons	**N in shoot(%)**		**P in shoot(%)**		**K in shoot(%)**		**N in root(%)**		**P in root(%)**		**K in root(%)**	
	2018/ 2019	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**
A- K-fulvate treatments:												
Without K-fulvate	0.915	1.048	0.052	0.060	0.538	0.616	1.909	2.187	0.078	0.089	4.411	5.050
Soil application of K-fulvate	0.937	1.073	0.054	0.062	0.550	0.630	2.207	2.527	0.090	0.103	5.158	5.909
Spraying with K-fulvate	1.000	1.145	0.057	0.065	0.700	0.802	2.283	2.615	0.097	0.111	5.189	5.942
Soil application of K-fulvate + Spraying with K-fulvate	1.253	1.436	0.075	0.085	0.761	0.871	2.286	2.619	0.130	0.149	5.312	6.085
LSD at 5%	0.121	0.131	0.003	0.004	0.049	0.054	0.252	0.269	0.004	0.005	0.549	0.566
B- Boron (B) levels:												
Without	0.961	1.101	0.051	0.059	0.568	0.651	1.655	1.896	0.087	0.099	4.582	5.248
20 mg B/liter	0.982	1.125	0.062	0.071	0.633	0.725	2.187	2.505	0.100	0.114	5.043	5.776
40 mg B/liter	1.135	1.300	0.065	0.075	0.710	0.813	2.672	3.061	0.109	0.125	5.427	6.216
LSD at 5%	0.109	0.113	0.003	0.003	0.088	0.100	0.148	0.158	0.002	0.003	0.243	0.251
C- Interaction (F. test):												
A × B	*	*	*	*	*	*	*	*	*	*	NS	NS

Table 4. Boron (B) content in sugar beet shoots and roots of and nitrogen (N), phosphorus (P) and potassium (K) percentages in soil as affected by K-fulvate treatments and boron levels as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters	**B in shoot**	**B in root**	**N in soil**	**P in soil**	**K in soil**

Treatments	(mgKg-1)		(mgKg-1)		(mgKg-1)		(mgKg-1)		(mgKg-1)	
Seasons	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020
A- K-fulvate treatments:										
Without K-fulvate	1030.76	1180.7	41.29	47.30	66.64	76.33	13.97	16.00	144.5	165.5
Soil application of K-fulvate	1097.94	1257.7	46.66	53.45	70.89	81.20	14.04	16.08	150.4	172.3
Spraying with K-fulvate	1141.13	1307.2	50.62	57.99	71.32	81.70	17.43	19.97	167.1	191.5
Soil application of K-fulvate + Spraying with K-fulvate	1271.01	1455.9	55.78	63.90	72.36	82.84	18.80	21.53	170.7	195.5
LSD at 5%	11.6	12.6	0.58	0.66	NS	NS	1.14	1.21	15.0	16.3
B- Boron (B) levels:										
Without	1026.0	1175.4	42.29	48.44	68.89	78.92	15.61	17.88	118.9	136.2
20 mg B/liter	1090.6	1249.3	49.65	56.87	70.64	80.90	16.03	18.36	167.3	191.6
40 mg B/liter	1288.9	1476.4	53.84	61.67	71.37	81.73	16.55	18.95	188.4	215.8
LSD at 5%	14.7	15.4	0.62	0.72	NS	NS	NS	NS	9.5	10.1
C- Interaction (F. test):										
A × B	*	*	*	*	NS	NS	NS	NS	NS	NS

3- Effect of treatments on yield and quality of sugar beet:
A-Effect of K- fulvate on yield sand quality

From the obtained results in Tables 5 and 6, it could be revealed that sugar beet yield components, quality, and yields had a gradual and significant increase due to different studied K- fulvate treatments in both seasons. It can be established that soil application of potassium fulvate (4 Liters fed^{-1}) besides spraying twice with K- fulvate (5 cm^3/liter water) after 50 and 70 days from sowing produced the highest values of gross sucrose, quality index, and extractable white sugar percentages in the juice of roots, root, top and extracted sugar yields/fed at the same time the lowest values of Na, K, α-amino-N, impurity and SLM percentages in the juice of roots in both seasons. Even as, spraying sugar beet plants twice with K- fulvate (5 cm^3/liter water) after 50 and 70 days from sowing came in the second rank followed by soil application of K- fulvate (4 Liters fed^{-1}) in both seasons. On the other hand, sugar beet plants growing without potassium fulvate application (control treatment) resulted in the lowest values of gross sucrose, quality index, and extractable white sugar percentages in the juice of roots, root, top, and extracted sugar yields/fed simultaneously the highest values of Na, K, α-amino-N, impurity and SLM percentages in the juice of roots in both seasons. These increases in sugar beet yield components, chemical constituents, quality, and yields as a result of soil application of K- fulvate (4 Liters fed-1) besides spraying twice with K- fulvate (5 cm3/liter water) can be ascribed to the role of fulvic acid as the main component of humic substances in the improvement of soil microbial activity, increases in germination, number of lateral roots, seedling growth, length and weight of shoots and roots (Nardi *et al.,* 2002 and Ulukan, 2008) and positively affects the uptake of most nutrients (Canellas and Olivares, 2014). These results are in concurrence with those stated by (El-Hassanin *et al.,* 2016), (Mohamed and Afifi 2017), (Wilczewski *et al.,* 2018), and (Kandil *et al.,* 2020)

Table 5. Sodium (Na), potassium (K), α-amino-nitrogen (α-amino-N), impurity, gross sucrose and quality index percentages in sugar beet juice roots as affected by K-fulvate treatments and boron levels as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters Treatments Seasons	Na (%)		K (%)		α-amino-N (%)		Impurity (%)		Gross sucrose (%)		Quality index (%)	
	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020	2018/ 2019	2019/ 2020
A- K-fulvate treatments:												
Without K-fulvate	2.34	2.68	5.33	6.11	4.448	5.094	12.02	13.76	20.13	23.06	78.51	89.90
Soil application of K-fulvate	2.24	2.57	5.26	6.03	2.71	3.11	10.13	11.60	20.15	23.07	79.53	91.07
Spraying with K-fulvate	1.93	2.21	5.24	5.99	2.63	3.02	9.80	11.22	20.16	23.09	79.67	91.26
Soil application of K-fulvate + Spraying with K-fulvate	1.75	2.01	5.15	5.90	2.53	2.89	9.61	11.00	20.26	23.20	79.99	91.58
LSD at 5%	0.05	0.06	NS	NS	0.134	0.14	0.51	0.53	NS	NS	NS	NS
B- Boron (B) levels:												
Without	2.33	2.670	5.60	6.42	3.51	4.02	11.19	12.81	19.25	22.04	78.61	90.04
20 mg B/liter	2.08	2.383	5.36	6.13	2.89	3.31	10.56	12.10	20.61	23.61	79.22	90.71
40 mg B/liter	1.79	2.047	4.78	5.47	2.85	3.26	9.41	10.78	20.67	23.66	80.43	92.11
LSD at 5%	0.04	0.049	0.48	0.50	0.04	0.052	0.45	0.47	NS	NS	NS	NS
C- Interaction (F. test):												
A × B	*	*	*	*	*	*	*	*	NS	NS	NS	NS

Table 6. Extractable white sugar, sugar lost to molasses (SLM) percentages, root, top and extracted sugar yields/fed of sugar beet as affected by K-fulvate treatments and boron levels as well as their interaction during 2018/2019 and 2019/2020 seasons.

Characters Treatments	Extractable white sugar (%)	SLM (%)	Root yield (t/fed)	Top yield (t/fed)	Extracted sugar yield (t/fed)

Seasons	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**	**2018/ 2019**	**2019/ 2020**
A- K-fulvate treatments:										
Without K-fulvate	16.83	19.28	3.30	3.79	12.08	13.84	5.65	6.47	2.06	2.36
Soil application of K-fulvate	17.05	19.52	3.11	3.56	23.10	26.46	9.63	11.03	3.99	4.58
Spraying with K-fulvate	17.19	19.68	2.98	3.41	28.66	32.83	11.49	13.16	4.89	5.60
Soil application of K-fulvate + Spraying with K-fulvate	17.28	19.79	2.96	3.39	28.77	32.95	12.16	13.93	4.94	5.66
LSD at 5%	NS	NS	0.18	0.21	3.53	3.60	1.26	1.35	0.92	1.01
B- Boron (B) levels:										
Without	16.44	18.82	3.26	3.73	19.07	21.84	8.25	9.45	3.33	3.81
20 mg B/liter	17.41	19.93	3.20	3.66	22.16	25.38	9.51	10.89	3.66	4.19
40 mg B/liter	17.41	19.94	2.81	3.22	28.23	32.34	11.44	13.10	4.92	5.64
LSD at 5%	NS	NS	0.16	0.16	0.91	1.02	0.96	1.01	0.32	0.33
C- Interaction (F. test):										
A × B	NS	NS	*	*	*	*	*	*	*	*

B-Effect of boron levels on yield and quality

Results presented in Tables 5 and 6 showed that increasing boron fertilization from zero up to 40 mg/liter water decreased significantly potassium %, α- amino nitrogen%, and sodium% in sugar beet root during 2018/2019 and 2019/2020 seasons. Where the lowest mean values percentage were recorded when applying the rate of 40 mg/liter water of boron during the two seasons. However, the highest mean values were recorded under control treatment (zero) during both seasons. These outcamesare in harmony with those obtained by (EL-Kamash, 2007, Osman 2008, and Ferweez *et al*., 2011). Boron foliar application twice at the rate of 20 ppm ranked secondly after boron at the rate of 40 ppm with regard to its effects on yield components, chemical constituents, quality, and yields of sugar beet plants during both seasons. Foliar spraying sugar beet plants twice with boron at the rate of 40 ppm gave the highest values of the root (28.233 and 32.336 t/fed), top yield (11.435 and 13.101 t/fed), and extracted sugar yield (4.924 and 5.640 t/fed) in the first and second seasons, respectively. This increases in yield components, chemical constituents, quality, and yields of sugar beet by foliar spraying twice 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). In addition, boron had a vital role in sugar translocation to roots, therefore improve growth, yields and quality of sugar beet. These findings are in agreement with those stated by (Mohamed and Afifi 2017, El-Hamdi *et al.*, 2018, Abdel-Nasser and Ben-Abdalla 2019, and Kandil *et al*., 2020). Increasing of root yield accompanying boron foliar application might have been due to the increase in root length and diameter as mentioned before Table 4. These results are in harmony with those achieved by (Kristek, *et al.,* 2006 and Abido, 2012).On the other said, the lowest sugar yield recorded with the control compared with all other treatments in 1st and 2nd seasons, respectively. Impact of a high boron rate may attribute to the increase in sucrose and sugar extraction percentages. These outcomes overall go in accordance with those got by certain agents among them (Maghrabi, 2006), El-Kammash, 2007, and Abido, 2012).

C-Effect of interaction

Data presented in Tables 5 and 6 indicated that sprayed sugar beet with boron at the concentration of 40 mgL^{-1} with potassium fulvate as soil application +foliar application gave the highest root yield per feddan as well as gave the most noteworthy sugar yield per feddan as compared with all these interaction treatments in 1st and 2nd seasons, respectively. Generally, Maximus beet with 40mg/l gave the best sugar and root yield ton/fed respectively.

As demonstrated from results graphically delineated in Figs. 1 and 2, the highest values of root and extracted sugar yields/fed of sugar beet were produced from soil application of potassium fulvate (4 liter/fed) besides spraying plants twice with solution of potassium fulvate (5 cm^3/liter water) and boron (40 mgL^{-1}) after 50 and 70 days from sowing in both seasons. The second best interaction treatment was spraying plants twice with solution of potassium fulvate (5 cm^3/liter water) and boron (40 mgL^{-1}) after 50 and 70 days from sowing in both seasons. On the other side, the lowest values of root and extracted sugar yields/fed of sugar beet were resulted from control treatment of both investigated factors (without application of fulvic acid and without spraying with boron fertilizer) in the two seasons.

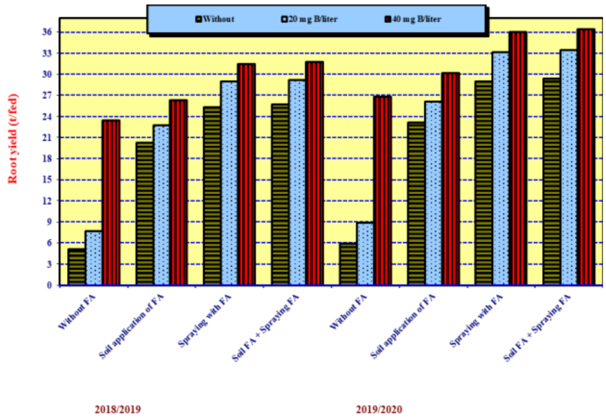

Fig. 1. Root yield (t/fed) of sugar beet as affected by the interaction between K-fulvate treatments and boron levels during 2018/2019 and 2019/2020 seasons.

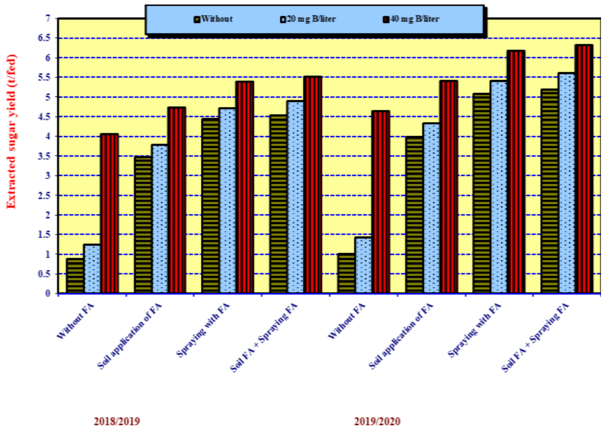

Fig. 2. Extracted sugar yield (t/fed) of sugar beet as affected by the interaction between K-fulvate treatments and boron levels during 2018/2019 and 2019/2020 seasons.

CONCLUSION

Could be concluded that maximum sugar beet yield components, chemical constituents, quality, and yields in lyzimeter experiment have resulted from soil application of potassium fulvate (4 Liters fed^{-1}) besides spraying plants twice with a solution of potassium fulvate (5 cm^3/liter water) and boron (40 mgL^{-1}) after 50 and 70 days from sowing under the environmental conditions of Sakha district, Kafrelsheikh Governorate, Egypt.

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تأثير إضافة فلفات البوتاسيوم و البورون على محصول وجودة بنجر السكر

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أجريت هذه الدراسة فى تجربة ليزمتر بمحطة البحوث الزراعية بسخا، محافظة كفر الشيخ، مركز البحوث الزراعية، مصر خلال موسمي الشتاء٢٠١٨/٢٠١٩ و ٢٠١٩/٢٠٢٠ لدراسة تأثير معاملات فلفات البوتاسيوم (بدون معاملة، إضافة أرضية من فلفات البوتاسيوم ، الرش الورقى فلفات البوتاسيوم وإضافه أرضيه + الرش الورقى فلفات البوتاسيوم) والرش الورقي بمستويات البورون (بدون و ٢٠ و ٤٠ملجم / لتر) على مكونات المحصول والمكونات الكيميائية والجودة والمحصول لبنجر السكر (الهجين الثلاثى فريدة كصنف متعدد الأجنة). أجريت كل تجربة حقلية فى تصميم الشرائح المتعامدة فى ثلاث مكررات. تم تخصيص الشرائح الرأسية لمعاملات فلفات البوتاسيوم كما تم تخصيص الشرائح الأفقية لمعاملات الرش الورقي بمستويات البورون. أظهرت النتائج المتحصل عليها أن إضافة فلفات البوتاسيوم (بمعدل ٤ لتر / فدان) للتربة إلى جانب الرش الورقى مرتين فلفات البوتاسيوم (٥ سم ٣/ لتر ماء) أدى إلى تحسين مكونات المحصول والمكونات الكيميائية والجودة والمحصول لبنجر السكر. كان الرش الورقي لنباتات بنجر السكر بمحلول البورون (٤٠ ملجم / لتر) أكثر فاعلية من مستويات البورون المدروسة الأخرى (بدون و ٢٠ ملجم / لتر) في زيادة مكونات المحصول والمكونات الكيميائية والجودة والمحصول. من نتائج هذه الدراسة يمكن استنتاج أن الحد الأقصى لمكونات المحصول والمكونات الكيميائية والجودة والمحصول لبنجر السكر في تجربة الليزمتر نتجت من معاملة التربة بفلفات البوتاسيوم (بمعدل ٤ لتر / فدان) بالإضافة إلى الرش الورقى للنباتات مرتين بمحلول فلفات البوتاسيوم (بمعدل ٥ سم ٣/ لتر ماء) والبورون (بمعدل ٤٠ ملجم / لتر) بعد ٥٠ و ٧٠ يومًا من الزراعة تحت الظروف البيئية لمنطقة سخا ، محافظة كفر الشيخ ، مصر.