

Research Article

Effect of Sources and Rates of Potassium Fertilizer on Growth, Productivity and Quality of Sugar Beet

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Abstract: To investigate the influence of sources and rates of potassium as foliar application (without, spraying with potassium silicate at the rates of 6.0 and 12 ml/ Liter and potassium borate at the rates of 3.0 and 6.0 ml/Liter) and potassium fertilizer rates as soil application (0, 24, 36 and 48 kg K₂O/fed) on sugar beet Kawemira cultivar growth, yields and its components as well as quality parameters, two field experiments were carried out at Tag Al-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt, during 2012/2013 and 2013/2014 seasons. The experiments were carried out in strip-plot design with four replications. The obtained results showed that foliar spraying sugar beet plants twice with potassium borate at the rate of 6.0 ml/ Liter produced the highest values of growth attributes, yields and its components, followed by spraying with potassium silicate at the rate of 12.0 ml/ Liter, then spraying with potassium borate at the rate of 3.0 ml/ Liter, spraying with potassium silicate at the rate of 6.0 ml/ Liter, and lastly the control treatment in both seasons. The quality characters had different trend, where the highest total soluble solids (TSS), sucrose and apparent purity percentages were obtained from control treatment. Fertilizing sugar beet plants with 48 kg K₂O/fed as a soil addition significantly increased growth attributes, yields and its components and produced the highest values as compared with without potassium fertilization treatment. While, increasing potassium fertilizer levels from 0 to 24, 36 and 48 K₂O/fed associated with gradual and significant decreases in quality parameters. It could be concluded that maximum sugar beet growth, yields and its components were resulted from foliar spraying twice with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with 48 kg K₂O/fed. However, to maintain the agricultural resources and reduce environmental pollution, it could be recommended that foliar spraying sugar beet plants twice at 50 and 70 DFS with potassium borate at the rate of 6.0 ml/ Liter and mineral fertilizing with 36 kg K₂O/fed as a soil application under the environmental conditions of Dakahlia Governorate, Egypt.

Keywords: Sugar beet, potassium fertilizer rates, foliar application, potassium borate, potassium silicate, soil application, growth, yields, quality.

INTRODUCTION

Sugar beet (*Beta vulgaris* var. *saccharifera* L.) crop has an important position in Egyptian crop rotation as winter crop for sugar production not only in the fertile soils, but also in poor, saline alkaline and calcareous soils. Where, it could be economically grown in the newly reclaimed soils such as at the Northern parts of Egypt as one of the most tolerant crops to salinity and wide range of climates. The total amount of sugar produced is not adequate enough to our consumption. So, increasing the cultivated area and sugar production per unit area is considered one of the important national targets to minimize the gap between sugar consumption and production. Improvement of sugar beet production can be achieved through use

appropriate source and rate of potassium as foliar application and optimum rate of potassium fertilizer as soil application.

Foliar fertilization is the application of nutrients, plant hormones and other beneficial substances to the leaves and stems of plants. The application of these substances during growth and development can improve the nutrient balance of crops as compared to soil applied method, which in turn, leads to increase yield and quality, greater resistance to diseases and insect pests and improved drought tolerance (Alexander, 1985).

Quick Response Code



Journal homepage:

<http://www.easpublisher.com/easjals/>

Article History

Received: 15.04.2019

Accepted: 30.05.2019

Published: 13.06.2019

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DOI: 10.36349/easjals.2019.v02i06.002

Potassium (K) as the main macronutrient that is participate in many important functions in plants *i.e.* growth of meristematic tissue, cell turgor pressure and cell expansion, photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use (Marschner, 1995 and Reddy *et al.*, 2004), enzyme activation and osmoregulation (Mengel 2007). Also, potassium enhances the ability of plants to resist stress such as diseases, pests, cold and drought. Potassium performs these roles in all crops and in sugar beet, therefore it is important plant nutrient to sustain high productivity and quality, in equilibrium with other essential plant nutrients (Yu-ying and Hong, 1997), so it is important to ensure adequate potassium for sugar beet. In this concern, Seadh *et al.*, (2007) cleared that root and top yields and its components were significantly increased by application the highest level of potassium fertilizer (60 kg K₂O/fed. On the other hand, the highest values of TSS and sucrose percentages were obtained by application of 48 kg K₂O/fed. Abdel-Motagally and Attia (2009), Gobarah *et al.*, (2011) and Salami and Saadat (2013) reported that that application the highest level of potassium fertilizer (114 kg K₂O/ha) associated with significant increases in root and foliage weights and root dimensions, sucrose and purity percentages, root, top and sugar yields/ha. Nafei *et al.*, (2010) found that potassium fertilizer level at 36 kg K₂O/fed gave significant increase in root length and diameter, fresh weight/plant, total soluble solids % and root and sugar yields. In general, potassium at the level 36 kg K₂O/fed was more effective than at 18 kg K₂O/fed. Seadh (2012) stated that increasing potassium fertilizer levels from 50 up to 100 % of the recommended dose significantly affected growth, yield and quality characters, and the most effective treatment was application 100 % of the recommended potassium fertilizer dose (48 kg K₂O/fed). El-Sarag and Moselhy (2013) showed that the highest sugar beet yields (top, root and sugar/ha) were obtained by adding the highest level of potassium fertilizer (140 kg K₂O/ha). While, the maximum sucrose content was achieved by adding 100 K₂O kg/ha. Hussain *et al.*, (2014) found that the application of the highest level of potassium fertilizer (150 kg K₂O/ha) promoted sugar beet top yield by 49.2% and fresh root yield by 45.0% over control treatment (0 kg/ha). Neseim *et al.*, (2014) recommended that application 100 kg potassium sulphate 48% K₂O/fed to recorded the highest root and sugar yields, sucrose % and the lowest impurities %. Abido *et al.*, (2015) showed that soil fertilizing sugar beet plants with 48 kg K₂O/fed produced the highest values of growth attributes, root and top yields and its components in both seasons. The highest values of sugar yield/fed, TSS%, sucrose % and apparent juice purity % were obtained from mineral fertilizing sugar beet plants with the 36 kg K₂O/fed as a soil addition.

Silicon (Si) is an important micronutrient for plant development (Regina and Katarzyna, 2011). Silicon helps plants survive in the conditions of water scarcity, decreasing transpiration in cells (Gao *et al.*, 2006), reduces micronutrient and metal toxicity (Britez *et al.*, 2002) and resistance against pathogens like fungi or herbivorous insects (Reynolds *et al.*, 2009). Many studies have suggested the positive growth effects of silicon, including increased dry mass and yield, enhanced pollination (Korndörfer and Lepsch, 2001) and most commonly increased disease resistance (Rodrigues, 2004). Laane (2018) stated that foliar spraying with silicates are effective as pesticides, while silicic acid spraying increased growth and yield and decrease biotic and abiotic stresses. 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 increased fertilizer use efficiency, and hence can save fertilizers.

Boron (B) is consider as micronutrient, and plays an important roles 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 micronutrients in obtaining high quality and crop yields (Marschner, 1995 and BARI, 2006). Although, boron is a trace element, but sugar beet have a higher requirement for boron more than other many crops. Where, an adequate boron supply severely decreased yield and quality of roots. Moreover, boron is essential for formation of new cells in meristems and translocation sugar to roots (Loomis and Durst, 1992). Foliar spraying sugar beet plants with boron at suitable rate depended 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 (Abido, 2012 ; Armin and Asgharipour, 2012 ; Abd El-Azez, 2014 ; El-Sheref, 2014 ; Abo-Steet *et al.*, 2015 ; Dewdar *et al.*, 2015 ; Mekdad, 2015 and Abdel-Nasser and Ben-Abdalla, 2019), seeing as roots absorbed boric acid and the role of boron in chloroplast formation, sink limitations and changes in cell wall, which lead to secondary effects in plant metabolism, development, growth and yield with good quality. Abd El-Hady (2017) revealed that the highest values of root yield, top yield, sugar yield, sucrose percentage and extractable sugar percentage were recorded with sugar beet plants sprayed with Borfam treatment, while the lowest values were recorded with control treatment. Hellal *et al.*, (2009) reported that the boron foliar application led to significant increase in both concentration and uptake of K, Fe, Mn, Zn in sugar beet.

Therefore, this study planned to study the effect of sources and rates of potassium as foliar application and potassium fertilizer rates as soil application on sugar beet growth, yields and its components as well as quality parameters under the environmental conditions of Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

At Tag Al-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt, two field experiments were carried out during 2012/2013 and 2013/2014 seasons to study the influence of sources and rates of potassium as foliar application and potassium fertilizer rates as soil application on sugar beet Kawemira cultivar growth, yields and its components as well as quality parameters.

The experiments were carried out in strip-plot design with four replications. The vertical plots were included with sources and rates of potassium as foliar application as follows: 1- Without spraying (control treatment). 2- Spraying with potassium silicate at the rate of 6.0 ml/ Liter. 3- Spraying with potassium silicate at the rate of 12.0 ml/ Liter. 4- Spraying with potassium borate at the rate of 3.0 ml/ Liter. 5- Spraying with potassium borate at the rate of 6.0 ml/ Liter. Spraying

was conducted by hand sprayer twice after 50 and 70 days from sowing (DFS) at the aforementioned rates until saturation point. The commercial fertilizer Potassium Sil Ghanem "Liquid silicon" (potassium silicate) was manufactured by Abo- Ghanema for Fertilizers and Chemical Industries. The chemical composition of potassium silicate is 10.0% K₂O and 25.0% SiO₂. The commercial fertilizer Porfam (potassium borate) was manufactured by Pham commercial for Agricultural Development. The chemical composition of Porfam is 34.0% K₂O, 4.0% boron and 2.0% P₂O₅.

The horizontal plots were allocated to four rates of potassium fertilizer (0, 24, 36 and 48 kg K₂O/fed) as soil addition. Potassium fertilizer in the form of potassium sulphate (48 % K₂O) was applied at aforementioned levels as a side-dressing in one dose after thinning and before the second irrigation (35 days from sowing).

The soil in study site was clay loam in texture, and at preparing seedbed, both physical and chemical analysis of soil were estimated according to the standard methods and the corresponding data are presented in Table 1.

Table1: Physical and chemical soil characteristics of the experimental site during 2012/2013 and 2013/2014 seasons.

Physical characteristics										
Seasons	Properties	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Soil texture	CaCO ₃ (%)	Water table (cm)	Field capacity (%)	Real density (g/cm ³)
	2012/2013	5.9	33.1	25.4	35.6	Clay loam	2.52	98	35.2	2.64
	2013/2014	6.1	33.7	24.9	35.3	Clay loam	2.49	101	34.6	2.62
Chemical characteristics										
Seasons	Properties	pH soil paste	EC dSm ⁻¹	Organic matter (%)	Available nutrients (ppm)					
					N	P	K			
	2012/2013	7.8	2.3	2.12	35.4	7.8	222			
	2013/2014	7.5	2.2	1.76	33.3	7.6	220			

Each experimental basic unit included 5 ridges, each of 60 cm apart and 3.5 m long, comprising an area of 10.5 m² (1/400 fed). The preceding summer crop was rice (*Oryza sativa* L.) in both seasons.

The experimental field well prepared by two ploughing, leveling, compaction, division and then divided to the experimental units. Calcium superphosphate (15.5 % P₂O₅) was applied during soil preparation at the level of 150 kg/fed. Nitrogen fertilizer in the form of urea (46.0% N) at level of 80 kg N/fed was applied in two equal doses, the first was applied after thinning and before the second irrigation (35 DFS) and the second portion was applied before the third irrigation (50 DFS).

Sugar beet balls (3-5 balls/hill) were hand sown using dry sowing method on one side of the ridge in hills 20 cm apart in the 20th and 25th of October in first and second seasons, respectively. The plots were irrigated immediately after sowing. Sugar beet plants were thinned to one plant/hill (35000 plants/fed) at the

age of 35 days from sowing. The recommended agricultural practices for growing sugar beet were followed, except the factors under study.

Studied Characters:

Two samples were taken during the growth periods *i.e.* 120 and 150 days from sowing (DFS) of five guarded plants, which were randomly chosen from outer ridges of each plot. Each sample was separated into foliages and roots to determine the following growth attributes:

1. Root fresh weight (g/plant).
2. Foliage fresh weight (g/plant).

- Leaf area index (LAI): Leaf area determined by using Field Portable Leaf Area Meter AM-300 (Bio-Scientific, Ltd., Great Amwell, Herforshire, England), and then the following equation was used to calculate LAI:

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Plant ground area (cm}^2\text{)}}$$

- Crop growth level (CGR) in g/week was determined according to Radford (1967), using the following equation:

$$CGR = \frac{W_2 - W_1}{T_2 - T_1}$$

Where: W_1 and W_2 refer to dry weight of plant at sampling time T_1 (120 DAS) and T_2 (150 DAS), respectively. To determine root and foliage dry weight, all plant fractions were air-dried, then oven dried at 70°C till constant weight obtained.

- Relative growth level (RGR) in g/g/week was determined according to Radford (1967), using the following equation:

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1}$$

- Net assimilation level (NAR) in g/m²/week as determined according to Watson (1958), using the following equation:

$$NAR = \frac{(W_2 - W_1)(\text{Log}_e A_2 - \text{Log}_e A_1)}{(T_2 - T_1)(A_2 - A_1)}$$

Where: W_1 , A_1 and W_2 , A_2 , respectively refer to dry weight and leaf area of plant at sampling time T_1 and T_2 , respectively.

At harvest time (205 DFS), five plants were randomly chosen from the outer ridges of each plot to determine yield components and quality characters as follows:

- Root fresh weight (g/plant).
- Foliage fresh weight (g/ plant).
- Root length (cm).
- Root diameter (cm).
- Total soluble solids (TSS %) in roots was measured in juice of fresh roots by using Hand Refractometer.
- Sucrose percentage (%) was determined Polarimetrically on lead acetate extract of fresh macelevel roots according to the method of Carruthers and OldField (1960).
- Apparent purity percentage (%). It was determined as a ratio between sucrose % and TSS % of roots as the method outlined by Carruthers and OldField (1960). Plants that produced from the two inner ridges of each plot at harvesting time were collected and cleaned.

Roots and tops were separates and weighted in kilograms, then converted to estimate:

- Root yield (t/fed).
- Top yield (t/fed).
- Sugar yield (t/fed) was calculated by multiplying root yield by sucrose 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. Least significant difference (LSD) method was used to compare the differences among treatment means at 5 % level of probability as described by Snedcor and Cochran (1980).

RESULTS AND DISCUSSION

A- Effect of sources and rates of potassium as foliar application:

Foliar application treatments with different sources and rates of potassium *i.e.* without spraying (control treatment), spraying with potassium silicate at the rates of 6.0 and 12.0 ml/ Liter and potassium borate at the rates of 3.0 and 6.0 ml/Liter significantly affected growth attributes, yield components and quality characters and yields of sugar beet in both seasons, with exemption relative growth rate (RGR) in the second season only (Tables 2, 3, 4 and 5).

From obtained results, it could be noticed that foliar spraying sugar beet plants twice after 50 and 70 days from sowing with different sources and rates of potassium caused a gradual increases in growth attributes, yield components and quality characters and yields as compared with control treatment (without spraying) in the two growing seasons. The highest values of growth attributes *i.e.* root and foliage fresh weight, leaf area index (LAI) at 120 and 150 days from sowing (DFS), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were resulted from spraying sugar beet plants with potassium borate at the rate of 6.0 ml/ Liter in both seasons. However, spraying sugar beet plants with potassium silicate at the rate of 12.0 ml/ Liter came in the second rank after aforementioned mentioned treatment, followed by spraying with potassium borate at the rate of 3.0 ml/ Liter, then spraying with potassium silicate at the rate of 6.0 ml/Liter, and control treatment in the two growing seasons.

As the same previous trend, the highest values of root fresh weight (817.0 and 805.5 g), foliage fresh weight (633.9 and 650.7 g), root length (31.92 and 32.29 cm), root diameter (12.00 and 12.56 cm), root yield (28.327 and 28.833 t/fed), top yield (16.232 and 16.713 t/fed) and sugar yield (5.223 and 5.647 t/fed) at harvesting were produced from foliar spraying sugar beet plants twice with potassium borate at the rate of 6.0 ml/ Liter with an increase of 31.35 and 27.55 % in root fresh weight, 74.87 and 69.54 % in foliage fresh

weight, 27.78 and 27.73 % in root length, 34.08 and 36.52 in root diameter, 18.08 and 17.42 % in root yield, 43.91 and 43.46 % in top yield and 4.13 and 7.01 % in sugar yield compared with control treatment (without spraying) in the first and second seasons, respectively. Spraying beet plants twice with potassium silicate at the rate of 12.0 ml/ Liter ranked after aforesaid treatment, followed by spraying twice with potassium borate at the rate of 3.0 ml/ Liter, then spraying twice with potassium silicate at the rate of 6.0 ml/ Liter, and lastly the control treatment concerning yields and its components in both seasons.

The characters of quality has taken a relatively different trend, where the highest total soluble solids (TSS), sucrose and apparent purity percentages were obtained from control treatment (without spraying), followed by spraying twice with potassium silicate at the rate of 6.0 ml/ Liter, then spraying twice with potassium borate at the rate of 3.0 ml/ Liter, spraying twice with potassium silicate at the rate of 12.0 ml/ Liter, and lastly spraying twice with potassium borate at the rate of 6.0 ml/ Liter in both seasons.

The advantageous effect of spraying sugar beet plants with potassium borate or potassium silicate at the highest level in growth attributes, yields and yield components probably due to the arrangement in the desired impact of foliar spraying with potassium and boron or potassium and silicon. Since, potassium participate in growth of meristematic tissue, cell turgor pressure and cell expansion, photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use (Marschner, 1995 and Reddy *et al.*, 2004), enzyme activation and osmoregulation (Mengel 2007). In addition, the desirable 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. However, silicon is an important micronutrient for plant development (Regina and Katarzyna, 2011), survive in the conditions of water scarcity, decreasing transpiration in cells (Gao *et al.*, 2006), reduces micronutrient and metal toxicity (Britez *et al.*, 2002) and resistance against pathogens like fungi or herbivorous insects (Reynolds *et al.*, 2009). Many researchers confirmed these results, including Abd El-Hady (2017) revealed that the highest values of root, top and sugar yields, sucrose percentage and extractable sugar percentage were recorded with sugar beet plants sprayed with Borfam treatment, while the lowest values were recorded with control treatment. Laane (2018) stated that foliar spraying with silicates increased growth and yield and decrease biotic and abiotic stresses. 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 increased fertilizer use efficiency, and hence can save fertilizers.

B- Effect of potassium fertilizer rates:

Potassium fertilizer levels (0, 24, 36 and 48 kg K₂O/fed) as a soil application had a significant effect on growth attributes, yields and its components and quality parameters of sugar beet, excluding crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and apparent purity percentages in both seasons as shown in Tables 2, 3, 4 and 5. It can be confirmed that growth attributes, yields and its components as well as quality parameters had a gradual and significant increases as a result of increasing potassium fertilizer levels from 0 to 24, 36 and 48 K₂O/fed in both seasons.

Soil fertilizing sugar beet plants with the highest level of potassium fertilizer (48 kg K₂O/fed) produced the highest values of root and foliage fresh weight and leaf area index (LAI) at 120 and 150 days from sowing (DFS), CGR, RGR, NAR, root and foliage fresh weights, root length and diameter at harvesting in both seasons. While, fertilizing beet plants with 36 kg K₂O/fed came in the second rank, then 24 kg K₂O/fed and 0 kg K₂O/fed (control treatment), which resulted in the lowest values of previously mentioned characters in both seasons.

Fertilizing sugar beet plants with 48 kg K₂O/fed (the highest level of potassium fertilizer in this study) as a soil addition significantly increased root, top and sugar yields/fed and caused increases estimated by 14.40 and 13.77 % in root yield, 91.30 and 88.17 % in top yield and 3.43 and 3.99 % in sugar yield compared with control treatment (without potassium fertilization) in the first and second seasons, respectively. While, soil fertilizing beet plants with 36 kg K₂O/fed significantly increased root, top and sugar yields/fed and produced increases about 9.48 and 10.02 % in root yield, 77.40 and 76.31 % in top yield and 2.22 and 2.42 % in sugar yield compared with control treatment (0 kg K₂O/fed) in the first and second seasons, respectively. Whereas, fertilizing sugar beet plants with 24 kg K₂O/fed as a soil addition significantly increased root and top yields/fed and exhibited increases amounted by 3.03 and 3.73 % in root yield, 34.62 and 33.19 % in top yield and 0.48 and 0.92 % in sugar yield compared with without potassium fertilization treatment (control treatment) in the first and second seasons, respectively.

Increasing potassium fertilizer levels from 0 to 24, 36 and 48 K₂O/fed associated with gradual and significant decreases in quality parameter (TSS, sucrose and apparent juice purity percentages) in both growing seasons. Hence, the optimum percentages of total soluble solids (TSS), sucrose and apparent juice purity were obtained from control treatment (without potassium fertilization) in both seasons. On the other hand, the lowest values of all quality parameters were produced from mineral fertilizing sugar beet plants with the 48 kg K₂O/fed as a soil addition in both seasons. It is worth mentioning that fertilizing beet plants with 24

kg K₂O/fed ranked after control treatment and followed by fertilizing with the 36 kg K₂O/fed and then fertilizing with 48 kg K₂O/fed in both seasons.

These increases in growth attributes, yields and its components as a result of increasing potassium fertilizer levels as a soil application can be ascribed to the role of potassium in photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use (Marschner, 1995 and Reddy *et al.*, 2004), enzyme activation and osmoregulation (Mengel 2007). Therefore, potassium is important plant nutrient to sustain high, growth, productivity and quality (Yu-ying and Hong, 1997). While, the reduction in quality parameter due to excessive application of potassium fertilizer (increasing potassium fertilizer levels up to 48 kg K₂O/fed) may be ascribed to the fact that high amounts of potassium in roots prevent crystallization of some sucrose in juice during the extraction, and thus it causes loss of sucrose that go out with the molasses. These results are in concurrence with those stated by Seadh *et al.*, (2007), Seadh (2012), El-Sarag and Moselhy (2013), Hussain *et al.*, (2014) and Abido *et al.*, (2015). However, Nafei *et al.*, (2010), Salami and Saadat (2013) and Neseim *et al.*, (2014) reported that potassium fertilizer level at the highest level gave significant increase in root length and diameter, fresh weight/plant, total soluble solids % and root and sugar yields.

C- Effect of interaction:

The interaction between sources and rates of potassium as foliar application and potassium fertilizer rates as soil application had a significant effect on root and foliage fresh weights and leaf area index (LAI) at 120 and 150 days from sowing, root and foliage fresh weights as well as root, top and sugar yields/fed at harvesting in both seasons, root length in the second season and total soluble solids in the first season as presented in Tables 2, 3, 4 and 5. The significant interaction between both studied factors on yields were presented in Figs. 1, 2 and 3.

From obtained results that graphically illustrated in Fig. 1, foliar spraying sugar beet plants twice with potassium borate at the rate of 6.0 ml/ Liter and mineral fertilizing with 48 kg K₂O/fed as a soil application resulted in the highest values of root yield/fed, which reached about 29.759 and 30.125 t/fed in the first and second seasons, respectively. Spraying

beet plants twice with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with 36 kg K₂O/fed ranked after aforementioned interaction treatment in both seasons. It is worth noting, foliar spraying sugar beet plants with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with the lowest level of potassium fertilizer significantly exceeded the common treatment that most farmer are used (fertilizing with the highest level of potassium fertilizer without spraying with potassium) in both seasons.

Likewise, top yield/fed had similar trend that mentioned in root yield/fed. Where, the highest values of top yield/fed were produced from foliar spraying beet plants twice with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with 48 kg K₂O/fed in both seasons (Fig. 2). The second best interaction treatment concerning top yield/fed was spraying with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with 36 kg K₂O/fed in both seasons.

Commencing sugar yield/fed, the highest values were obtained from foliar spraying sugar beet plants twice (50 and 70 DFS) with potassium borate at the rate of 6.0 ml/ Liter and mineral fertilizing with 36 kg K₂O/fed as a soil application in both seasons (Fig. 3). While, spraying beet plants twice with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with the highest level of potassium fertilizer (48 kg K₂O/fed) ranked after aforementioned interaction treatment in both seasons. Consequently, the favorable treatment that increased sugar beet yields and quality parameters in the same time reduces agriculture costs and environmental pollution was foliar spraying sugar beet plants twice at 50 and 70 DFS with potassium borate at the rate of 6.0 ml/ Liter and mineral fertilizing with 36 kg K₂O/fed as a soil application under the environmental conditions of Dakahlia Governorate, Egypt.

CONCLUSION

From our results in this study, it can be seen that maximum sugar beet growth, yields and its components were resulted from foliar spraying twice with potassium borate at the rate of 6.0 ml/ Liter and fertilizing with 48 kg K₂O/fed. However, to maintain the agricultural resources and reduce environmental pollution, it could be recommended that foliar spraying sugar beet plants twice at 50 and 70 DFS with potassium borate at the rate of 6.0 ml/ Liter and mineral fertilizing with 36 kg K₂O/fed as a soil application.

Table 2: Root and foliage fresh weights and leaf area index (LAI) at 120 and 150 days from sowing (DFS) as affected by sources and rates of potassium as foliar application and potassium rates as soil application as well as their interaction during 2012/2013 and 2013/2014 seasons.

Characters Sampling times Treatments Seasons	Root fresh weight (g)				Foliage fresh weight (g)				LAI			
	120 DFS		150 DFD		120 DFS		150 DFD		120 DFS		150 DFD	
	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
A- Sources and rates of potassium as foliar application:												
Without	324.8	329.4	454.0	458.6	339.1	341.5	468.2	474.2	4.33	4.36	5.32	5.35
Potassium silicate 6 ml/L	357.1	360.9	483.7	486.9	351.8	355.1	504.8	508.5	4.58	4.60	5.50	5.52
Potassium silicate 12 ml/L	375.9	380.8	507.8	512.1	377.7	380.3	539.3	545.7	4.79	4.83	5.73	5.76
Potassium borate 3 ml/L	364.8	368.2	492.8	495.0	367.2	369.9	521.6	520.7	4.70	4.73	5.63	5.64
Potassium borate 6 ml/L	387.3	389.1	529.6	532.5	389.1	390.0	553.8	556.1	4.91	4.93	5.92	5.95
LSD at 5 %	2.9	2.4	2.2	2.6	1.6	1.5	2.0	1.6	0.02	0.02	0.03	0.03
B- Potassium fertilizer rates (kg K₂O/fed) as soil application:												
0	344.7	348.9	458.9	462.8	352.9	355.0	456.1	461.0	4.36	4.40	5.49	5.51
24	358.7	362.2	484.9	489.3	363.5	366.4	513.3	517.2	4.60	4.63	5.60	5.62
36	368.9	372.4	509.0	512.0	369.3	371.8	540.5	544.1	4.77	4.82	5.67	5.70
48	375.5	379.3	521.6	523.9	374.1	376.2	560.1	561.9	4.91	4.92	5.73	5.74
LSD at 5 %	3.3	3.1	2.0	2.2	1.0	1.3	1.7	1.8	0.01	0.02	0.01	0.01
C- Interaction (F. test):	*	*	*	*	*	*	*	*	*	*	*	*

Table 3: Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) as affected by sources and rates of potassium as foliar application and potassium rates as soil application as well as their interaction during 2012/2013 and 2013/2014 seasons.

Characters Treatments Seasons	CGR (g/week)		RGR (g/g/week)		NAR (g/m ² /week)	
	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
A- Sources and rates of potassium as foliar application:						
Without	10.61	10.61	0.070	0.068	16.83	16.79
Potassium silicate 6 ml/L	10.40	10.42	0.073	0.073	17.95	17.83
Potassium silicate 12 ml/L	11.96	12.19	0.074	0.074	18.55	18.77
Potassium borate 3 ml/L	11.52	11.66	0.074	0.073	18.19	18.32
Potassium borate 6 ml/L	12.40	12.57	0.074	0.074	18.65	18.83
LSD at 5 %	0.42	0.56	0.003	NS	0.64	0.72
B- Potassium fertilizer rates (kg K₂O/fed) as soil application:						
0	11.16	11.28	0.072	0.072	17.59	17.87
24	11.31	11.39	0.073	0.072	17.97	17.90
36	11.51	11.55	0.073	0.072	18.07	18.09
48	11.54	11.74	0.074	0.074	18.50	18.57
LSD at 5 %	NS	NS	NS	NS	NS	0.41
C- Interaction (F. test):	NS	NS	NS	NS	NS	NS

Table 4: Root and foliage fresh weights, root length and diameter at harvesting as affected by sources and rates of potassium as foliar application and potassium rates as soil application as well as their interaction during 2012/2013 and 2013/2014 seasons.

Treatments	Characters Seasons	Root fresh weight (g)		Foliage fresh weight (g)		Root length (cm)		Root diameter (cm)	
		2012/20	2013/20	2012/20	2013/20	2012/20	2013/20	2012/20	2013/2014
		13	14	13	14	13	14	13	
A- Sources and rates of potassium as foliar application:									
Without		622.0	631.5	362.5	383.8	24.98	25.28	8.95	9.20
Potassium silicate 6 ml/L		664.7	676.3	455.4	477.7	27.48	29.30	9.68	10.23
Potassium silicate 12 ml /L		771.0	778.1	591.0	612.9	30.28	31.25	10.51	11.15
Potassium borate 3 ml /L		716.8	708.6	512.4	525.8	28.75	30.09	10.32	10.51
Potassium borate 6 ml /L		817.0	805.5	633.9	650.7	31.92	32.29	12.00	12.56
LSD at 5 %		19.5	20.4	22.8	23.1	0.66	0.75	0.40	0.50
B- Potassium fertilizer rates (kg K₂O/fed) as soil application:									
0		643.1	637.8	375.5	409.4	25.20	26.61	8.92	9.43
24		694.6	699.4	500.6	524.0	28.02	29.29	9.87	10.62
36		754.0	755.0	573.7	580.0	30.31	30.95	10.91	10.96
48		781.6	787.7	594.4	607.3	31.19	31.73	11.47	11.90
LSD at 5 %		21.3	19.4	20.6	21.9	0.48	0.54	0.32	0.49
C- Interaction (F. test):									
		*	*	*	*	NS	*	NS	NS

Table 5: Total soluble solids (TSS), sucrose and apparent purity percentages, root, top and sugar yields/fed as affected by sources and rates of potassium as foliar application and potassium rates as soil application as well as their interaction during 2012/2013 and 2013/2014 seasons.

Character s Treatmen ts Seasons	TSS (%)		Sucrose (%)		Apparent purity (%)		Root yield (t/fed)		Top yield (t/fed)		Sugar yield (t/fed)	
	2012/20	2013/20	2012/20	2013/20	2012/20	2013/20	2012/20	2013/20	2012/20	2013/20	2012/20	2013/20
	13	14	13	14	13	14	13	14	13	14	13	14
A- Sources and rates of potassium as foliar application:												
Without	23.33	23.58	19.89	20.93	87.15	88.74	23.989	24.555	11.279	11.650	5.016	5.277
Potassiu m silicate 6 ml/L	22.85	23.36	19.77	20.44	84.71	87.75	25.177	25.707	12.990	13.447	5.087	5.380
Potassiu m silicate 12 ml /L	21.75	22.85	17.91	18.79	82.34	82.23	27.114	27.571	14.538	14.922	5.115	5.441
Potassiu m borate 3 ml /L	22.57	23.30	18.73	19.22	82.96	82.26	25.999	26.657	13.966	14.465	5.102	5.419
Potassiu m borate 6 ml /L	21.32	21.84	17.09	17.88	80.18	81.89	28.327	28.833	16.232	16.713	5.223	5.647
LSD at 5 %	0.34	0.44	0.29	0.33	1.49	1.23	0.157	0.133	0.220	0.217	0.073	0.098
B- Potassium fertilizer rates (kg K₂O/fed) as soil application:												
0	23.27	23.76	19.64	20.37	84.35	85.70	24.475	24.948	9.150	9.530	5.019	5.335
24	22.74	23.37	18.98	19.83	83.43	84.82	25.216	25.879	12.318	12.693	5.043	5.384
36	22.13	22.76	18.35	19.27	83.23	84.65	26.795	27.448	16.232	16.802	5.155	5.464
48	21.32	22.05	17.74	18.32	82.86	83.12	27.999	28.384	17.504	17.933	5.216	5.548
LSD at 5 %	0.28	0.27	0.36	0.41	NS	NS	0.264	0.227	0.290	0.252	0.123	0.116
C- Interacti on (F. test):												
	*	NS	NS	NS	NS	NS	*	*	*	*	*	*

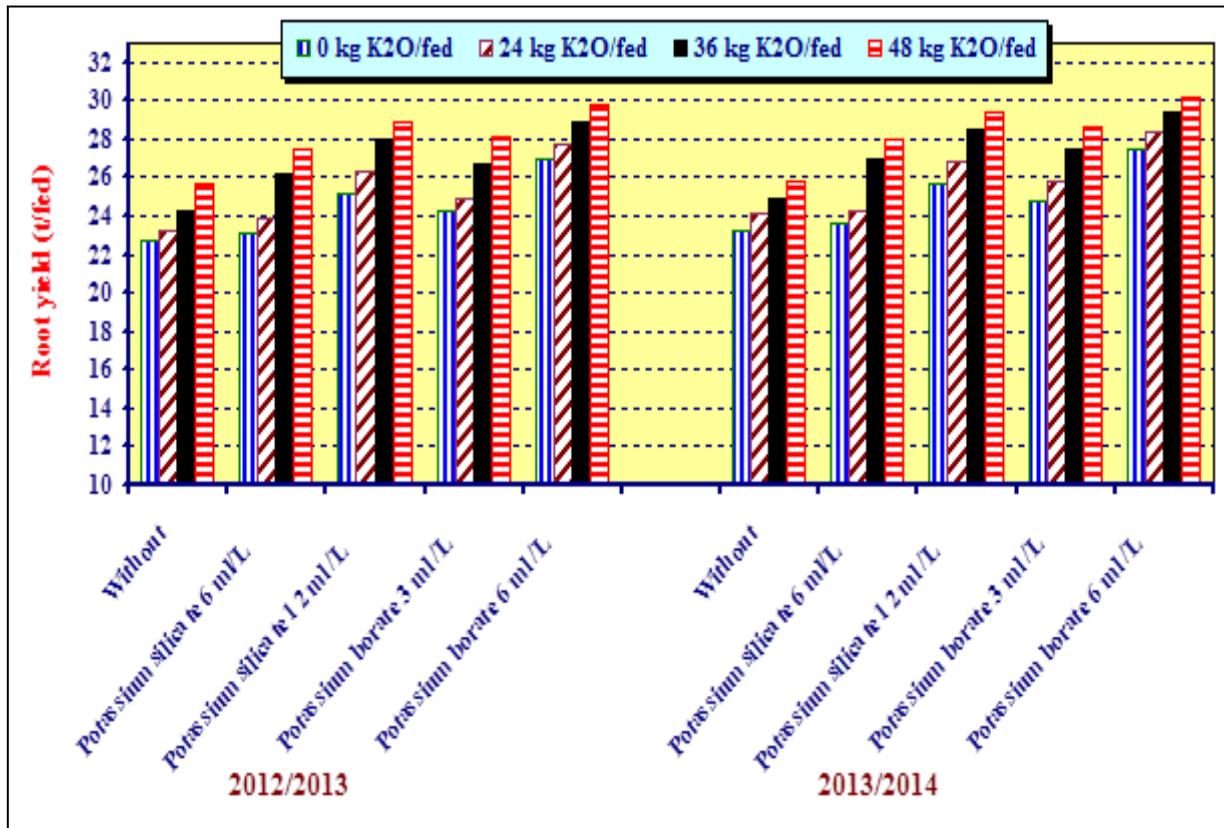


Fig. 1: Root yield (t/fed) as affected by the interaction between sources and rates of potassium as foliar application and potassium rates as soil application during 2012/2013 and 2013/2014 seasons.

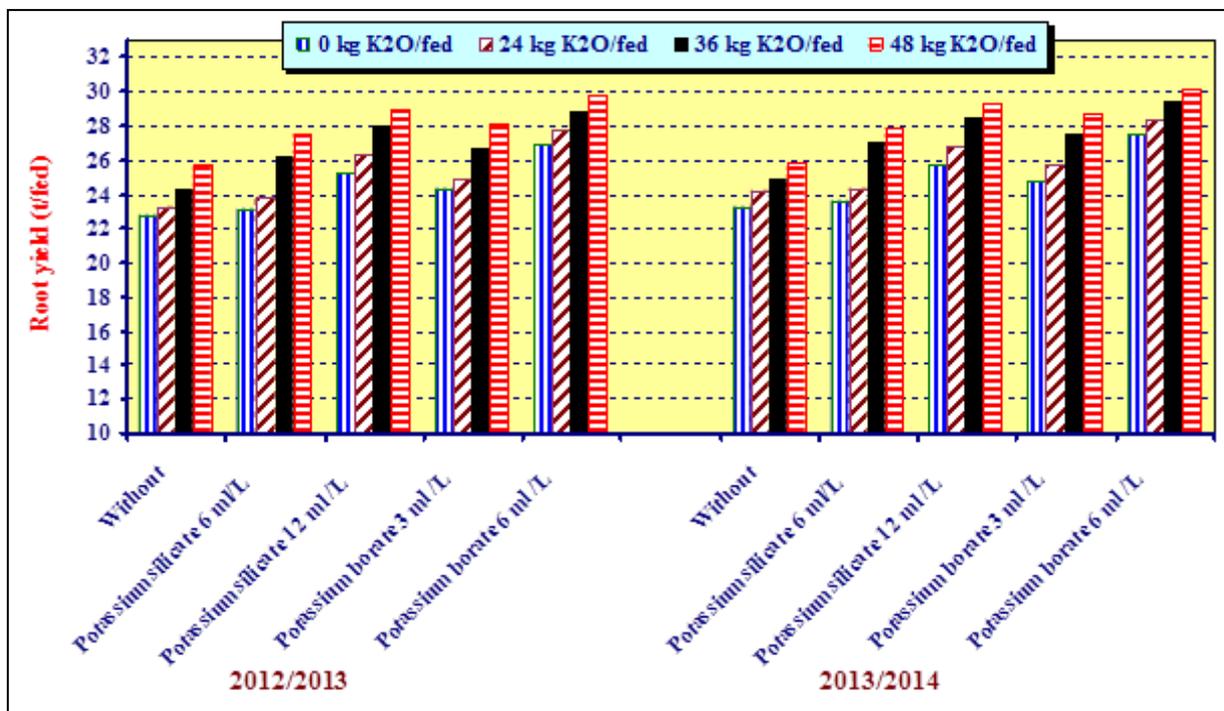


Fig. 2: Top yield (t/fed) as affected by the interaction between sources and rates of potassium as foliar application and potassium rates as soil application during 2012/2013 and 2013/2014 seasons.

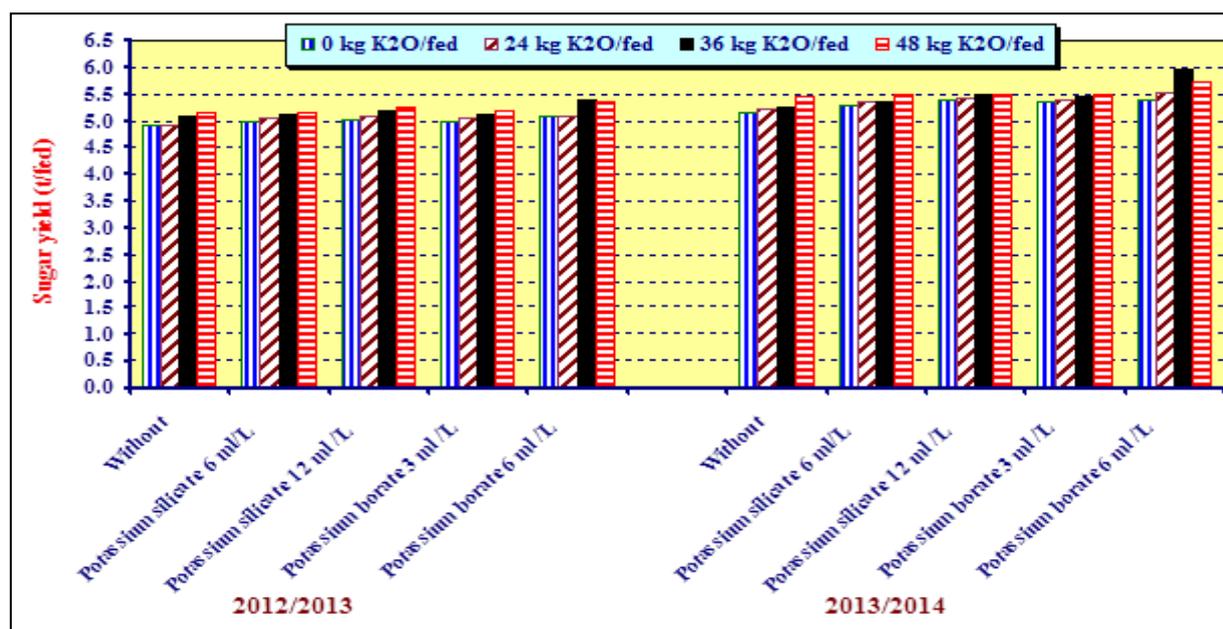


Fig. 3: Sugar yield (t/fed) as affected by the interaction between sources and rates of potassium as foliar application and potassium rates as soil application during 2012/2013 and 2013/2014 seasons during 2012/2013 and 2013/2014 seasons.

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