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Growth, Productivity and Quality of Sugar Beet as Affected by Antioxidants Foliar Application and Potassium Fertilizer Top Dressing

[1]W.A.E. Abido, [2]M.E.M. Ibrahim and [2]Maha M. El-Zeny
[1]Department of Agronomy, Faculty of Agriculture, Mansoura University, 35516, Egypt
[2]Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt

Corresponding Author: W.A.E. Abido, Department of Agronomy, Faculty of Agriculture, Mansoura University, 35516, Egypt

ABSTRACT

To study the effects of antioxidants foliar application (without spraying, spraying with ascorbic acid “AA”, salicylic acid “SA” and citric acid “CA”, in addition, spraying with the mixture of AA+SA+CA) and potassium fertilizer levels as top dressing (12, 24, 36 and 48 kg K_2O/fed, fed or feddan = 4200 m^2) on sugar beet growth, yields, its components and root quality. Two field experiments were conducted in Tag Al-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt during 2012/2013 and 2013/2014 seasons. A strip-plot design with four replications was used. Results showed that highest growth attributes, yields and its components were resulted from foliar spraying twice with the mixture of antioxidants of 150 ppm of each of AA+SA+CA in both seasons. However, spraying with 150 ppm of AA came in the second rank. Highest Total Soluble Solids (TSS) and sucrose percentages were obtained from foliar spraying twice with 150 ppm of CA. In addition, highest apparent juice purity percentages were obtained from spraying twice with 150 ppm of SA in the first season and spraying twice with 150 ppm of CA in the second season. Fertilizing with 48 kg K_2O/fed recorded highest growth attributes, root and top yields and its components in both seasons. While, fertilizing with 36 kg K_2O/fed came in the second rank. Highest sugar yield/fed, TSS%, sucrose% and apparent juice purity% were obtained from fertilizing with 36 kg K_2O/fed in both seasons. In order to maintain the agricultural resources, reduce environmental pollution and maximum sugar beet growth, yields and its attributes, it could be recommended that spraying twice with the mixture of antioxidants of 150 ppm of each of AA+SA+CA and mineral fertilizing with 36 kg K_2O/fed as a top dressing application.

Key words: Sugar beet, foliar application, antioxidants, ascorbic acid, salicylic acid, citric acid, potassium fertilizer levels, growth, yields, quality

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is considered the second important for edible sugar supply in Egypt. Approximately, 66% of local needs of white sugar in Egypt are produced locally from sugar cane and sugar beet while the rest is imported from foreign countries. So that, increasing cultivated area and sugar production from unit area is considered one of the important national targets to minimize gap between sugar consumption and production. Improvement of sugar beet production can be achieved through foliar application of antioxidants and fertilizing by potassium.

Foliar application using antioxidants such as Ascorbic Acid (AA) which is a small water-soluble antioxidant molecule, that acts as a primary substrate in the cyclical pathway for detoxification and neutralization of superoxide radicals and singlet oxygen (Noctor and Foyer, 1998). Ascorbic acid (vitamin C) is one of the key products of D-glucose metabolism which synthesized in higher plants. It has been shown to play multiple roles in plant growth and development, i.e., cell division, cell wall expansion (Pignocchi and Foyer, 2003), electron transport system (El-Kobisy *et al*., 2005) and other developmental processes. The beneficial effects of ascorbic acid upon growth and productivity have been reported on many field crops i.e., sugar beet (Salem *et al*., 2000), cotton (Ghourab and Wahdan, 2000), wheat (Abdel-Hameed *et al*., 2004; Bakry *et al*., 2012), sunflower (El-Gabas, 2006) and maize (Darvishan *et al*., 2013). Orabi and Mekki (2008) found that foliar spraying of sugar beet plants with ascorbic acid (at the rate of 400 ppm) resulted in an increases in all growth characters, yields and quality parameters as compared with untreated plants.

Salicylic Acid (SA) is considered as a hormone like substance which acting an important role in regulating a number of physiological processes such as stomata closure, ion uptake and transport, inhibition of ethylene biosynthesis, transpiration, membrane permeability, photosynthesis and growth (Abdel-Wahed *et al*., 2006; Ashraf *et al*., 2010), nitrate metabolism, flowering and stress tolerance (Hayat *et al*., 2007). Application of SA stimulated tolerance in plants to many biotic and abiotic stresses counting fungi, bacteria and viruses, chilling, salinity, drought and heat (Khan *et al*., 2010). The effects of SA on physiological processes of plants depend on its concentration, plant type, stage of plant growth and environmental conditions. Accordingly, SA can have useful or inhibitory effects on plant physiological processes. In this concern; Khodary (2004) stated that SA enhanced the maize salt tolerance in terms of improving the measured plant growth criteria. The SA appears to stimulate maize salt tolerance by activating the photosynthetic process. El-Housini *et al*. (2014) reported that foliar spraying with 100 mg L^{-1} salicylic acid gave the highest significant values for growth characters of stevia plants.

Citric Acid (CA) is an organic compound belong to carboxylic acids group. It is one of a series of compounds involved in the physiological oxidation of fats, proteins and carbohydrates to CO_2 and water. In this respect, Abd-Allah *et al*. (2007) indicated that plant height, yield and its components as well as protein content in common bean, pea and faba bean were increased with application of citric acid. Sheteawi (2007) stated that ascorbic and citric acids appeared to act in a concert which indicates a complete set of antioxidant defense system, rather than protection by a single antioxidant under stressful conditions. Fawy and Atyia (2012) showed that yield parameters of wheat were increased with increasing foliar application rates of citric acid from 100 up to 300 ppm. Maleki *et al*. (2013) revealed that foliar spray of citric acid significantly increased shoot fresh weight, shoot dry weight, root fresh weight and root dry weight of sweet basil.

Potassium (K) is participate in many important functions in plants i.e., photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use (Marschner, 1995; 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, with equilibrium with other essential plant nutrients (Yu-Ying and Hong, 1997). Abdel-Mawly and Zanouny (2004) found that TSS and purity percentages of root juice, root and top yields of sugar beet increased as potassium fertilizer levels increased up to 72 kg K_2O/fed. Amer *et al*. (2004) revealed that fertilizing sugar beet plants with potassium fertilizer at the level of 90 kg K_2O/fed caused a significant increase in root and sugar yields/fed and quality traits (TSS, sucrose and purity percentages). 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 K_2O/fed). On the other hand, the highest values of TSS and sucrose percentages were obtained by application of 48 kg K_2O/fed. Abdel-Motagally and Attia (2009), Gobarah *et al.* (2011) and Salami and Saadat (2013) reported that application of 114 kg K_2O/ha associated with significant increases in root and foliage weights and root dimensions, sucrose and purity percentages, root, top and sugar yields per hectare. Seadh (2012) stated that increasing potassium fertilizer levels from 50 up to 100% of the recommended dose significantly affected all studied characters and the most effective treatment on growth, yield and quality characters was application 100% of the recommended potassium fertilizer dose (48 kg K_2O/fed). El-Sarag and Moselhy (2013) showed that highest sugar beet yields (top, root and sugar/ha) were obtained by adding 140 kg K_2O ha^{-1}. While, the maximum sucrose content was achieved by adding 100 K_2O kg ha^{-1}. Hussain *et al.* (2014) found that application of 150 kg K_2O ha^{-1} promoted sugar beet top yield by 49.2% and fresh root yield by 45.0% over control treatment (0 kg ha^{-1}). Neseim *et al.* (2014) recommended that application 100 kg potassium sulphate 48% K_2O/fed to recorded highest root and sugar yields, sucrose percentage and the lowest impurities percentage.

There is no accurate and comprehensive information regard to the effect of antioxidants as foliar application in combination with potassium fertilizer on quantity and quality parameters of sugar beet. This research intended to study the effect of foliar application treatments with antioxidants and potassium fertilizer levels on sugar beet growth, yields and its components as well as quality parameters under the environmental conditions of Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

A field experiment was carried out twice at Tag Al-Ezz, Agricultural Research Station Farm, Dakahlia Governorate, Agricultural Research Center, Egypt (+7 m altitude, 31′36″ latitude and 30′57″ longitude) during 2012/2013 and 2013/2014 seasons to decide the impact of antioxidants foliar application and potassium fertilizer levels on sugar beet (*Beta vulgaris* L.) cv. Raspoly growth, yields, its components and quality parameters.

Experimental design was laid-out in strip-plot design with four replications. The vertical plots were included with five foliar application treatments with antioxidant materials (150 ppm) as follows: (1) Without spraying (control treatment). (2) Spraying with ascorbic acid (AA). (3) Spraying with salicylic acid (SA). (4) Spraying with citric acid (CA). (5) Spraying with the mixture of Ascorbic Acid (AA) + Salicylic Acid (SA) + Citric Acid (CA). Foliar spraying was conducted by hand sprayer twice at the aforementioned levels after 50 and 70 days from sowing (DFS). Ascorbic acid, salicylic acid and citric acid anhydrous were produced by El-Nasr Pharmaceutical Chemicals Co., Abu Zaabal, Egypt and obtained from El-Gomhouria Company for Trading Pharmaceutical Chemical and Medical. The horizontal plots were assigned to four levels of potassium fertilizer levels i.e., 12, 24, 36 and 48 kg K_2O/fed "fed or feddan = 4200 m^2") as top dressing. Potassium fertilizer in the form of potassium sulphate (48% K_2O) 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 site was clay loam in texture. Both physical and chemical analysis of soil were estimated according to the standard methods and the corresponding data is presented in Table 1. Each experimental basic unit included 5 ridges, each of 60 cm apart and 3.5 m long, comprising an area of 10.5 m^2 (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% P_2O_5) was applied during soil

Table 1: Physical and chemical soil characteristics of the experimental site during 2012/2013 and 2013/2014 seasons

Physical characteristics	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	pH soil paste	EC (dS m^{-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

preparation at the level of 150 kg/fed. Nitrogen fertilizer in the form of urea (46.0% N) at level of 90 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 15th and 20th 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 according to ARC recommendation.

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:

- Root fresh weight (g/plant)
- Foliage fresh weight (g/plant)
- In 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 Rate (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 Rate (RGR) in g/g/week was determined according to Radford (1967), using the following equation:

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1}$$

- Net Assimilation Rate (NAR) in g/m^2/week as determined according to Watson (1958), using the following equation:

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

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 (210 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 maceleveld roots according to the method of Carruthers and Oldfield (1961)
- Apparent purity percentage (%). It was determined as a ratio between sucrose% and TSS% of roots as the method outlined by Carruthers and Oldfield (1961)

Plants that produced from the two inner ridges of each plot at harvesting time were collected and cleaned. Roots and tops were sepaleveld and weighted in kg, 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

Statistical analysis: All obtained data was 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 (MSTAT-C with MGRAPH version 2.10, Crop and Soil Sciences Department, Michigan State University, USA) developed by Russell (1986). Least Significant Difference (LSD) method was used to test the differences between treatment means at 5% level of probability as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Effect of foliar application with antioxidants: Foliar application treatments with antioxidants i.e., without spraying, spraying with Ascorbic Acid (AA), Salicylic Acid (SA), Citric Acid (CA) and the mixture of AA+SA+CA significantly affected growth attributes, yields, its components and quality parameters of sugar beet in both seasons, with exception Relative Growth Rate (RGR) in the second season (Table 2-5). From obtained results, it could be noticed that foliar spraying twice after 50 and 70 days from sowing with antioxidants (AA, SA or CA) individually or as a

Table 2: Root and foliage fresh weights and leaf area index at 120 and 150 days from sowing as affected by foliar application treatments with antioxidants and potassium fertilizer levels as well as their interaction during 2012/2013 and 2013/2014 seasons

	Root fresh weight (g)				Foliage fresh weight (g)				LAI			
	120 DFS		150 DFD		120 DFS		150 DFD		120 DFS		150 DFD	
Treatments	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Foliar application with antioxidants												
Without (control)	333.1	337.9	465.7	470.4	347.8	350.3	480.2	486.4	4.44	4.48	5.46	5.49
Ascorbic acid (AA)	385.5	390.6	520.9	525.3	387.4	390.1	553.2	559.8	4.91	4.96	5.88	5.90
Salicylic acid (SA)	374.2	377.7	505.5	507.8	376.6	379.5	535.0	534.1	4.82	4.85	5.78	5.79
Citric acid (CA)	366.3	370.2	496.2	499.5	360.9	364.2	517.8	521.6	4.70	4.72	5.64	5.66
Mixture of AA+SA+CA	397.3	399.1	543.3	546.2	399.1	400.0	568.0	570.5	5.04	5.06	6.08	6.11
LSD at 5%	4.1	3.4	2.2	3.1	1.6	1.6	2.0	1.7	0.02	0.02	0.03	0.03
Potassium fertilizer levels												
12 kg K_2O/fed	353.6	357.9	470.7	474.8	362.0	364.2	467.9	472.9	4.47	4.51	5.63	5.66
24 kg K_2O/fed	368.0	371.5	497.4	501.9	372.8	375.9	526.6	530.5	4.72	4.75	5.74	5.77
36 kg K_2O/fed	378.4	382.0	522.2	525.2	378.8	381.4	554.4	558.1	4.90	4.95	5.82	5.85
48 kg K_2O/fed	385.2	389.0	535.0	537.4	383.8	385.9	574.6	576.4	5.04	5.05	5.88	5.89
LSD at 5%	3.9	3.2	2.1	2.7	1.1	1.4	1.7	1.8	0.02	0.02	0.02	0.02
Interaction	*	*	*	*	*	*	*	*	*	*	*	*

LAI: Leaf area index, DFS: Days after showing, *Significant at probability level 5%

Table 3: Crop growth rate, relative growth rate and net assimilation rate as affected by foliar application treatments with antioxidants and potassium fertilizer levels as well as their interaction during 2012/2013 and 2013/2014 seasons

	CGR (g week^{-1})		RGR (g g^{-1} week^{-1})		NAR (g m^{-2} week^{-1})	
Treatments	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Foliar application with antioxidants						
Without (control)	10.67	10.69	0.071	0.070	17.26	17.22
Ascorbic acid (AA)	12.27	12.50	0.076	0.076	19.03	19.25
Salicylic acid (SA)	11.82	11.96	0.075	0.075	18.65	18.79
Citric acid (CA)	10.89	10.89	0.075	0.075	18.42	18.29
Mixture of AA+SA+CA	12.72	12.89	0.076	0.077	19.13	19.32
LSD at 5%	0.43	0.58	0.003	NS	0.66	0.84
Potassium fertilizer levels						
12 kg K_2O/fed	11.45	11.57	0.073	0.074	18.05	18.33
24 kg K_2O/fed	11.60	11.68	0.075	0.074	18.44	18.36
36 kg K_2O/fed	11.80	11.85	0.075	0.074	18.53	18.56
48 kg K_2O/fed	11.84	12.04	0.076	0.076	18.98	19.05
LSD at 5%	NS	0.25	NS	0.002	NS	0.42
Interaction	NS	NS	NS	NS	NS	NS

NS: Non significant, CGR: Crop growth rate, RGR: Relative growth rate, NAR: Net assimilation rate

Table 4: Root and foliage fresh weights, root length and diameter at harvesting as affected by foliar application treatments with antioxidants and potassium fertilizer levels as well as their interaction during 2012/2013 and 2013/2014 seasons

	Root fresh weight (g)		Foliage fresh weight (g)		Root length (cm)		Root diameter (cm)	
Treatments	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Foliar application with antioxidants								
Without (control)	638.1	647.8	371.8	393.7	25.62	25.93	9.18	9.43
Ascorbic acid (AA)	790.9	798.1	606.2	628.7	31.06	32.06	10.78	11.43
Salicylic acid (SA)	735.3	726.8	525.6	539.3	29.50	30.87	10.59	10.78
Citric acid (CA)	681.8	693.7	467.1	490.0	28.18	30.06	9.93	10.50
Mixture of AA+SA+CA	838.1	826.2	650.3	667.5	32.75	33.12	12.31	13.03
LSD at 5%	20.1	22.9	23.4	23.7	0.68	0.77	0.41	0.63
Potassium fertilizer levels								
12 kg K_2O/fed	659.7	654.3	385.2	420.0	25.85	27.30	9.15	9.67
24 kg K_2O/fed	712.5	717.5	513.5	537.5	28.75	30.05	10.12	10.90
36 kg K_2O/fed	773.5	774.5	588.5	595.0	31.10	31.75	11.20	11.25
48 kg K_2O/fed	801.7	808.0	609.7	623.0	32.00	32.55	11.77	12.32
LSD at 5%	20.1	19.9	21.2	23.6	0.49	0.56	0.33	0.48
Interaction	*	*	*	*	NS	NS	NS	NS

*Result are significant at 5% level of probability, NS: Non significant

mixture had an impact in a gradual increase in growth attributes, yields and yield components 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 plants with the mixture of antioxidants (AA+SA+CA at the level of 150 ppm of each one) in both seasons. However, spraying sugar beet plants with AA at the level of 150 ppm came in the second rank after aforementioned treatment, followed by spraying with 150 ppm of SA, then spraying with 150 ppm of CA and control treatment in the two growing seasons.

Table 5: Total soluble solids, sucrose and apparent purity percentages, root, top and sugar yields/fed as affected by foliar application treatments with antioxidants and potassium fertilizer levels as well as their interaction during 2012/2013 and 2013/2014 seasons

	TSS (%)		Sucrose (%)		Apparent purity (%)	
Treatments	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Foliar application with antioxidants						
Without (control)	23.15	23.90	19.21	19.71	82.98	82.46
Ascorbic acid (AA)	22.31	23.43	18.37	19.28	82.34	82.29
Salicylic acid (SA)	23.43	23.96	20.28	20.96	86.57	87.50
Citric acid (CA)	24.15	24.18	20.68	21.46	85.63	88.75
Mixture of AA+SA+CA	23.87	24.15	20.40	21.03	85.46	87.08
LSD at 5%	0.34	0.27	0.32	0.42	1.30	1.92
Potassium fertilizer levels						
12 kg K_2O/fed	22.37	23.00	18.80	19.275	84.02	83.82
24 kg K_2O/fed	23.72	24.27	20.12	20.925	84.79	86.18
36 kg K_2O/fed	24.25	24.70	20.75	21.400	85.53	86.62
48 kg K_2O/fed	23.20	23.75	19.50	20.375	84.05	85.80
LSD at 5%	0.29	0.21	0.31	0.350	1.19	1.23
Interaction	NS	NS	NS	NS	NS	NS

	Root yield (t/fed)		Top yield (t/fed)		Sugar yield (t/fed)	
Treatments seasons	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Foliar application with antioxidants						
Without (control)	24.606	25.188	11.569	11.950	4.731	4.972
Ascorbic acid (AA)	27.812	28.281	14.913	15.306	5.115	5.455
Salicylic acid (SA)	26.669	27.344	14.325	14.838	5.412	5.734
Citric acid (CA)	25.825	26.369	13.325	13.794	5.343	5.665
Mixture of AA+SA+CA	29.056	29.575	16.650	17.144	5.929	6.225
LSD at 5%	0.161	0.135	0.225	0.215	0.082	0.097
Potassium fertilizer levels						
12 kg K_2O/fed	25.105	25.590	9.385	9.775	4.719	4.934
24 kg K_2O/fed	25.865	26.545	12.635	13.020	5.205	5.553
36 kg K_2O/fed	27.485	28.155	16.650	17.235	5.702	6.026
48 kg K_2O/fed	28.720	29.115	17.955	18.395	5.601	5.931
LSD at 5%	0.271	0.233	0.297	0.262	0.109	0.134
Interaction	*	*	*	*	*	*

NS: Non significant, *Significant at 5% probability level, TSS: Total soluble solids

As the same previous trend, the highest values of root fresh weight (838.1 and 826.2 g), foliage fresh weight (650.3 and 667.5 g), root length (32.75 and 33.12 cm), root diameter (12.31 and 13.03), root yield (29.056 and 29.575 t/fed), top yield (16.650 and 17.144 t/fed) and sugar yield (5.929 and 6.225 t/fed) at harvesting were produced from foliar spraying sugar beet plants twice with the mixture of 150 ppm of each of AA+SA+CA with an increase of 31.3 and 27.5 in root fresh weight, 74.9 and 69.5 in foliage fresh weight, 27.83 and 27.73 in root length, 34.10 and 38.18 in root diameter, 18.085 and 17.417 in root yield, 43.919 and 43.464 in top yield and 25.322 and 25.201 in sugar yield as compared with control treatment (without spraying) in the first and second seasons, respectively. Spraying beet plants twice with AA at the level of 150 ppm ranked after aforesaid treatment, followed by spraying twice with SA at the level of 150 ppm, then spraying twice with CA at the level of 150 ppm and lastly the control treatment concerning root and foliage fresh weights, root length and diameter and root and top yields/fed in both seasons. Moreover, regarding sugar yield/fed, spraying beet plants twice with SA at the level of 150 ppm ranked after spraying beet plants twice with the mixture of 150 ppm of each of AA+SA+CA, followed by spraying twice with 150 ppm of CA, then spraying twice with 150 ppm AA and lastly the control treatment in both seasons.

The characteristics of root quality has taken a relatively different trend, where the highest Total Soluble Solids (TSS) and sucrose percentages were obtained from foliar spraying beet plants twice with 150 ppm of CA, followed by spraying twice with the mixture of 150 ppm of each of AA+SA+CA, spraying twice with 150 ppm of SA, then control treatment (without spraying) and lastly spraying twice with 150 ppm of AA in both seasons. Whereas, highest apparent juice purity percentages were obtained from spraying twice with 150 ppm of SA in the first season and spraying twice with 150 ppm of CA in the second season, followed by spraying twice with 150 ppm of CA in the first season and spraying twice with 150 ppm of SA in the second season, spraying twice with the mixture of 150 ppm of each AA+SA+CA, then control treatment (without spraying) and lastly spraying twice with 150 ppm of AA in both seasons.

The advantageous effect of spraying sugar beet plants with the mixture of Ascorbic Acid (AA), Salicylic Acid (SA) and Citric Acid (CA) in growth attributes, yields and yield components probably due to the combination in the desired impact of them. Since, ascorbic acid plays multiple roles in plant growth and development, such as cell division, cell wall expansion (Pignocchi and Foyer, 2003), the electron transport system (El-Kobisy *et al*., 2005) and other developmental processes. However, salicylic acid is considered as a hormone like substance which acting an important role in regulating a number of physiological processes such as stomata closure, ion uptake and transport, inhibition of ethylene biosynthesis, transpiration, membrane permeability, photosynthesis and growth (Abdel-Wahed *et al*., 2006; Ashraf *et al*., 2010), nitrate metabolism and stress tolerance (Hayat *et al*., 2007). While, citric acid is one of a series of compounds involved in the physiological oxidation of fats, proteins and carbohydrates to CO_2 and water. Many researchers confirmed these results, including Orabi and Mekki (2008) found that foliar sprayed sugar beet plants with ascorbic acid resulted in an increase in all growth characters, yields and quality parameters as compared with untreated plants. Fawy and Atyia (2012) showed that the yield parameters of wheat were increased with increasing rates of citric acid as foliar application from 100 up to 300 ppm. Maleki *et al*. (2013) revealed that foliar spraying of citric acid significantly increased shoot fresh weight, shoot dry weight, root fresh weight and root dry weight of sweet basil. El-Housini *et al*. (2014) reported that foliar spraying with salicylic acid at 100 mg L^{-1} yielded the highest significant values for growth characters of stevia plants.

Effect of potassium fertilizer levels: Potassium fertilizer levels (12, 24, 36 and 48 kg K_2O/fed) as top dressing had a significant effect on growth attributes, yields, its components and quality parameters of sugar beet in both seasons, excluding Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) in the first season as shown in Table 2-5. 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 12-24, 36 and 48 K_2O/fed in both seasons.

Fertilizing sugar beet plants with the highest level of potassium fertilizer (48 kg K_2O/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 K_2O/fed came in the second rank, then 24 kg K_2O/fed and 12 kg K_2O/fed which resulted in the lowest values of previously mentioned characters in both seasons.

Fertilizing sugar beet with 48 kg K_2O/fed (the highest level of potassium fertilizer in this study) as top dressing significantly increased root, top and sugar yields/fed and caused increases estimated by 14.400 and 13.775% in root yield, 91.316 and 88.184% in top yield and 18.690 and 20.207% 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 K_2O/fed significantly increased root, top and sugar yields/fed and produced increases about 9.480 and 10.023% in root yield, 77.411 and 76.317% in top yield and 20.831 and 22.132% in sugar yield as compared with control treatment (0 kg K_2O/fed) in the first and second seasons, respectively. Whereas, fertilizing sugar beet plants with 24 kg K_2O/fed as a soil addition significantly increased root and top yields/fed and exhibited increases amounted by 3.027 and 3.732% in root yield, 34.630 and 33.197% in top yield and 10.299 and 12.546% in sugar yield compared with 12 kg K_2O/fed in the first and second seasons, respectively.

Increasing potassium fertilizer levels from 12-24 and 36 K_2O/fed associated with gradual and significant increases in quality parameter (TSS, sucrose and apparent juice purity percentages) in both growing seasons. Whereas, increasing potassium fertilizer levels from 36 to 48 K_2O/fed associated with significant decreases in all studied quality parameters in both seasons, except apparent juice purity percentage in the second season only. Hence, the optimum percentages of Total Soluble Solids (TSS), sucrose and apparent juice purity percentage were obtained from fertilizing sugar beet with 36 kg K_2O/fed as a top dressing in both seasons. On the other hand, 12 kg K_2O/fed treatment produced the lowest values of all quality parameters in both seasons. It is worth mentioning that fertilizing beet plants with 24 kg K_2O/fed ranked after fertilizing with the 36 kg K_2O/fed and followed by fertilizing with 48 kg K_2O/fed in both seasons.

These increases in growth attributes, yields, its components and quality parameters as a result of increasing potassium fertilizer levels 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; 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 parameters due to excessive application of potassium fertilizer (increasing potassium fertilizer level up to 48 kg K_2O/fed) may be ascribed to the fact that high amounts of potassium in roots decrease crystallization of percent of sucrose in juice during sugar extraction and loss of sucrose in molasses. These results are in concurrence with those stated by Seadh *et al.* (2007), Gobarah *et al.* (2011), Seadh (2012), El-Sarag and Moselhy (2013), Hussain *et al.* (2014) and Neseim *et al.* (2014).

Effect of interaction: The interaction between foliar application treatments with antioxidants and potassium fertilizer levels 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 at harvesting as well as root, top and sugar yields/fed in both seasons as presented in Table 2-5. The significant interaction between both studied factors on yields and its components were presented in Fig. 1-5.

As shown from results graphically illustrated in Fig. 1 the highest values of root fresh weight at harvesting were produced from foliar spraying sugar beet plants twice (at 50 and 70 DFS) with the mixture of 150 ppm of AA+SA+CA and top dressing of 48 kg K_2O/fed in both seasons. The second best interaction treatment was spraying with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 36 kg K_2O/fed in both seasons.

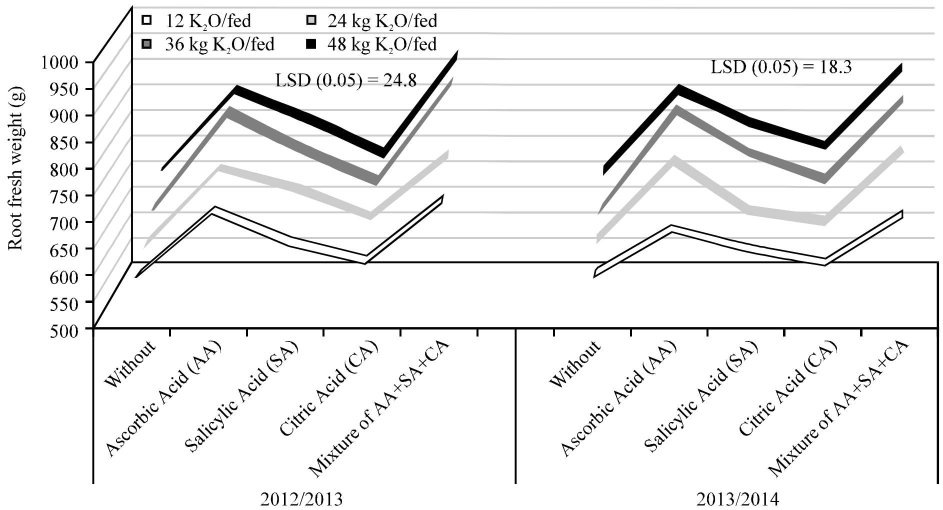

Fig. 1: Root fresh weight at harvesting as affected by the interaction between foliar application treatments with antioxidants and potassium fertilizer levels during 2012/2013 and 2013/2014 seasons

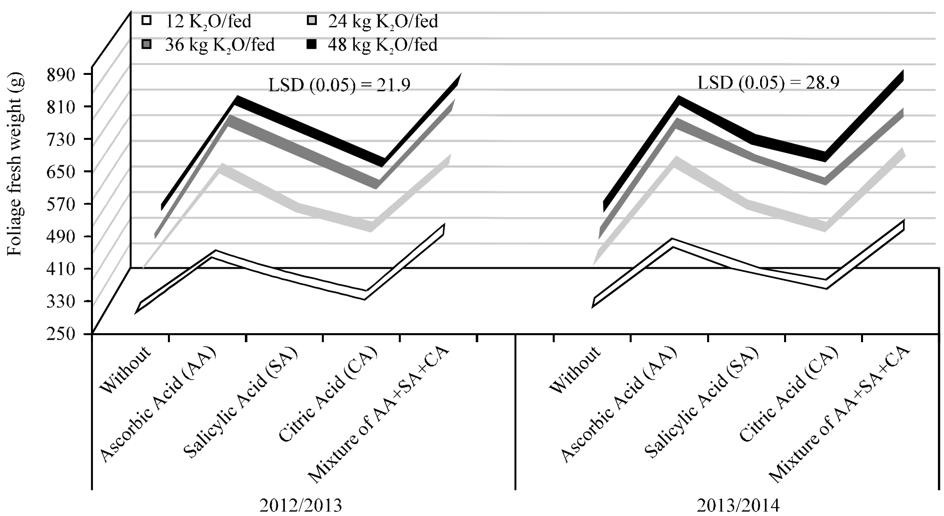

Fig. 2: Foliage fresh weight at harvesting as affected by the interaction between foliar application treatments with antioxidants and potassium fertilizer levels during 2012/2013 and 2013/2014 seasons

Foliage fresh weight at harvesting take the same trend that mentioned in root fresh weight, where the highest values of foliage fresh weight were obtained due to foliar spraying beet plants twice with the mixture of 150 ppm of each AA+SA+CA and fertilizing with 48 kg K_2O/fed in both seasons (Fig. 2). Also, spraying beet plants with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 36 kg K_2O/fed came in the second rank in both seasons.

From obtained results that graphically illustrated in Fig. 3, foliar spraying sugar beet plants twice at 50 and 70 days from sowing with the mixture of antioxidants 150 ppm of each of AA+SA+CA and mineral fertilizing with 48 kg K_2O/fed as a soil application resulted in the highest

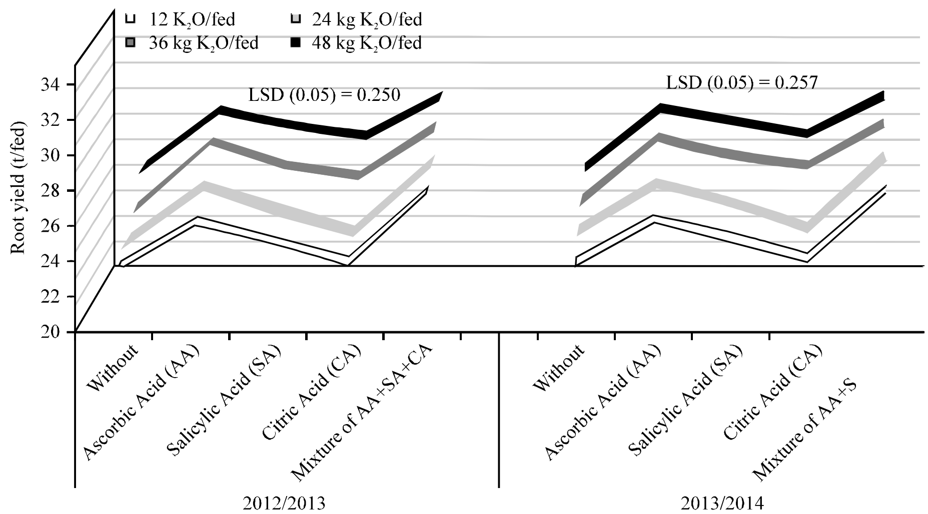

Fig. 3: Root yield as affected by the interaction between foliar application treatments with antioxidants and potassium fertilizer levels during 2012/2013 and 2013/2014 seasons

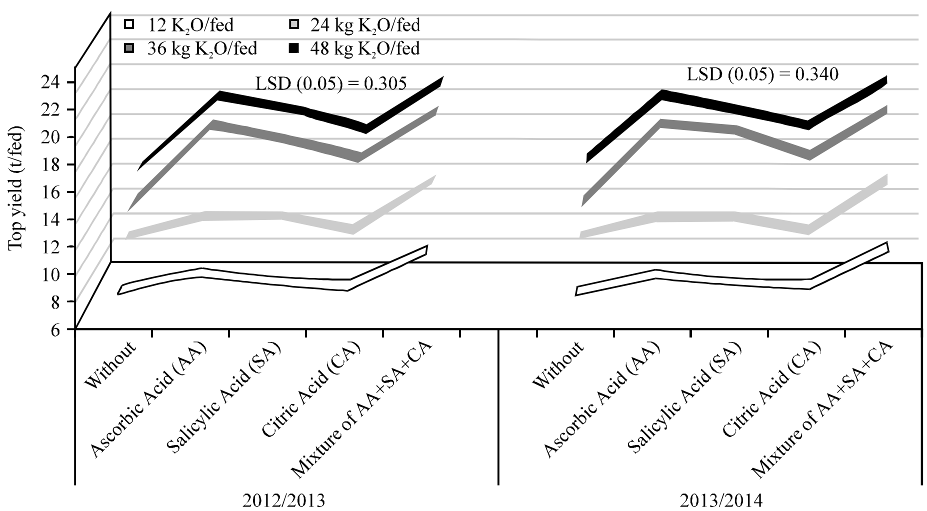

Fig. 4: Top yield as affected by the interaction between foliar application treatments with antioxidants and potassium fertilizer levels during 2012/2013 and 2013/2014 seasons

values of root yield/fed which reached about 30.525 and 30.900 t/fed in the first and second seasons, respectively. Spraying beet plants twice with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 36 kg K_2O/fed ranked after aforementioned interaction treatment in both seasons. It is worth noting, foliar spraying sugar beet plants with the mixture of antioxidants of 150 ppm of each of AA+SA+CA 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 antioxidants) in both seasons.

Likewise, top yield/fed had similar trend that mentioned in root yield/fed. Whereas, the highest values of top yield/fed were produced from foliar spraying beet plants twice with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 48 kg K_2O/fed in both seasons (Fig. 4). The

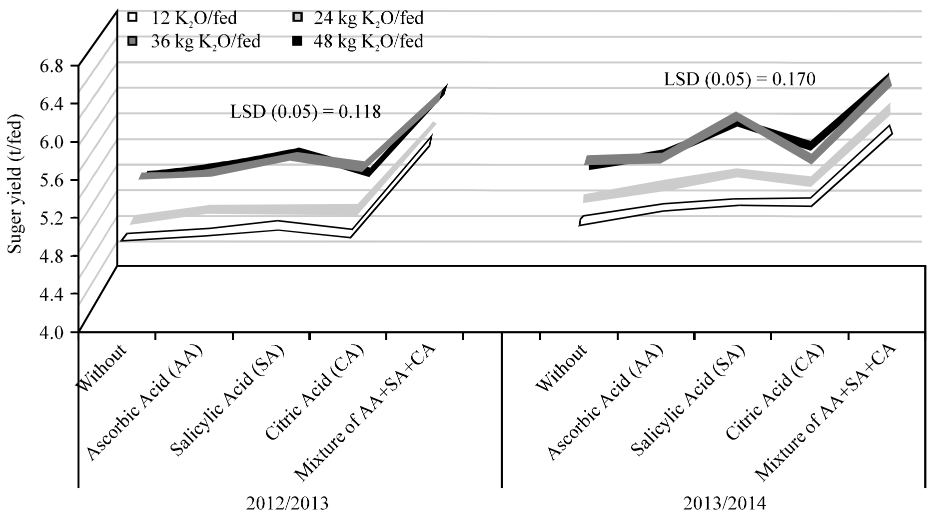

Fig. 5: Sugar yield as affected by the interaction between foliar application treatments with antioxidants and potassium fertilizer levels during 2012/2013 and 2013/2014 seasons

second best interaction treatment produced by spraying with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 36 kg K_2O/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 the mixture of antioxidants 150 ppm of each of AA+SA+CA and mineral fertilizing with 36 kg K_2O/fed as a soil application in both seasons (Fig. 5). While, spraying beet plants twice with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 48 kg K_2O/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 inputs and environmental pollution was foliar spraying sugar beet plants twice at 50 and 70 DFS with the mixture of antioxidants of 150 ppm of each of 150 ppm of each of AA+SA+CA and mineral fertilizing with 36 kg K_2O/fed as top dressing application.

CONCLUSION

It can be concluded that maximum sugar beet growth, yields and its components were resulted from foliar spraying twice with the mixture of 150 ppm of each of AA+SA+CA and fertilizing with 48 kg K_2O/fed. However, to maintain the agricultural resources and reduce environmental pollution, it could be recommended that foliar spraying of sugar beet plants twice at 50 and 70 DFS with the mixture of antioxidants 150 ppm of each of AA+SA+CA and mineral fertilizing with 36 kg K_2O/fed as top dressing application.

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