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Boron Foliar Application in Relation to Sweet Potato Productivity

Sharaf-Eldin, M. A.[1]; M. A. AbdAlla[2]; S. A. Mostafa[1] and W. E. Montaser[1]
[1]Horticulture Department, Faculty of Agriculture, Kafrelsheikh University.
[1]E-mail: maseldeen@yahoo.com
[2]Vegetation Department, Horticulture Institute, Agricultural Research Center, Giza, Cairo, Egypt.

ABSTRACT

This study was carried out to evaluate the effect of spray by boron at different concentrations (0, 10, 20, 30, 40, 50 ppm) for one time (60 days after transplanting, DAT) or two times (60 and 90 DAT) on sweet potato plant, Abees cv. The experiment was conducted at Kafr El-Sheikh governorate that counted the main growing area in Egypt, under clay soil conditions. The results indicated that repeat spraying of B at 60 and 90 DAT by the concentration of 40 or 50 ppm increased vegetative growth parameters (plant length, number of branches and plant leaf area) and growth attributes (leaf area index, absolute growth rate and net assimilation rate). Also, morphological quality of the tuberous root (diameter, length and shape index) as well as yield with high average of marketable yield percentage were improved.

Keywords: *Ipomoea batatas,* boron concentrations, foliar application, growth attributes, quality, yield

INTRODUCTION

Sweet potato *(Ipomoea batatas* (L.) Lam.) is an important crop in tropical and subtropical regions overall the world. In Egypt, it is grown in the summer season with an average area of 29106 fed with an annual production of about 385499 tons (Bulletin of the FAO Agricultural web statistics, 2016). Kafr El-Sheikh governorate is one of the most important locations for growing sweet potato in Egypt. The surface irrigation is used traditionally at this area which could cause boron leaching (Hall, 2008). Limit crop production was reported due to boron deficiency (Kaur and Nelson, 2015; Haytova, 2013). Boron requirements for vegetables are more than in the other crops (Dursun, 2010), and may increase production efficiency and quality (Haytova, 2013). Boron is important for biochemical, cell elongation and physiological changes (Brown and Hu, 1996; Imtiaz *et al*., 2010 and Müller *et al*., 2011), and enhancing sugar metabolism (Marschner, 2012). On the contrary, the toxicity may be habits because there is narrow rang among deficiency and toxicity. So, foliar applications may be useful and facilitated to the rapid absorption of mineral elements (Kerin, 2003), foliar doses are strongly differ according to the crop kind. Sweet potato seems to be more susceptible to boron (B) deficiency than many other crops (O'Sullivan *et al*., 1997). Moreover, storage roots development may be greatly reduced or completely inhibited by severe B deficiency (Pillai *et al.* 1986). B deficiency mostly decrease storage roots quality. They appear with blunt-ended, short, may split and overgrow, producing cankers and deformities (O'Sullivan *et al*., 1997). Also, the skin may be rough and may wrinkle towards the ends. Even though it seems there is no available information on soil B in relation to B deficiency in sweet potato. Overview, there has been limited researches on B application with suitable concentration on sweet potato. Although, frequently B application on different growth stages achieved positive effect (Armin and Asgharipour, 2012; Abdallah and Mekdad, 2015; Dewdar *et al*., 2015). So, the main goal of this study was to investigate different boron concentrations and times as foliar spray on sweet potato, and explores its effect on growth, yield and quality under clay soil conditions.

MATERIALS AND METHODS

This study was carried out during the summer seasons of 2017 and 2018 on sweet potato cv. Abees in the farm of the Faculty of Agriculture, Kafrelsheikh University, Egypt. Some physical and chemical properties of the soil characteristics were presented in Tables 1 and 2. The metrological data during the studied periods were presented in Table 3.

The top and sub top stem cuttings of sweet potato cv Abees with 25 cm length were transplanted manually on the 8th of May by using 25 cm spacing between the plants and 70 cm spacing between rows. Each experimental unit consisted of five ridges and was separated by one ridge between each other's. Ammonium nitrate, calcium super phosphate and potassium sulphate were used as sources for N, P and K (respectively) with 20 kg/fed of N, 40 kg/fed of P2O5, and 72 kg/fed of K2O. The other culture practices; e.g., weeds and pests control were applied according to the recommendations of the Ministry of Agriculture. The recommendations of Sharaf-Eldin (2002) in the same experiment site were used for cuttings preparation and transplanting. The plants were harvested after 140 days of transplanting.

Table 1. Some physical properties of the experiment soil (0-30 cm)

Particle distribution,%			Texture class	Bulk density, Kg/m^3	Field capacity, %	Wilting point, %	Available water,%
Sand	Silt	Clay					
21.55	26.91	51.54	Clay	1298	41.26	21.29	19.97

Table 2. Some chemical properties of the experiment soil

EC ds/m	ESP	pH	Soluble cations, (ppm)				Soluble anions, meg/l					
			Ca^{++}	Mg^{++}	Na^{++}	K^{+}	Co_3^{-}	Hco_3^{-}	Cl^{-}	so_4^{--}	OM%	$CaCo_3$
1.85	5.42	8.1	143.4	65.3	209.4	22.2	0.00	7.90	5.0	11.45	0.87	1.58
	Available elements (ppm)				N		P		K		B	
					30.80		1.6		522.8		0.93	

Soil analysis were determined by using soluble soil saturation extent.
B analysis were determined by using hot water– extractable with spectrophotometer using the azomethine-H method.

Table 3. Some metrological data for Kafr El-Sheikh area during 2017 and 2018 seasons

Month	T (°C)			RH%			Pan Evap.
	Max	Min	Mean	Max	Min	Mean	mm/day
				2017			
May	31.4	21.8	26.6	75.0	45.8	60.4	613
June	32.4	24.0	28.2	74.6	51.3	62.95	661
July	32.3	24.3	28.3	79.6	54.7	67.15	611
Aug.	33.8	24.8	29.3	83.6	60.5	72.05	513
Sept.	32.5	22.9	27.7	81.0	56.6	68.8	382
Oct.	27.8	19.4	23.6	76.2	57.4	66.8	287
				2018			
May	30.5	19.6	25.05	77.2	48.6	62.9	587.1
June	32.7	20.6	26.65	52.3	86.3	69.3	655.5
July	33.2	23.6	28.4	83.2	55.1	69.15	772.9
Aug.	34.1	21.8	27.95	92.4	53.5	72.95	813.5
Sept.	32.5	20.8	26.65	87.6	52.2	69.9	664.5
Oct.	29.8	18.8	24.3	80.9	53.4	67.15	451.1

Source: meteorological station at 'Sakha' 31 07Nlatitude, 30 57 E longitude and with an elevation of about 6 meters above mean sea level.

The experiment was layout in a split-plot design in three replicates. Two applications times of boron were conducted, one time (S1) after 60 days of transplanting or two times (S2) after 60 and 90 days of transplanting were put in the main-plots. Six boron concentrations; 0 (distilled water only), 10, 20, 30, 40 and 50 ppm were arranged in the sub-plots. Boric acid (17.5% B) was used as a source for boron.

Five plants were randomly chosen from each experimental unit to determine vegetative growth parameters, i.e., plant length (cm), number of branches/ plant, plant leaf area (m^2) and chlorophyll content. Plant leaf area was measured by a portable leaf area meter (LI-3100 - LI-COR, Lincoln, Nebraska, USA). Chlorophyll content was determined by the SPAD-501 (Minolta Corp, Ramsey, N.J.) which used for total greenness measurement in the first fully expended leaves (the fifth leaf from the shoot growing tip) without destroying them. The taken samples for growth analysis parameters were, also, used for calculated the growth attributes according to the formulas of (McCollum, 1978). Leaf area index (LAI) was determined according to the following formula: LAI = Leaf area per plant/land area per plant. However, absolute growth rate (AGR) is defined as the increase in vine dry matter per unit of time (g/day) as follows: AGR= $(W_2\text{-}W_1)/(T_2\text{-}T_1)$ Where: W_1 and W_2 refer to dry weight for two samples at time T_1 and T_2 (90-120 days after transplanting).

Also, Net assimilation rate (NAR) is distinct as the increase in vine dry material per unit of leaf area per unit of time: NAR= $[(W_2\text{-}W_1)/(T_2\text{-}T_1)] * [(InL_2\text{-}InL_1)/(L_2\text{-}L_1)]$ Where: W_1 and W_2 are dry weight of vine at time T_1 and T_2, L_1 and L_2 are leaf area at T_1 and T_2 (90-120 days after transplanting). Relative water content (RWC%) was calculated using the equation:= [(FW-DW/FW)]*100 where, FW are fresh weight of the vines and DW are dry weight of the vines (Chen *et al*., 2009).

At harvesting time, all tuberous roots were taken from each experimental unit to determine the total, marketable and non-marketable yields. However, 40 tubers were randomly taken from the marketable roots and used to determine average tuberous root length, diameter and weight. The marketable yield was taken from the roots without damages of insects, disease and mechanical and with suitable size according to the Egyptian market priority.

Statistical procedures were performed using the statistical software MSTAT. Data for both seasons were subjected to analysis of variance (ANOVA) and mean comparisons were made using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

RESULTS

1- Vegetative growth

Data in Table (4) indicate that spraying sweet potato plants by Boron twice at 60 and 90 days after transplanting (DAT) caused significant higher of plant length comparing to one time spray at 60 DAT only at sampling date of 120 DAT. However, the significant differences did not detect at sampling date (140 DAT) in the case of number of plant branches. Increasing B concentration from 0 to 50 ppm significantly increased plant length and number of branches at both sampling dates in both growing seasons. The interaction between spraying numbers and B concentrations was also significant in both growing seasons with noticed high values in the case of two times spray by the highest B concentration (50 ppm), while the control was the lowest.

Spraying B twice increased plant leaf area, however the differences were significant only in the second season (Table 5). The high B levels gained high leaf area comparing the control. Whereas, insignificant interaction between spraying numbers and B concentrations was noticed in both growing seasons.

In the case of leaves chlorophyll content, all studied treatments did not cause any significant changes (Table 5).

It was noticed that regardless spraying time, boron spray significantly decreased relative water content of leaves (Table 5). The control (without B) had the highest value in both growing seasons.

2- Growth attributes

The repetition of B application at 60 and 90 DAT significantly increased all studied growth attributes (leaf area index, absolute growth rate and net assimilation rate). Leaf area index was positively increased by increasing B concentration especially when the application was repeated twice with significant interaction in both growing seasons (Table 6).

Sweet potato plants produced more dry matter per day (AGR) when B was sprayed twice at 60 and 90 DAT with steadily increase through increasing B concentrations from 0 to 30 or 40 ppm then decreased at 50 ppm. These results were true in both growing seasons and the interaction was significant. Net assimilation rate took the same trend of absolute growth rate.

3- Yield and its components

Data in Table 7 illustrate the effect of B fertilization on yield parameters. Intermediate concentrations was more effective to produce wide roots especially when the applications were repeated twice at 60 and 90 DAT compering with untreated control. Likewise, average root length had the same trend of root diameter however, spraying numbers had significant effect only in the first season. Two sprays of B significantly increased root shape index only in the first season with progress decreases with increasing B concentrations was which the control gave the highest value with significant interaction.

Table 4. Effect of foliar spray by boron on plant length and number of branches/plant of sweet potato

Treatments	Plant length (cm)		No. of branches/plant	
	Days after transplanting			
	120	140	120	140
2017				
Spraying numbers				
S1 (60 DAT)	127.9 b	153.1 b	16.8 b	19.2 a
S2 (60 & 90DAT)	141.0 a	156.4 a	18.6 a	19.5 a
Boron concentrations (ppm)				
0	99.2 e	130.3 e	12.3 f	12.9 f
10	118.0 d	143.0 d	16.3 e	16.5 e
20	132.3 c	146.0 d	17.3 d	17.7 d
30	138.5 c	152.9 c	18.7 c	20.2 c
40	154.5 b	170.6 b	20.0 ab	22.9 b
50	164.6 a	186.1 a	21.0 a	25.7 a
Interaction				
S1 x 0	99.2 g	130 i	12.3 j	12.9 f
S1 x 10	111.0 f	141.5 h	15.6 i	16.5 e
S1 x 20	126.6 de	144.9 gh	16.3 hi	17.6 de
S1 x 30	134.3 cd	151.1 ef	17.6 fg	19.9 c
S1 x 40	140.0 c	167.8 d	19.0 de	22.8 b
S1 x 50	156.6 b	183.4 b	20.3 bc	25.3 a
S2 x 0	99.2 g	130 i	12.3 j	12.9 f
S2 x 10	125.0 e	144.5 gh	17.0 gh	16.6 e
S2 x 20	138.0 c	147.1 fg	13.3 ef	17.8d
S2 x 30	142.6 c	154.7 e	19.8 cd	20.5 c
S2 x 40	169.0 a	173.3 c	21.1 b	23.1 b
S2 x 50	172.6 a	188.8 a	22.5 a	26.2 a
2018				
Spraying numbers				
S1 (60 DAT)	129.6 b	155.0 b	16.0 b	20.7 a
S2 (60 & 90DAT)	150.7 a	160.0 a	18.2 a	21.3 a
Boron concentrations (ppm)				
0	97.5 e	124.1 f	11.0 e	15.3 d
10	113.0 d	131.2 e	14.8 d	19.0 c
20	128.1c	145.6 d	16.4 c	20.0 c
30	153.0 b	162.1 c	19.3 b	22.9 b
40	174.6 a	187.1 b	20.5 ab	232 b
50	175.0 a	196.9 a	21.0 a	25.0 a
Interaction				
S1 x 0	97.5 g	124.0 g	11.0 f	15.3 f
S1 x 10	100.3 g	128.5 fg	13.6 e	15.8 f
S1 x 20	109.3 f	136.6 e	16.5 cd	18.8 e
S1 x 30	155.0bc	162.0 c	18.3 bcd	19.3 de
S1 x 40	156.0 bc	178.9 b	18.3 bcd	19.7 de
S1 x 50	160.0 b	198.1 a	18.6 bc	20.4 d
S2 x 0	97.5 g	124.0 g	11.0 f	15.3 f
S2 x 10	125.6 e	133.9 ef	16.0 d	23.5 bc
S2 x 20	147.0 d	154.6 d	16.5 cd	23.3 bc
S2 x 30	151.0 cd	162.5 c	20.3 b	23.1 c
S2 x 40	193.3 a	193.3 a	22.6 a	24.7 ab
S2 x 50	190.0 a	195.8 a	23.3 a	25.4 a

Means with the same letter within the same column are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests.

Table 5. Effect of foliar spray by boron on plant leaf area, leaf Chlorophyll content and relative water content (RWC%) of sweet potato, 120 DAT

Treatments	Plant leaf area (m^2)	Chlorophyll (SPAD)	RWC %
2017			
Spraying numbers			
S1 (60 DAT)	0.83 a	48.9 a	87.4 a
S2(60&90DAT)	0.86 a	46.7 a	88.3 a
Boron concentrations (ppm)			
0	0.72 c	48.8 a	89.9 a
10	0.79 bc	49.7 a	89.2 a
20	0.86 ab	47.4 a	87.0 b
30	0.87 ab	44.3 a	86.4 b
40	0.93 a	47.5 a	87.3 b
50	0.91ab	49.4 a	87.5 b
Interaction			
S1 x 0	0.71 a	44.63 a	90.4 a
S1 x 10	0.75 a	46.66 a	89.4 b
S1 x 20	0.84 a	41.33 a	88.0 cd
S1 x 30	0.89 a	50.43 a	85.0 e
S1 x 40	0.93 a	49.23 a	85.7 e
S1 x 50	0.87 a	44.63 a	86.1 e
S2 x 0	0.71 a	46.36 a	89.3 b
S2 x 10	0.84 a	48.16 a	89.1 bc
S2 x 20	0.89 a	47.20 a	86.1 e
S2 x 30	0.85 a	44.50 a	87.8 d
S2 x 40	0.92 a	49.56 a	88.8 bcd
S2 x 50	0.95 a	44.63 a	88.9 bcd
2018			
Spraying numbers			
S1 (60 DAT)	0.83 b	48.8 a	86.4 a
S2 (60 & 90DAT)	1.02 a	49.7 a	86.9 a
Boron concentrations (ppm)			
0	0.72 c	46.1 a	88.9 a
10	0.79 bc	45.1 a	86.7 bc
20	0.86 ab	44.8 a	84.7 d
30	0.93 a	46.3 a	86.5 bc
40	0.91 ab	44.9 a	87.3 b
50	1.10 a	44.3 a	85.6 cd
Interaction			
S1 x 0	0.70 a	45.90 a	89.2 a
S1 x 10	0.73 a	46.10 a	86.6 bc
S1 x 20	0.74 a	42.90 a	83.7 d
S1 x 30	0.89 a	47.20 a	86.8 bc
S1 x 40	0.93 a	44.60 a	86.7 bc
S1 x 50	0.94 a	44.90 a	85.9 c
S2 x 0	0.70 a	45.90 a	89.2 a
S2 x 10	0.89 a	46.60 a	86.9 bc
S2 x 20	0.92 a	44.70 a	85.7 c
S2 x 30	1.28 a	45.10 a	86.3 c
S2 x 40	1.50 a	44.00 a	88.0 ab
S2 x 50	1.60 a	44.40 a	85.4 c

Means with the same letter within the same column are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests.

Table 6. Effect of foliar spray by Boron on leaf area index (LAI), absolute growth rate (AGR) and net assimilation rate (NAR) of sweet potato, (90-120 days after transplanting)

Treatments	LAI	AGR (g/day)	NAR (g/m^2/day)
	2017		
Spraying numbers			
S1 (60 DAT)	4.48 b	0.51 b	0.64 b
S2 (60 & 90DAT)	5.02 a	0.66 a	0.79 a
Boron concentrations (ppm)			
0	3.03 c	0.42 c	0.55 bc
10	4.25 b	0.51 bc	0.67 bc
20	4.62 b	0.66 ab	0.81 ab
30	5.55 a	0.84 a	1.03 a
40	5.72 a	0.75 a	0.82 ab
50	5.34 a	0.3 4 c	0.39 c
Interaction			
S1 x 0	3.02 e	0.30 f	0.44 de
S1 x 10	4.02 d	0.60 cd	0.81 bc
S1 x 20	4.54 cd	0.62 cd	0.80 bc
S1 x 30	5.55 b	0.62 cd	0.72 bcd
S1 x 40	4.77 c	0.62 cd	0.69 b-e
S1 x 50	4.96 c	0.31 f	0.38 e
S2 x 0	3.02 e	0.54 cde	0.67 b-e
S2 x 10	4.47 cd	0.42 def	0.53 cde
S2 x 20	4.70 c	0.70 bc	0.83 bc
S2 x 30	5.55 b	1.05 a	1.34 a
S2 x 40	6.66 a	0.88 ab	0.95 b
S2 x 50	5.72 b	0.36 ef	0.40 e
	2018		
Spraying numbers			
S1 (60 DAT)	4.76 b	0.46 b	0.57 b
S2 (60 & 90DAT)	5.84 a	0.78 a	0.78 a
Boron concentrations (ppm)			
0	3.98 d	0.27 d	0.44 c
10	4.37 cd	0.46 cd	0.60 bc
20	4.93 bc	0.65 bc	0.78 ab
30	6.50 a	0.84 ab	0.78 ab
40	5.75 ab	0.96 a	0.94 a
50	6.29 a	0.53 c	0.52 c
Interaction			
S1 x 0	3.80 h	0.23 e	0.39 e
S1 x 10	3.92 h	0.40 cde	0.57 cde
S1 x 20	4.60 fg	0.66 b	0.81 bc
S1 x 30	5.65 c	0.50 bcd	0.50 ce
S1 x 40	5.02 def	0.63 bc	0.74 cd
S1 x 50	5.56 cd	0.36 de	0.39 e
S2 x 0	3.8 0 h	0.31 de	0.48 de
S2 x 10	4.81 ef	0.52 bcd	0.63 ce
S2 x 20	5.25 cde	0.65 b	0.74cd
S2 x 30	7.35 a	1.19 a	1.06 ab
S2 x 40	6.47 b	1.30 a	1.13 a
S2 x 50	7.02 a	0.70 b	0.64 cde

Means with the same letter within the same column are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests.

Although, number of B applications did not significantly effect on average root weight, B concentrations and the interaction were significant in both growing seasons. The heaviest roots were noticed with intermediate concentrations, however, the lowest ones were accompanied with the control or the highest B concentration (50 ppm).

The highest plant yield as number or weight of roots were reported when the plants were sprayed by B twice (60 and 90 DAT). Increasing B concentrations increased number of roots from 3.7 or 3.9 with the control (in the first and second season, respectively) to 4.8 or 4.9 with 50 ppm B. However, plant yield was increased from 0.843 or 0.835 kg with the control to 1.187 or 1.175 kg with 50 ppm. The companied treatment of 50 ppm B and two sprays was the best for high yield (Table 7).

Table 7. Effect of foliar spray by boron at different numbers and concentrations on yield and its components of sweet potato

Treatments	Root diameter D, (cm)	Root length L, (cm)	Root shape L/D	Root weight (g)	No. of roots/ plant	Plant yield (kg)
			2017			
Spraying numbers						
S1 (60 DAT)	5.3 b	16.4 b	3.1 b	56.0 a	4.1 b	1.05 b
S2(60&90DAT)	5.4 a	17.4 a	3.2 a	54.0 a	4.3 a	1.09 a
Boron concentrations (ppm)						
0	3.8 e	14.3 e	3.8 a	227.0 c	3.7 c	0.84 e
10	5.1 d	17.1 c	3.3 b	258.9 ab	3.9 c	1.01 d
20	5.8 c	17.2 c	2.9 d	264.2a	4.2 b	1.11 c
30	6.4 a	17.9 b	2.7 e	262.7 ab	4.3 b	1.13 b
40	6.1 b	19.12 a	3.1 c	256.8 ab	4.4 b	1.13 b
50	5.0 d	15.7 d	3.1 c	245.8 b	4.8 a	1.18 a
Interaction						
S1 x 0	3.7 g	14.3 f	3.7 a	229.7 a	3.7 g	0.85 g
S1 x 10	3.8 g	14.3 f	3.7 a	260.5 a	3.8 g	0.99 f
S1 x 20	5.0 ef	17.5 bc	3.4 b	264.2 a	4.2 ef	1.11 d
S1 x 30	5.1 e	16.6 e	3.2 c	255.8 a	4.3 de	1.10 d
S1 x 40	5.7 d	16.8 e	2.9 d	260.4 a	4.3 cde	1.12 cd
S1 x 50	6.0 c	17.5 bc	2.9 de	246.6 a	4.5 b	1.11 cd
S2 x 0	6.2 bc	17.9 b	2.8 de	224.3 a	3.7 g	0.83 g
S2 x 10	6.6 a	17.9 b	2.7 e	253.6 a	4.1 f	1.04 e
S2 x 20	6.3 ab	17.3 cd	2.7 e	266.6 a	4.2 ef	1.12 cd
S2 x 30	6.0 c	20.99 a	3.4 b	263.6 a	4.4 bcd	1.16 b
S2 x 40	4.8 f	14.4 f	2.9 d	255.5 a	4.5 bc	1.15 bc
S2 x 50	5.1 e	16.9 de	3.3 bc	245.0 a	5.1 a	1.25 a
			2018			
Spraying numbers						
S1 (60 DAT)	4.6 b	17.4 a	3.7 a	250.0 a	4.2 b	1.05b
S2(60&90DAT)	4.4.8 a	17.3 a	3.7 a	246.6 a	4.5 a	1.11 a
Boron concentrations (ppm)						
0	3.5 e	14.8 d	4.1 a	214.d	3.9 d	0.83 e
10	4.6 d	16.7 c	3.6 c	256.0b	4.1 c	1.05 d
20	5.0 c	17.5 b	3.5 c	271.4 a	4.2 c	1.14 c
30	5.4 a	18.8 a	3.5 c	263.5ab	4.4 b	1.16 b
40	5.1 b	18.5 a	3.5 c	257.7ab	4.5 b	1.16 ab
50	4.5 d	18.0 b	3.9 b	239.0c	4.9 a	1.17 a
Interaction						
S1 x 0	3.5 a	14.8 d	4.1 a	218.4 a	3.8 f	0.83 h
S1 x 10	4.4 a	16.7 c	3.6 bcd	252.5 a	4.0 ef	1.01 g
S1 x 20	4.7 a	17.5 bc	3.6 bcd	264.2 a	4.2 de	1.11 e
S1 x 30	5.1 a	19.8 a	3.8 abc	258.1 a	4.3 cde	1.11 e
S1 x 40	5.2 a	17.4 bc	3.4 de	261.0 a	4.4 bcd	1.15 d
S1 x 50	4.5 a	18.0 bc	3.9 abc	250.0 a	4.4 bcd	1.10 ef
S2 x 0	3.5 a	14.8 d	4.2 a	218.4 a	3.8 f	0.83 h
S2 x 10	4.7 a	16.6 c	3.6 cde	257.1 a	4.2 de	1.08 f
S2 x 20	5.3 a	17.5 bc	3.3 de	276.1 a	4.2 de	1.16 cd
S2 x 30	5.7 a	17.8 bc	3.2 e	260.8 a	4.6 bc	1.20 b
S2 x 40	5.1 a	18.9 ab	3.7 bcd	251.0 a	4.7 b	1.18 bc
S2 x 50	4.4 a	18.1 abc	4.0 ab	233.9 a	5.3 a	1.24 a

Means with the same letter within the same column are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests.

4- Marketable and nonmarketable yields:

Data in Fig. 1 clear that there were significant differences between one and two sprays of B in total and marketable yields (ton/fed). Two sprays treatment recorded higher total yield (26.4 and 26.4 ton/fed) and marketable yield (24.1 and 24.6 ton/fed with 91.2 and 93.1% of the total yield in 2017 and 2018, respectively) with lower percentage of non-marketable yield (2.2 and 1.8 ton/fed with 8.3 and 6.8% of the total yield) comparing one spray. However, the treatment of one spray produced 23.1 and 23.2 ton/fed of the total yield with 87.5 and 87.8% of the marketable yield in 2017 and 2018, respectively.

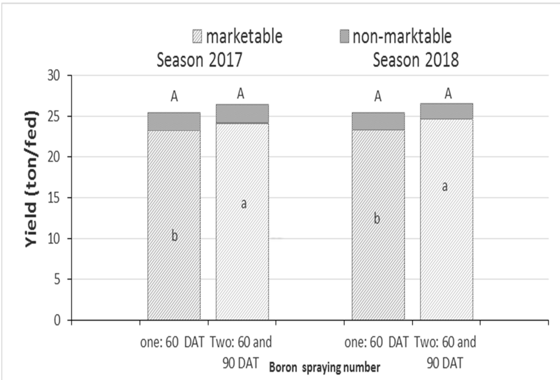

Fig. 1. Effect of boron spraying number on total, marketable (small case letters) and nonmarketable (capital case letters) yields of sweet potato.

Means with the same letter within the same case are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests.

Concerning boron concentration, data in Fig. 2 illustrate that all concentrations increased the total and marketable yields (ton/fed) comparing with the control. The highest percentages of marketable yield were recorded with 50 ppm (98.8 and 97.7% in 2017 and 2018 seasons, respectively), while they were 81% and 85% with the control. The highest percentages of unmarketable yield were 16.1 and 12.5 % which resulted by the control.

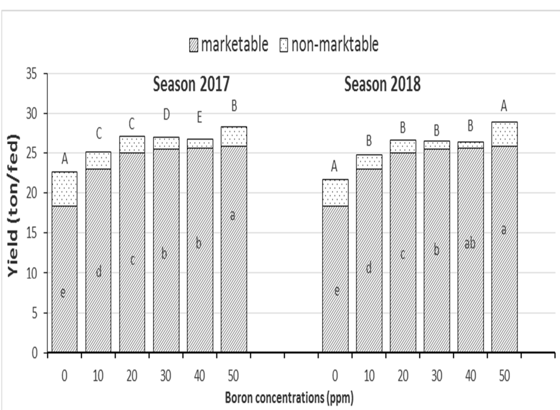

Fig. 2. Effect of boron concentration on marketable (small letters), nonmarketable (capital letters) and total yields of sweet potato during.

Means with the same letter within the same case are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests

There were significant interaction between number of sprays and boron concentrations as for total yield, marketable and unmarketable yields in both growing seasons (Fig. 3). Plants sprayed with 50 ppm at 60 and 90 DAT gave the highest total and marketable yields. However, the differences were insignificant in the case of nonmarketable yield in both growing seasons.

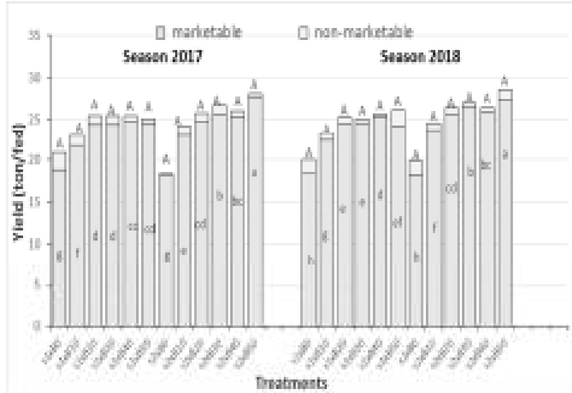

Fig. 3. Effect of the interaction between number of boron sprays (S1 and S2) x boron concentrations (0, 10, 20, 30, 40 and 50 ppm) on marketable (small letters) and nonmarketable (capital letters) yields of sweet potato.

Means with the same letter within the same case are not significantly different at ($P \leq 0.05$) according to Duncan's multiple range tests.

Discussion

Boron element has vital for shoot and root growth development because it involves in cell wall and plasma membrane structure and function (Brown *et al*., 2002), but it is not sufficient in the soil solution as well as the plant which it was recorded less than 2 ppm B in soil solution at the experiment site of North River Nile Delta (Table 2 & Abido, 2012). Sweet potato plant has a huge vine which could cover the soil after almost two months of transplanting (Sharaf-Eldin *et al*., 2017). To get this target, boron foliar was reported as a facility practice for supported plant growth (Haytova, 2013). Moreover, no evidence or references to know what the range of dosage which sweet potato endured it for boron, although the narrow range between boron deficiency and toxicity was reported (Gupta, 2014). Acharya *et al*. (2015) obtained a positive effect of boron on onion on plant growth. The positive effect of add boron at 60 and 90 DAT on vegetative growth is shown in higher plant length, number of branches, plant leaf area and growth attributes more than add boron at 60 DAT (Tables, 4& 5). With add boron at 60 and 90 DAT, the soil area that covered by plant (LAI) was enhanced and the leaves produced high dry matter (AGR and NAR) as shown in Table 5. RWC results suggest that B might increase photosynthesis, dry matter, nutrient uptake which might decrease RWC of vines and moisture content of sweet potato vines.

The higher plant growth with boron at 40 or 50 ppm than the lower levels or the control (Tables, 4 & 5) may be due to its role in cell elongation, (Reid *et al*., 2004; Gobarah and Mekki, 2005), which led to an increase in growth characters. Also, repeated the same application cause an increase in vegetative growth Tariq and Mott (2006) it's often reflected to Auxins that increased with increasing B rates (Abou EL-Yazied and Mady, 2012) or regarding to the regular work of stomata (Muller *et al*., 2011). Similar results were mentioned by Abido (2012) and Dewdar *et al*. (2015) on sugar beet.

Summing up the previous results in Table (5), it is evident that the highest values of plant growth characters were recorded with stepping boron and dosage at 60 and 90 DAT compared with the other treatments at most sampling dates in both growing seasons. The increment in plant growth by number of application either with 40 ppm may be due to the role of boron in increasing of leaf area (Bogiani *et al*., 2013), which improve plant growth as well as the important role of photosynthetic efficiency for achieving physiological processes in plant.

The highest values of average tuberous root weight, No. of tuberous roots/ plant, root diameter, root length, plant yield (kg) and total yield (ton/fed) were obtained with boron application (Table 7). These increases may be due to the role of boron in photosynthetic efficiency and increasing mineral nutrients uptake as well as dry matter translocation and accumulation toward the roots, which in turn reflected for high yield (Tariq and Mott, 2006). These findings are in the line with those obtained by (Abido, 2012; Farag and Fang, 2014; El-Tohamy *et al*., 2014).

The lower yield and quality with the control (Table 7 & Fig. 2) are force indicator to the direct relationship between the low yield and insufficient of boron. These results are in harmony with those obtained by (Ferweez *et al*., 2011).

CONCLUSION

Fertilizing sweet potato plant by 40 or 50 ppm boron as a foliar application at 60 and 90 DAT reflected in high growth, yield and quality with regular and reduced the nonmarketable roots under North River Nile Delta conditions.

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تطبيق الرش الورقى بالبورون وعلاقته بانتاجية البطاطا

محمد على شرف الدين[١] ، منال عبدالرحمن عبد الله[٢] ، شوقى على مصطفى[١] و وليد الشحات منتصر[١]
[١]قسم البساتين ـ كلية الزراعة ـ جامعة كفر الشيخ
[٢]معهد بحوث البساتين ـ مركز البحوث الزراعية

تم اجراء هذه الدراسة لتقييم تاثير الرش بالبورون بتركيزات مختلفة (٠ و ١٠ و ٢٠ و ٣٠ و ٤٠ و ٥٠ جزء فى المليون) رشة واحدة (بعد ٦٠ يوم من الشتل) أو رشتين (بعد ٦٠ و ٩٠ يوم من الشتل) على نبات البطاطا، صنف أبيس. تم اجراء التجربة فى محافظة كفر الشيخ والتى تعتبر محافظة زراعة المحصول الرئيسية فى مصر. اشارت النتائج الى أن تكرار رش البورون بعد ٦٠ و ٩٠ يوم من الشتل بتركيز ٤٠ أو ٥٠ جزء فى المليون تسبب فى زيادة خصائص النمو الخضرى (طول النبات، وعدد الأفرع، ومساحة النبات الورقية) وخصائص النمو (دليل المساحة الورقية، ومعد النمو المطلق، ومعدل النمو الصافى). أيضا تم تحسين الجودة المورفولوجية للجذور المتدرنة (قطر، وطول، ومعامل شكل الجذر) علاوة على تحسين المحصول وزيادة نسبة المحصول القابلة للتسويق.