Scientific Journal of Agricultural Sciences 4 (1): 12-22, 2022
Print (ISSN 2535-1796) / Online (ISSN 2535-180X) DOI: 10.21608/sjas.2022.111487.1175

Stimulating the growth, storage root yield and quality of carrot plants by phosphoric acid, potassium and boric acid foliar applications

Salim, B.B.M[1]., N. M. Taha[2], A. Abou El-Yazied[2]

[1]Department of Agricultural Botany, Faculty of Agriculture, Ain Shams University, P.O. Box 68, Hadayek Shubra 11241,Cairo, Egypt
[2]Department of Horticulture, Faculty of Agriculture, Ain Shams University, P.O. Box 68, Hadayek Shubra 11241, Cairo, Egypt

*Corresponding Email: dr.bahaa_badry@agr.asu.edu.eg

Received on: 15-12-2021 Accepted on: 12-2-2022

ABSTRACT

Two field experiments were conducted on November, 2017/2018 and 2018/2019 at the Faculty of Agriculture, Ain Shams University Farm, Shoubra El-Kheima, Egypt. Foliar applications of phosphoric acid (as P source at 1000 and 2000 ppm), potassium (KOH as K source at 1000 and 2000 ppm), boric acid (as B source at 500 ppm) and their combinations were designed in complete randomized block design with three replications and sprayed at 30, 55 and 75 days after sowing to enhance the growth, yield and the biochemical constituents of carrot (*Daucus carota* L.) cv Kuroda orange. Data indicated that spraying phosphoric acid, potassium, boric acid individually and in combination stimulated vegetative growth characters, biochemical constituents and storage roots yield compared to control plants in both seasons. Foliar supply of the individual phosphoric acid (2000 ppm) and the combined treatment of P (2000 ppm) plus K **(**2000 ppm) and B (500 ppm) achieved higher significant improvements of most vegetative growth traits, macro and micronutrients, photosynthetic pigments in carrot leaf at 90 days after sowing and storage roots yield, N, P, K, Mg, Ca, Fe, Mn, Zn, Cu, carotene, vitamin C, total sugars concentrations and TSS in storage roots at 105 days after sowing compared to control plants.

KEYWORDS: Phosphorus, Potassium, Boron, Carrot, *Daucus carota* L.

1. INTRODUCTION

The consumption of storage carrot roots (*Daucus carota* L.) is important vegetable crop in the world now during it is a great source of carotenes, carbohydrates, flavonoids, vitamins, polyphenols, minerals, and fibers (Nicolle et al., 2004; Sharma et al., 2012; Silva Dias, 2014; Subba et al., 2016; Cielo Char, 2017; Que et al., 2019). Additionally, carrot leaves are favorite for human consumption food products via its high content of fatty acids, antioxidants and nutrients (Leite et al., 2011). Therefore, quality properties of carrot root positively influenced by nutrients supply (Singh et al., 2012).

All higher plants cannot grow without phosphorus (P) supply. It is a major part of membranes phospholipids, nucleic acids (DNA and RNA) and plant energy compounds (adenosine di- and triphosphate (ADP and ATP)) (Schachtman et al., 1998; Uchida, 2000; Kow and Nabwami, 2015). Nevertheless, shortage available phosphorus in soils decreases P uptake and caused plant P deficiency, thus limiting the growth and development (Shen et al., 2011; Malhotra et al., 2018). So, spraying P sources such as phosphoric acid achieves higher positive effects on growth and yield of faba bean Zewail et al. (2011) and wheat (Peirce et al., 2019).

Potassium (K) is an essential macronutrient has vital functions in osmotic adjustment, water use efficiency and enzyme activation (Uchida, 2000; Guo et al., 2013; Wang et al., 2013). Moreover, K controls many physiological and biochemical processes reflexed on crops growth, yield and quality (Wang and Wu, 2013; Hasanuzzaman et al., 2018). Consequently, many authors suggested that using K sources as foliar application enhanced the vegetative growth, yield and the biochemical composition of fodder beet Kassab et al. (2012), potato Salim et al. (2014), onion Behairy et al. (2015) and carrot by (Abou El-Nasr and Ibrahim 2011; Omar and Ramadan 2018; Shaban et al. 2018).

Boron (B) is one of the essential micronutrient which demands in cell walls formation, cell elongation, enzyme activation, sugars transport, carbohydrate metabolism, nucleic acid RNA formation and metabolism (Marschner, 1995; Uchida, 2000;

Broadley, et al., 2012). Therefore, B necessary required for plants growth and biological processes (Khaliq et al., 2018). Furthermore, Day and Aasim (2020) B promotes plant pigments and nutrients uptake and translocation. Accordingly, Abou EL-Yazied and Mady, 2012; El-Dissoky and Abdel-Kadar, 2013; Salim et al. 2019 stated that, B foliar applications increased the vegetative growth, biochemical constituents and yield productivity of different vegetable crops. Also, minerals, carotenes and vitamin C concentrations of carrot root improved by B supply (Singh et al., 2012).

The objective of this research was to study the interrelationship between the foliar spray with the phosphoric acid, potassium and boric acid on photosynthetic pigments, mineral composition, vegetative growth, storage roots yield and quality of carrot plant.

2. MATERIALS AND METHODS

2.1. Seeds sowing and experimental conditions

Two field Experiments were carried out of winter seasons on 4 November of 2017/2018 and 2018/2019 in the Faculty of Agriculture, Ain Shams University Farm, Shoubra El-Kheima, Egypt (30.114953 N, 31.247934 E) to study the effect of foliar spray with phosphoric acid ($H_3\ PO_4$: 85 % P_2O_5), potassium (KOH: 48 % K_2O), boric acid ($H_3\ BO_3$:17 % B) and their combinations on the vegetative growth, yield and the biochemical constituents of carrot plants *(Daucus carota* L.) cv Kuroda orange. Carrot seeds cv. Kuroda (orange), were sown on two sides of the row the distance was 20 cm between plants under the following soil conditions, pH 7.82, EC = 0.91 ds/m, HCO_3^- 0.60 meq /l, Na^+ 2.71 meq /l, Ca^{+2} 3.30 meq /l, Mg^{+2} 2.91 meq /l, K^+ 0.19 meq /l, Cl^- 5.00 meq /l and SO_4^{-2} 3.40 meq /l. This experiment included 8 treatments as follows:

1. Control (distill water)
2. Phosphoric acid (P) at 1000 ppm
3. Phosphoric acid (P) at 2000 ppm
4. Potassium (K) at 1000 ppm
5. Potassium (K) at 2000 ppm
6. Boric acid (B) at 500 ppm
7. P+ K+ B at 1000+1000 + 500 ppm
8. P+ K+ B at 2000 + 2000 + 500 ppm

These treatments arranged in a randomized complete block design with three replications. Foliar treatments were applied at 30, 55 and 75 days after sowing. Ammonium sulfate 20.6 % N at rate 300 kg (60 kg N/fed), calcium superphosphate 15.5 % P_2O_5 at rate 350 kg/fed (40 kg P_2O_5/fed) and potassium sulfate 48 % K_2O at rate 200 kg (50 kg K_2O) and other agricultural practices were used according to the recommendations of the Egyptian Ministry of Agriculture.

2.2. Growth and yield characteristics

Carrot growth parameters included plant length (cm), number of leaves/plant, plant fresh and dry weights (g/plant), shoot FW were determined at 90 days after sowing. Storage root length (cm), diameter, root fresh weight (g/plant), and storage root yield/ fed (ton) were measured at 105 days after sowing in two seasons.

2.3. Biochemical composition measurements

Chlorophyll a, chlorophyll b, and carotenoids concentrations of carrot leaf at 90 days after sowing were extracted of 0.1 g leaf samples with 10 ml N, N-dimethylformamide (Minocha et al., 2009) and calculated according to Wellburn (1994). Leaf and root samples of carrot plant at 90 and 105 days after sowing respectively (main of two seasons) were dried at 60 °C in air oven for 72 h and digested using H_2SO_4 and H_2O_2 to determine N, P, K, Mg, Ca, Fe, Mn, Zn and Cu Concentrations. Total N was determined using micro-Kjeldahl method by Horneck and Miller (1998). The molybdenum blue method used to determine total P (Bernhart and Wreath, 1955). The K concentration was measured by the flame photometer as described by Horneck and Hanson (1998). Concentrations of Ca, Mg, Zn, Fe, Mn and Cu were determined according to Stefánsson et al. (2007). Total carotene and vitamin C concentrations (mg/ 100 g FW) in storage root were determined according to Ellong et al. (2015). Total sugars concentration was determined in storage root using the method of (Dubois et al., 1956). TSS measured by hand digital Refractometer.

2.4. Statistical analysis

Results of the vegetative growth, yield and biochemical constituents of two seasons were arranged and statistically analyzed using CoStat software according to Gomez and Gomez (1984). One- way analysis of variance was used to test for significant differences at $P < 0.05$, followed by Duncan's multiple range test.

3. RESULTS AND DISCUSSION

3.1. The vegetative growth and storage roots yield

Results recorded in Tables 1 and 2 reveal that the plant length, plant fresh and dry weights, leaves number per plant, fresh weights of shoot and storage root, root length, root diameter and storage root yield

Table 1. Influence of foliar spray with P, K and B on the vegetative growth of carrot at 90 days after sowing during 2017/2018 and 2018/2019 growing seasons.

Treatments	Plant height (cm)		Leaves number/ plant		Plant FW (g)		Plant DW (g)		Shoot FW (g)	
	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2
Control	42.00e	47.67b	9.33c	10.67b	60.00c	58.33c	8.83b	7.67c	28.00b	31.67a
P at 1000 ppm	49.00d	50.67ab	10.67bc	11.67ab	67.33bc	80.00a-c	9.00b	9.33bc	32.67b	36.67a
P at 2000 ppm	56.67a	56.00a	11.33ab	12.70a	115.00a	105.67a	16.17a	11.53a	48.33a	47.33a
K at 1000 ppm	53.00bc	52.67ab	11.00a-c	12.00ab	68.33bc	72.33bc	9.42b	9.45a-c	31.00b	31.33a
K at 2000 ppm	54.67ab	55.00a	11.67ab	12.33ab	80.00bc	81.67a-c	10.17b	9.83ab	33.33b	34.00a
B at 500 ppm	50.33d	52.33ab	12.67ab	12.00ab	85.00bc	81.67a-c	10.20b	10.58ab	38.67ab	35.00a
P+ K+ B at 1000 + 1000 + 500 ppm	51.33cd	52.00ab	12.00ab	12.67a	71.67bc	88.33a-c	9.50b	11.40ab	30.00b	41.67a
P+ K+ B at 2000 + 2000 + 500 ppm	55.33ab	55.00a	13.00a	13.33a	88.33b	96.67ab	11.33b	11.70ab	31.67b	38.33a
LSD	2.42	6.04	1.80	1.93	22.74	29.23	2.94	1.91	11.43	15.85

Means (±SD) followed by different letters are significantly different at *P*< 0.05 level; Duncan's Multiple Range Test. Where LSD = Least significant difference.

Table 2. Influence of foliar spray with P, K and B and their combinations on root yield characteristics of carrot at 105 days during 2017/2018 and 2018/2019 growing seasons.

Treatments	Root length (cm)		Root diameter (cm)		Root FW (g)		Storage roots yield (ton/fed)	
	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2
Control	14.50c	15.00b	2.50b	2.80a	32.00c	26.67b	15.50d	14.83d
P at 1000 ppm	18.67ab	18.00ab	3.07a	3.00a	34.67c	43.33ab	18.25c	19.17c
P at 2000 ppm	20.67a	20.00a	3.07a	3.23a	66.67a	58.33a	23.73a	23.03a
K at 1000 ppm	18.00b	18.33ab	3.13a	3.33a	37.00bc	35.00b	19.16c	20.98b
K at 2000 ppm	17.33b	18.70ab	3.20a	3.03a	46.67a-c	47.67ab	21.20b	22.25a
B at 500 ppm	17.67b	19.33a	3.20a	3.00a	46.33a-c	47.00ab	19.33c	20.35bc
P+ K+ B at 1000 + 1000 +5 00 ppm	18.67ab	18.70ab	3.30a	3.27a	41.67bc	46.67ab	19.70c	20.50bc
P+ K+ B at 2000 + 2000 + 500 ppm	19.00ab	19.70a	3.57a	3.43a	56.67ab	58.33a	22.17b	22.70a
LSD	2.66	3.39	0.46	0.58	21.54	23.39	1.51	1.26

Means (±SD) followed by different letters are significantly different at *P*< 0.05 level; Duncan's Multiple Range Test. Where LSD = Least significant difference.

per fed of carrot plant responded positively to foliar treatments of phosphoric acid (1000, 2000 ppm), potassium (1000, 2000 ppm), boron (500 ppm) and their combinations comparing with control in both seasons. These results may be due to increases in the photosynthetic pigments and nutrients content caused by P, K, and B treatments compared with control plants (Tables, 3 and 4).

The individual foliar application of phosphoric acid (2000 ppm) gave a significant increase in the plant length, leaves number per plant, plant FW, plant DW, root length, root FW and roots yield compared to control plants in both seasons and the shoot FW and root diameter values in the first season. In this regard, the highest plant length, plant FW, plant DW, shoot FW, root length, root FW and storage root yield were produced by phosphoric acid (2000 ppm) treatment comparing with other treatments and control plants in both seasons.

These results are agree with Zewail et al. (2011) who found that foliar spray with phosphoric acid at 500 ppm increased the plant height, leaf number, number of branches, total leaf area, shoot dry weight and yield of faba bean. Also, Peirce et al., (2019) indicated that grains yield of wheat plants sprayed with phosphoric acid increased by 12% more than the control. In addition, spraying phosphoric acid (3, 6 and 9 liters ha-1) significantly enhanced the dry matter production, leaf area index and grains yield characteristics of rice (Zayed et al., 2019). Therefore, P stimulated the vegetative growth and yield of potato (Soratto et al., 2019). Increase P supply increased linearly the shoot and root dry matters, total and commercial yields of carrot (Reis Gonçalves et al., 2019). Zewail et al. (2011) spraying faba bean with phosphoric acid animates the photosynthesis and assimilates and translocation of biochemical constituents from sources to sink. Phosphorus is essential for metabolic processes including growth, photosynthesis, and respiration (Malhotra et al., 2018).

Therefore, spraying the high level of potassium (2000 ppm) was more effective than K at the low level (1000 ppm) on enhancing the vegetative growth and yield comparing with control plants in both seasons (Tables 1 and 2). These results are in accordance with Zewail et al., (2011) on faba bean and Salim et al. (2014) on potato. Also, the vegetative growth and storage roots traits of carrot were significantly increased by K foliar applications (El-Abou El-Nasr and Ibrahim, 2011; Omar and Ramadan, 2018; Shaban et al., 2018). Respecting the positive effect of K foliar application in the present study may be due to that potassium maintenance the cell membrane stability, osmotic regulation, root elongation and dry mass (Wang et al., 2013). Moreover, K controls enzyme activation, photosynthesis, organic compounds synthesis, cells signaling and translocation of photosythates which enhanced plant growth and yield (Marschner, 1995; Uchida, 2000; Hasanuzzaman et al., 2018).

Regarding, enhanced the vegetative growth and yield traits of carrot in the present study by using boron foliar application at 500 ppm were similar with results of Abou EL-Yazied and Mady, 2012 on broad bean, El-Dissoky and Abdel-Kadar, 2013 on potato, Gondim et al., 2015 on beet and tomato plants and Salim et al. 2019 on hot pepper. Synergistic effect of B foliar spray which improved the plant growth and yield may be due to increase the photosynthetic pigments and endogenous auxins and cytokinins (Abou EL-Yazied and Mady, 2012). Furthermore, Day and Aasim (2020) reported that B promotes plant pigments, nutrients uptake and translocation. Additionally, boron is necessary in keeping plasma membrane function, cell walls formation, cells elongation, enzyme activation, sugars transportation and carbohydrate metabolism (Uchida, 2000; Broadley et al., 2012; Bubarai et al., 2017; Khaliq et al., 2018; Sidhu et al., 2019).

Using the high combined treatment of phosphoric acid (2000 ppm) plus potassium (2000 ppm) and boron (500 ppm) significantly increased the plant length, leaves number per plant, plant FW, root length, root FW and storage root yield of carrot plants compared to control plants in both seasons. The same treatment produced the highest values of number of leaves per plant, and root thickness (Tables 1 and 2). The superiority of spraying the combination of P and K and B at 2000 + 2000+ 500 related to it gave higher leaf N, P, K, Mg, Ca, Fe, Mn, Zn, Cu concentrations than check plants (Table 4). Results are supported with El Nagy et al., (2020) who obtained that foliar spray with K and P at 4 ml l-1 was the best treatment increased the morphological characters, total and marketable storage roots yields, roots fresh weight, length and diameter of sweet potato.

3.2. Leaf pigments

Foliar application with phosphoric acid (1000 and 2000 ppm), potassium **(**1000 and 2000 ppm), and boron (500 ppm) individually and in combination improved chlorophylls a, b, a+ b and carotenoids concentrations compared with control plants in both seasons. Chlorophyll a, total chlorophylls and carotenoids concentrations in leaf of carrot plants significantly increased with foliar applications of phosphoric acid (1000, 2000 ppm), potassium (2000 ppm) comparing with control in both seasons. Foliar spray with potassium (2000 ppm) recorded the highest values of carotenoids in carrot leaf meanwhile, the lowest concentrations of chlorophylls a, b, a+ b and carotenoids were recorded in control plants in both seasons (Table 3).

Table 3. Influence of foliar spray with P, K, B and their combinations on photosynthetic pigments concentrations of carrot leaves at 90 days during 2017/2018 and 2018/2019 growing seasons.

Treatments	Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Chlorophylls *a*+ *b* (mg/g FW)		Carotenoids (mg/g FW)	
	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2
Control	1.54c	1.05b	0.53c	0.60b	2.07b	1.65c	0.31e	0.22c
P at 1000 ppm	1.85ab	1.83a	0.81ab	0.65ab	2.66a	2.48ab	0.41cd	0.46b
P at 2000 ppm	1.99a	1.79a	0.62bc	0.73ab	2.61a	2.52ab	0.53b	0.42b
K at 1000 ppm	1.72b	1.60ab	0.87a	0.89ab	2.59a	2.49ab	0.63a	0.56a
K at 2000 ppm	1.94a	1.70a	0.59bc	0.75ab	2.53a	2.45ab	0.63a	0.61a
B at 500 ppm	1.61c	1.59ab	0.56c	0.73ab	2.17b	2.32b	0.34de	0.29c
P+ K+ B at 1000 + 1000 + 500 ppm	1.64c	1.62ab	0.62bc	0.77ab	2.26b	2.39ab	0.54b	0.24c
P+ K+ B at 2000 + 2000 + 500 ppm	1.83ab	1.85a	0.72a-c	0.96a	2.55a	2.81a	0.45c	0.27c
LSD	0.1812	0.5966	0.222	0.3045	0.250	0.407	0.077	0.0638

Means (±SD) followed by different letters are significantly different at $P< 0.05$ level; Duncan's Multiple Range Test. Where LSD = Least significant difference.

3.3. Leaf and root mineral composition

Table 4 shows that, N, Mg, Ca, Fe, Mn, Zn and Cu concentrations in carrot leaf increased significantly with foliar applications of phosphoric acid, potassium and boron individually or in combination treatments compared to control plants. Foliar sprays of phosphoric acid at 2000 ppm, potassium at 2000 ppm, boron at 500 ppm and their combinations achieved significant increases in P and K concentrations than control plants. However, there were no significant differences in the P and K concentrations when using the low levels of phosphoric acid (1000 ppm) or potassium (1000 ppm) treatments compared to control.

Spraying phosphoric acid at 1000, 2000 ppm, potassium at 1000, 2000 ppm and boron at 500 ppm individually or in combinations gave a significant increase in P, Ca, Fe, Mn, Zn and Cu concentrations in carrot root. All foliar treatments led to a significant increase in N, K and Mg concentrations than control plants except using the phosphoric acid (1000 ppm) were no significant differences (Table 5). In this context, spraying the combined of phosphoric acid (2000 ppm) and potassium (2000 ppm) and boron (500 ppm) treatment recorded the highest N, P, K, Mg, Ca, Fe, Mn, Zn and Cu concentrations of carrot leaf and roots (Tables 4 and 5).

3.4. Storage root quality

Application of phosphoric acid, potassium and boron individually or in combination treatments caused a significant increase in carotene, vitamin C, total sugars concentrations, and TSS in carrot roots compared to control plants at 105 days after sowing during two seasons (Table 6). Using mixture of phosphoric acid (2000 ppm) and potassium (2000 ppm) and boron (500 ppm) recorded the highest concentrations of carotene, vitamin C, total sugars and TSS compared to the other foliar treatments and control plants in both seasons however, the lowest concentrations were recorded in control plants in both seasons. These data may be due to that same mixture treatment recorded the highest N, P, K, Mg, Ca, Fe, Mn, Zn, and Cu concentrations of carrot leaf and root as compared with the check plants (Tables 4 and 5).

The positive impacts of the individual foliar spray with phosphoric acid (1000 or 2000 ppm) on the biochemical constituents of carrot compared to control (Tables, 3- 6) are similar with Zewail et al. (2011) who showed that, chlorophyll forms, carotenoids, N, P, K, Fe and Zn, and total carbohydrate concentrations increased in faba bean sprayed with phosphoric acid (500 ppm). In addition, chlorophyll content of rice gradually positively responded to increase the level of sprayed phosphoric acid rates up to 9 liters ha-1,

Table 4. Influence of foliar spray with P, K, B and their combinations on some macro and micronutrients concentrations of carrot leaves at 90 days during 2017 and 2018 growing seasons (main of two seasons).

Treatments	Macronutrients (%)					Micronutrients (mg/ kg DW)			
	N	P	K	Mg	Ca	Fe	Mn	Zn	Cu
Control	2.50d	0.30d	2.72d	0.22e	0.32e	308.33d	113.00f	34.33e	25.00e
P at 1000 ppm	2.72c	0.36cd	3.08cd	0.25d	0.35d	334.00c	119.33e	41.33d	30.67d
P at 2000 ppm	2.88a-c	0.38c	3.58a-c	0.26cd	0.37cd	350.33a	125.00d	46.00c	33.00cd
K at 1000 ppm	2.87a-c	0.37cd	3.18b-d	0.27bc	0.36d	335.33bc	132.00c	50.00b	34.67bc
K at 2000 ppm	3.00ab	0.43bc	3.42bc	0.29b	0.37b-d	346.33ab	138.00b	52.67ab	36.00a-c
B at 500 ppm	2.82bc	0.39c	3.65ab	0.27bc	0.39a	351.00a	136.00bc	51.00b	37.67ab
P+ K+ B at 1000 + 1000 + 500 ppm	2.93ab	0.47b	3.68ab	0.28bc	0.38a-c	354.00a	140.67ab	53.67ab	38.00ab
P+ K+ B at 2000 + 2000 + 500 ppm	3.03a	0.58a	3.93a	0.31a	0.39a	357.33a	143.33a	56.67a	39.33a
LSD	0.1731	0.0726	0.4664	0.0194	0.017	11.686	4.9338	3.9502	3.7392

Means (±SD) followed by different letters are significantly different at *P*< 0.05 level; Duncan's Multiple Range Test. Where LSD = Least significant difference.

Table 5. Influence of foliar spray with P, K, B and their combinations on some macro and micronutrients concentrations of carrot roots at 105 days during 2017 and 2018 growing seasons (main of two seasons).

Treatments	Macronutrients (%)					Micronutrients (mg/ kg DW)			
	N	P	K	Mg	Ca	Fe	Mn	Zn	Cu
Control	0.80e	0.11d	1.67d	0.17d	0.27c	36.67d	26.67e	21.67e	11.00f
P at 1000 ppm	0.95de	0.18c	2.10cd	0.19d	0.34b	43.00bc	30.33d	26.00d	15.67e
P at 2000 ppm	1.04cd	0.24b	2.57bc	0.21c	0.40ab	44.33bc	33.67c	30.33c	18.33d
K at 1000 ppm	1.32b	0.23bc	2.73ab	0.24b	0.37ab	42.00c	34.67bc	30.00c	19.33cd
K at 2000 ppm	1.18bc	0.27ab	2.62ab	0.25ab	0.38ab	46.67ab	36.33ab	32.33bc	21.33bc
B at 500 ppm	1.62a	0.26ab	2.83ab	0.24b	0.35b	46.00a-c	35.00a-c	33.00ab	20.67c
P+ K+ B at 1000 + 1000 + 500 ppm	1.55a	0.29ab	2.92ab	0.25ab	0.38ab	47.33ab	36.00a-c	34.00ab	23.00ab
P+ K+ B at 2000 + 2000 + 500 ppm	1.73a	0.31a	3.13a	0.27a	0.42a	49.00a	37.33a	35.00a	24.33a
LSD	**0.2137**	**0.0558**	**0.4723**	**0.0203**	**0.0645**	**4.1656**	**2.2898**	**2.2898**	**1.9352**

Means (±SD) followed by different letters are significantly different at *P*< 0.05 level; Duncan's Multiple Range Test. Where LSD = Least significant difference.

Table 6. Influence of foliar spray with P, K, B and their combinations on quality of carrot roots at 105 days during 2017/2018 and 2018/2019 growing seasons

Treatments	Carotene (mg/100 g FW)		Vitamin C (mg/100 g FW)		Total sugars (mg/100 g FW)		TSS %	
	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2	Ses 1	Ses 2
Control	148.33c	155.00d	3.20f	3.60d	9.00d	9.67d	6.00d	7.33f
P at 1000 ppm	169.67b	166.67bc	3.80e	4.33c	11.67c	12.33c	8.00c	9.00e
P at 2000 ppm	170.00b	175.00a-c	4.17de	4.83bc	13.00bc	14.00bc	9.00bc	10.00c-e
K at 1000 ppm	168.00b	170.00bc	4.73cd	5.08ab	12.67bc	13.67bc	8.67bc	9.67de
K at 2000 ppm	176.67ab	176.67ab	5.50ab	5.25ab	14.67ab	15.00b	9.33bc	11.00cd
B at 500 ppm	168.33b	165.00c	4.83c	4.75bc	14.33ab	14.67b	10.00a-c	11.33bc
P+ K+ B at 1000 + 1000 + 500 ppm	173.33ab	175.00a-c	5.00bc	5.50ab	14.00a-c	15.00b	10.67ab	12.67ab
P+ K+ B at 2000 + 2000 + 500 ppm	181.67a	185.00a	5.83a	5.67a	16.00a	17.00a	11.50a	13.00a
LSD	8.55	9.51	0.58	0.71	2.32	1.66	1.97	1.41

Means (±SD) followed by different letters are significantly different at $P< 0.05$ level; Duncan's Multiple Range Test. Where LSD = Least significant difference.

(Zayed et al., 2019). Phosphorus has essential function in phospholipids, ADP and ATP, photosynthesis carbohydrate ester, phosphorylated sugars, proteins and plant metabolism (Araujo and Machado 2006; Malhotra et al., 2018; Reis Gonçalves et al., 2019).

For improved the biochemical constituents and some quality factors of carrot using K foliar spray (1000 or 2000 ppm) compared with control plants are compatible with Abou El-Nasr and Ibrahim (2011) who showed that, N, P and K concentrations in leaves and carotenoids concentration and TSS in roots of carrot significantly increased by potassium foliar application. Also, Salim et al. (2014) found that, K sources foliar supply enhanced chlorophylls, N, P, K, Mg, Zn, Mn and Fe concentrations of potato leaves. Likewise, K gave markedly increased in N, P, K, and total carbohydrate concentrations of faba bean and onion plants (Zewail et al., 2011; Behairy et al. 2015), respectively. Potassium enhancements the osmotic adjustment, establishing cell turgor, enzyme activation, carbohydrate metabolism and translocation of sugars from sinks to sources which improves crops quality (Guo et al., 2013; Kow and Nabwami, 2015; Ahmad et al., 2018; Hasanuzzaman et al., 2018). Also, K has a prominent role in translocation of photo assimilates, sugars and other soluble solids which are responsible for increased TSS (Kumar et al., 2015).

Improved the biochemical constituents of carrot plants by B foliar supply (500 ppm) compared with control plants in the present study are harmony with Abou EL-Yazied and Mady (2012) who observed that using B at 50 ppm increased leaf N, P, K and photosynthetic pigments concentrations of broad bean. Therefore, adding B increased the P, K, Mg, carotenes and vitamin C concentrations in storage roots of carrot (Singh et al., 2012). Also, foliar spray with boric acid at levels 200 or 400 ppm increased concentrations of N, P, and K in the leaf and carotenoids and vitamin C of hot pepper fruit (Salim et al., 2019). Furthermore, Day and Aasim (2020) reported that, B has synergistic impacts on photosynthetic pigments, P, N, K, Zn, Fe, and Cu uptake and translocation in plants. In this connection, boron associate in keeping plasma membrane function, enzyme activation, nutrients, metabolic pathways, sugars transportation and carbohydrates metabolism (Uchida, 2000; Broadley et al., 2012; Bubarai et al., 2017; Khaliq et al., 2018; Sidhu et al., 2019).

Respecting the simulative impacts of spraying the combinations of P+ K+ B on most of the biochemical changes and quality characteristics of storage roots as compared with control treatment (Tables 3- 6). Spraying the mixture of P plus K plus B (2000+ 2000+ 500 ppm) produced the highest N, P, K, Mg, Ca, Fe, Mn, Zn, Cu, carotene, vitamin C, total sugars concentrations and TSS (Tables 4- 6). These data are harmony with results obtained by El Nagy et al. (2020) who found that using the mixture of K and P at 4 ml l^{-1} as foliar spray was the best treatment which produced the maximum concentration of carotene, starch, N, P and K of sweet potato roots. As well, the application of K and B significantly increased carotene, ascorbic acid and total sugar concentrations of carrot storage roots (Subba et al., 2016). In addition, Karam et al. (2009) reported that enhanced sugar concentration may be related to the role of K and B in biosynthesis and transfer of sugars.

4. CONCLUSION

From the foregoing results, it could be concluded that the foliar supply with phosphoric acid (1000 or 2000 ppm), potassium (1000 or 2000 ppm), boric acid (500 ppm) individually and in combinations improving the vegetative growth, yield and quality characteristics of carrot plant. Using the high level of phosphoric acid at 2000 ppm or potassium at 2000 ppm was more effective than its low levels (1000 ppm). The best foliar application gave the highest values of the vegetative growth, storage roots yield and biochemical constituents of carrot were phosphoric acid at 2000 ppm and the mixture application of P plus K plus B at 2000+ 2000 + 500 ppm.

5. REFERENCES

Abou El-Nasr M.E., Ibrahim E.A. (2011). Effect of different potassium fertilizer rates and foliar application with some sources of potassium on growth, yield and quality of carrot plants (Daucus carota L.). J. Plant Production, Mansoura Univ., 2 (4): 559 – 569.

Abou EL-Yazied A., Mady M.A. (2012). Effect of boron and yeast extract foliar application on growth, pod setting and both green pod and seed yield of broad bean (Vicia faba L). Journal of American Science, 8(4): 517-534.

Ahmad Z., Anjum S., Waraich E.A., Ayub M.A., Ahmad T., Tariq R.M.S., Ahmad R., Iqbal M.A. (2018). Growth, physiology, and biochemical activities of plant responses with foliar potassium application under drought stress – a review, Journal of Plant Nutrition, 41:13, 1734-1743.

Araujo A.P., Machado C.T.T. (2006). Phosphorus In Mineral nutrition of plants (in Portuguese), ed. M. S. Fernandes, 254–280. Vic¸osa, Brazil: Sociedade Brasileira de Ci^encia do Solo.

Behairy A.G., Mahmoud A.R., Shafeek M.R., Ali A.H., Hafez M.M. (2015). Growth, yield and bulb quality of onion plants (Allium cepa L.) as affected by foliar and soil application of potassium. Middle East J. Agric. Res., 4(1): 60-66.

Bernhart D.N., Wreath A.R. (1955). Colorimetric determination of phosphorus by modified phosphomolybdate method. Anal. Chem. 27, 440–441.

Broadley M., Brown P., Cakmak I., Rengel Z., Zhao F. (2012). Chapter 7 - Function of Nutrients: Micronutrients. In Marschner, P. ed, Marschner's Mineral Nutrition of Higher Plants (Third Edition). Academic Press, San Diego, pp, 191-248.

Bubarai M.L., Tahir A.M., Solomon R.I. (2017). The micronutrients boron its influence on growth and development of plants and factors affecting availability: a review. Journal of Agriculture and Veterinary Science, **10 (**12), 10- 13.

Cielo D., Char (2017). Carrots (*Daucus carota* L.). Fruit and vegetable phytochemicals: Chemistry and human health, Volume I, Second Edition. Edited by Elhadi M. Yahia. © 2017 John Wiley & Sons Ltd. Published 2017 by John Wiley & Sons Ltd. Chapter 46, pp., 969- 978.

Day S., Aasim M. (2020). Role of boron in growth and development of plant: Deficiency and toxicity perspective. In: Aftab T., Hakeem K.R. (eds) Plant Micronutrients. Springer, Cham. https://doi.org/10.1007/978-3-030-49856-6_19.

Dubois M., Gilles R.A., Hamillon J., Rebers R., Smith I. (1956). Colorimertic method for determination of sugars and related substances. Anal. Chem., 28: 350-356.

El Nagy M.M., Abou El- Salehein E.H., Fekry W.A., Wahdan H.M. (2020). Effect of chopped rice straw and foliar application of potassium and phosphorus on growth, yield and tuberous root quality of sweet potato (*Ipomoea batatas* L.) growing at late summer seasons under clay soil conditions. J. Product. & Dev., 25(2): 213-229.

El-Dissoky R.A., Abdel-Kadar A.E.S. (2013). Effect of boron as a foliar application on some potatoes cultivars under Egyptian alluvial soil conditions. Research Journal of Agriculture and Biological Sciences, 9, 232-240.

Ellong E.N., Billard C., Adenet S., Rochefort K. (2015). Polyphenols, carotenoids, vitamin C content in tropical fruits and vegetables and impact of processing methods. Food and Nutrition Sciences, 6, 299-313.

Gomez K.A., Gomez A.A. (1984). "Statistical Procedures for Agricultural Research" (2nd ed.). John Wiley and sons, New York, 680p.

Gondim A.R.D.O., Prado R.D.M., Filho A.B.C., Alves A.U., Correia M.A.R. (2015). Boron foliar application in nutrition and yield of beet and tomato, journal of plant nutrition, 38:10, 1573-1579, DOI: 10.1080/01904167.2015.1043373

Guo S., Wang M., Zheng Q., Shen Q. (2013). The critical role of potassium in plant stress response. Int. J. Mol. Sci., 14, 7370-7390; doi:10.3390/ijms14047370.

Hasanuzzaman M., Bhuyan M.H.M.B., Nahar K., Hossain M.S., Mahmud J.A., Hossen M.S., Masud A.A.C., Moumita Fujita M. (2018). Potassium: A Vital Regulator of Plant Responses and Tolerance to Abiotic Stresses. Agronomy, 8, 31; doi:10.3390/agronomy8030031.

Horneck D.A., Hanson D. (1998). Determination of potassium and sodium by flame emission spectrophotometry. In: Kalra, Y.P. (Ed.), Handbook of Reference Methods for Plant Analysis, pp. 153–155.

Horneck D.A., Miller R.O. (1998). Determination of total nitrogen in plant tissue. In: Kalra, Y.P. (Ed.), Handbook of Reference Methods for Plant Analysis, pp. 75–83.

Karam F., Rouphacl Y., Lahoud R., Breidi J., Coll G. (2009). Influence of Genotypes and potassium Application Rates on Yield and potassium Use Efficiency of Potato. J Agro. 8(1): 27-32.

Kassab O.M., Orabi S.A., Abo Ellil A.A. (2012). Physiological response to potassium application in fodder beet plant grown under water stress. Australian Journal of Basic and Applied Sciences, 6(13): 566-574.

Khaliq H., Zhong Juming., Peng Ke-Mei. (2018). The Physiological Role of Boron on Health. Biological Trace Element Research 186, 31–51 https://doi.org/10.1007/s12011-018-1284-3.

Kow N., Nabwami J. (2015). A review of effects of nutrient elements on crop quality. African J. of food, Agriculture, Nutrition and Development, 15(1): 9777- 9793.

Kumar J., Kumar R., Rai R., Mishra D.S. (2015). Response of 'pant prabhat' guava trees to foliar sprays of zinc, boron, calcium and potassium at different plant growth stages. The Bioscan. 10(2): 495- 498.

Leite C.W., Boroski M., Boeing J.S., Aguiar A.C., França P.B., de Souza N.E., Visentainer J.V. (2011). Chemical characterization of leaves of organically grown carrot (*Dacus carota* L.) in various stages of development for use as food. Ciênc. Tecnol. Aliment., Campinas, 31(3): 735-738, jul.-set.

Malhotra H., Vandana., Sharma S., Pandey R. (2018). Phosphorus Nutrition: Plant Growth in Response to Deficiency and Excess. In: Hasanuzzaman M., Fujita M., Oku H., Nahar K., Hawrylak-Nowak B. (eds) Plant Nutrients and Abiotic Stress Tolerance. Springer, Singapore. https://doi.org/10.1007/978-981-10-9044-8_7

Marschner H. (1995). Mineral nutrition of higher plants. 2nd Edition, Academic Press, London, 889 PP.

Minocha R., Martinez G., Lyons B., Long S. (2009). Development of a standardized methodology for quantifying total chlorophyll and carotenoids from foliage of hardwood and conifer tree species. *Can. J. For. Res*., 39: 849-861.

Nicolle C., Simon G., Rockm E., Amouroux P., Rémésy C. (2004). Genetic variability influences carotenoid, vitamin, phenolic, and mineral content in white, yellow, purple, orange, and dark-orange carrot cultivars. Journal of the American Society for Horticultural Science, 129:523–529.

Omar M.M., Ramadan A.Y. (2018). Response of carrot (*Daucus carota* L.) to foliar application of potassium fertilizers and some soil amendments under clay soil conditions. J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9 (4): 197 – 202.

Peirce C.A.E., McBeath T.M., Priest C., McLaughlin M.J. (2019). The timing of application and inclusion of a surfactant are important for absorption and translocation of foliar phosphoric acid by wheat leaves. Front. Plant Sci. 10:1532. doi: 10.3389/fpls.2019.01532.

Que F., Hou X., Wang G. (2019). Advances in research on the carrot, an important root vegetable in the Apiaceae family. Hortic. Res. 6, 69 https://doi.org/10.1038/s41438-019-0150-6.

Reis Gonçalves F.A., de Castro G.F., de Carvalho A.M.X., de Aquino L.A., Novais R.F. (2019). Forms of application of phosphorus fertilization on carrot, Journal of Plant Nutrition, 42:16, 1884-1899, DOI: 10.1080/01904167.2019.1648676.

Salim B.B.M., Abd El-Gawad H.G., Abou El-Yazied A. (2014). Effect of Foliar Spray of Different Potassium Sources on Growth, Yield and Mineral Composition of Potato (*Solanum tuberosum* L.). Middle East Journal of Applied Sciences, 4(4): 1197-1204.

Salim B.B.M., Abd El-Gawad H.G., Abou El-Yazied A., Hikal M.S. (2019). Effect of Calcium and Boron on Growth, Fruit Setting and Yield of Hot Pepper (*Capsicum annuum* L.). Egypt. J. Hort., 46, 1, 53-62.

Schachtman D.P., Reid R.J., Ayling S.M. (1998). Phosphorus Uptake by Plants: From Soil to Cell, *Plant Physiology*, 116, 2, 447–453, https://doi.org/10.1104/pp.116.2.447.

Shaban K.A., Mahrous M.S., Abdel-Azeem S.M., Rashad R.T. (2018). Effect of different sources of potassium on the nutrient status of saline calcareous soil and carrot (*Daucus carota* L.) yield and quality. Asian Journal of Soil Science and Plant Nutrition, 3(3): 1-14.

Sharma K.D., Karki S., Thakur N.S., Attri S. (2012). Chemical composition, functional properties and processing of carrot -a review. J. Food Sci. Technol., 49(1): 22-32.

Shen J., Yuan L., Zhang J., Li H., Bai Z., Chen X., Zhang W., Zhang F. (2011). Phosphorus dynamics: from soil to plant. Plant Physiol. Jul;156(3):997-1005. doi: 10.1104/pp.111.175232. Epub 2011 May 12. PMID: 21571668; PMCID: PMC3135930.

Sidhu M.K., Raturi H.C.h., Kachwaya D.S., Sharma A. (2019). Role of micronutrients in vegetable production: A review. Journal of Pharmacognosy and Phytochemistry, SP1: **8** (1), 332-340.

Silva Dias J.C. (2014). Nutritional and Health Benefits of Carrots and Their Seed Extracts. Food and Nutrition Sciences, 5, 2147-2156. http://dx.doi.org/10.4236/fns.2014.522227.

Singh D.P., Beloy J., McInerney J.K., Day L. (2012). Impact of boron, calcium and genetic factors on vitamin C, carotenoids, phenolic acids, anthocyanins and antioxidant capacity of carrots (*Daucus carota*). Food Chemistry, 132, 1161–1170. doi:10.1016/j.foodchem.2011.11.045.

Soratto R.P., Fernandes A.M., Pilon C., Souza M.R. (2019). Phosphorus and silicon effects on growth, yield, and phosphorus forms in potato plants. Journal of Plant Nutrition, 42:3, 218-233, DOI: 10.1080/01904167.2018.1554072.

Stefánsson A., Gunnarsson I., Giroud N. (2007). New methods for the direct determination of dissolved inorganic, organic and total carbon in natural waters by Reagent- FreeTM Ion Chromatography and inductively coupled plasma atomic emission spectrometry. Anal. Chim. Acta, 582, 69–74.

Subba S.K., Yambem P., Asha R.K., Das A., Chattopadhyay S.B., Choudhuri P. (2016). Effects of potassium and boron on quality parameters of carrot (*Daucus carota* L.). The Ecoscan, an International Quarterly Journal OF Environmental Sciences, Special issue, Vol. IX: 487-490.

Uchida R. (2000). Essential nutrients for plant growth: Nutrient functions and deficiency symptoms. from: plant nutrient management in Hawaii's soils, approaches for tropical and subtropical agriculture, J. A. Silva and R. Uchida, eds. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, ©2000.

Wang M., Zheng Q., Shen Q., Guo S. (2013). The critical role of potassium in plant stress response. International journal of molecular sciences, 14(4), 7370–7390. https://doi.org/10.3390/ijms14047370.

Wang Y.i., Wu W.H. (2013). Potassium Transport and Signaling in Higher Plants Annual Review of Plant Biology, 64:1, 451-476.

Wellburn A.R. (1994). The spectral determination of chlorophylls a and b, as well as total carotenoids, using various solvents with spectrophotometers of different resolution. J. of Plant Physiology, 144, (3): 307- 313.

Zayed B.A., Okasha A.M., Rashwan E. (2019). Impact of different rates of phosphoric acid foliar spraying on rice growth and yield traits under normal and saline soils conditions. East African Scholars J Agri Life Sci., 2, 2, 56- 66.

Zewail R.M.Y., Khder Z.M.A., Mady M.A. (2011). Effect of potassium, some antioxidants, phosphoric acid and napthalen acetic acid (NAA) on growth and productivity of faba bean plants *(Faba vulgaris).* Annals of Agric. Sci., Moshtohor, 49 (1), 53- 64.

الملخص العربي

تحفيز النمو الخضري ومحصول الجذور المُخزنه وصفات جودة نباتات الجزر عن طريق الرش الورقي بحمض الفوسفوريك والبوتاسيوم وحمض البوريك

بهاء بدري موسى سالم [١] ، نورا محمد طه [٢] و أحمد أبواليزيد [٢]

[١]قسم النبات الزراعي – كلية الزراعه – جامعة عين شمس – شبرا الخيمه – القليوبيه – مصر

[٢]قسم البساتين– كلية الزراعه – جامعة عين شمس – شبرا الخيمه – القليوبيه – مصر

تم إجراء تجربه حقليه من موسمين متتاليين في نوفمبر ٢٠١٨/٢٠١٧ و ٢٠١٩/٢٠١٨ بمزرعة كلية الزراعة ، جامعة عين شمس ، شبرا الخيمة ، مصر. لدراسة تأثير الإضافات الورقية لحمض الفوسفوريك (كمصدر للفوسفور ١٠٠٠ و ٢٠٠٠ جزء في المليون) ،هيدروكسيد البوتاسيوم (كمصدر للبوتاسيوم ١٠٠٠ و ٢٠٠٠ جزء في المليون) ، وحمض البوريك (كمصدر للبورون ٥٠٠ جزء في المليون) ومخلوطاتهم داخل تصميم قطاعات عشوائية كاملة يشتمل ثلاث مكررات لثماني معاملات رُشت عند ٣٠ و ٥٥ و ٧٥ يومًا من الزراعه لتحفيز النمو والمحصول والمكونات البيوكيميائية لنبات الجزر (*Daucus carota* L.) – صنف كورودا البرتقالي. أشارت النتائج أن رش معاملات حامض الفوسفوريك والبوتاسيوم وحمض البوريك منفردة ومختلطه سبب تنشيط جميع صفات النمو الخضري والمكونات البيوكيميائية ومحصول الجذور التخزينيه مقارنة بنباتات الكنترول في كلا الموسمين. كما حقق الرش الورقي بمعاملة حمض الفوسفوريك منفرداً بتركيز ٢٠٠٠ جزء في المليون ومعاملة الخليط من حمض الفوسفوريك ٢٠٠٠ جزء في المليون مع البوتاسيوم بتركيز ٢٠٠٠ جزء في المليون و حمض البوريك بتركيز ٥٠٠ جزء في المليون أعلى زيادات ملحوظة بالنسبة ل معظم صفات النمو الخضري والمغذيات الكبرى والصغرى وصبغات التمثيل الضوئي في أوراق الجزر عند ٩٠ يومًا من الزراعه وكذلك محصول الجذور المخزنه، N، P، K، Mg، Ca، Fe، Mn، Zn، Cu ، الكاروتينات الكليه ، فيتامين C ، السكريات الكليه و نسبة TSS في الجذور المخزنه عند الحصاد ١٠٥ يوم بعد الزراعه مقارنة بنباتات الكنترول.