



## Plant Production Science

Available online at <http://zjar.journals.ekb.eg>  
<http://www.journals.zu.edu.eg/journalDisplay.aspx?JournalId=1&queryType=Master>



# IMPROVING GROWTH, YIELD, AND ROOT QUALITY OF TABLE BEET PLANTS BY PHOSPHORUS FERTILIZATION AND BORAX FOLIAR APPLICATION UNDER NEW VALLEY CONDITONS

Mohammed A.M. Ali<sup>1\*</sup> and I.N. Nasef<sup>2</sup>

1. Hort. Dept., Fac. Agric., New Valley Univ., Egypt

2. Hort. Dept., Fac. Agric., Suez Canal Univ., Egypt

Received: 17/04/2024; Accepted: 28/04/2024

**ABSTRACT:** Two field experiments were conducted during 2020/2021 and 2021/2022, at the Experimental Farm, Faculty of Agriculture, New Valley University, New Valley Governorate, Egypt with aim of investigation of phosphorus (P) as soil fertilization and borax as foliar application on growth, yield and chemical constituents of table beet. Four phosphorus levels, *i.e.*, 30, 45, 60 and 75 kg/Feddin in the form of calcium phosphate were applied as soil application and four borax levels, *i.e.*, 0, 2, 4 and 6 g/L were applied as foliar application in the recently reclaimed areas, especially New Valley governorate as a promising area for agriculture expansion in Egypt. The results showed that application of P at 60 kg/feddin improved the vegetative growth and root parameters, total sugar, total carbohydrates, soluble solids content (SSC), phenolic, total betalains and mineral contents of table beet. In addition, foliar application of borax at 4 g/L improved the above-mentioned traits compared to other rates. In addition, the combination between P at 60 kg/feddin as soil application and borax at 4 g/L as foliar application was the more effective for enhancing yield and root quality of table beet.

**Key words:** Table beet, phenolic, phosphorus, boron, betalains, foliar application.

## INTRODUCTION

Table beet (*Beta vulgaris* L.) is one of the most important fresh vegetables belonging to the *Chenopodiaceae* family. It is a winter crop cultivated in Egypt for its root. Beetroot is a good source of betalain pigments and exhibits antioxidant, chemo-preventive activities and anti-inflammatory (Raish *et al.*, 2019). Several investigations confirmed that beetroot ameliorates multiple diseases such as atherosclerosis, type 2 diabetes, dementia and hypertension, and (Winkler *et al.*, 2005). Betanin pigments is considered the primary molecules recognized having anticancer effects (Ninfali and Angelino, 2013) as it works to make an interruption in the exchange of metabolites between tumor cells and surrounding tissues (Reddy, 2005) in order to hinder the infiltration capacity of the tumor cells. Moreover, it has antiproliferative effect on human chronic leukemia (Sreekanth *et al.*,

2007). Phosphorus is considered a primary nutrient for growth of plants (Hinsinger, 2001). It is needed to optimum production and quality (Zapata and Zaharah, 2002). Phosphorus is essential for reproduction, cell division, and plant metabolism; likewise, its role is related to the storage, acquisition and use of energy (Epstein and Bloom 2004). Practically, phosphorus fertilizer resulted in maximized the root and sugar content of sugar beet (Marinkovic *et al.*, 2008). Also, Seadh (2012) found that application of 30 kg P per feddan produced the highest values of vegetative growth, root and sugar yield of sugar beet plants.

Micronutrients are essential elements for normal plant growth, development and productivity of plants as they play important roles in the meristematic development, photosynthesis, chlorophyll formation and transpiration as well as phenolic compound development (Tripathi *et al.*, 2015). Boron (B) is very important for growth

\* Corresponding author: Tel. :+20100 643 8356

E-mail address: innasef@hotmail.com

and development of plants as it is involved in cell division, root elongation, calcium metabolism, auxin synthesis, sugar metabolism and protein synthesis (Camacho-Cristóbal *et al.*, 2018). In addition, Subba *et al.* (2016) reported that boron enhanced the productivity and root quality of carrot. Furthermore, foliar application of boron improved root yield and its components, white and gross sugar percentages of sugar beet (Mekdad, 2015).

The literature on the interaction between phosphorus and boron in table beet plant is limited. Therefore, the present study was to investigate the effects of phosphorus fertilizer as soil application and foliar application of boron as well as their interaction on vegetative growth, yield and chemical constituents of table beet.

## MATERIALS AND METHODS

### Plant Materials and Treatments

Two field experiments were carried out at Agricultural Research Farm of the Faculty of Agriculture, New Valley University, New Valley Governorate, Egypt during two consecutive winter growing seasons 2020-2021 and 2021/2022 in order to study the effect of phosphorus levels as soil application and foliar application of borax as well as their interaction on vegetative growth, yield, and chemical components of table beet (*Beta vulgaris* L.) "cv. Detroit dark red". P was applied as calcium super phosphate (15.5% P<sub>2</sub>O<sub>5</sub>) at level of 30, 45, 60, 75 kg P/fed. as soil application Borax was applied at 0, 2, 4, 6 g/L as foliar application. The both treatments were arranged in a split plot in randomized complete block design with three replications. Phosphorus levels were applied during soil preparation. Borax with three drops of tween-twenty were sprayed 5 times. The first borax treatment was applied at age 20 days after germination with 7 days intervals on the whole foliage in the morning (9-10 am). According to the stage of plant development, the sprayed solution volume ranged from 15 to 40 ml per plant each time by a manual pump. The control plants were sprayed with the same amount of distilled water plus tween-twenty.

### Experimental Design

The experiment was laid out in a split plot in randomized complete block design with three replications. The experiment comprised of 16

treatment combinations of 4 rates of phosphorus and 4 levels of borax. Phosphorus rates contributed as the main plot while, Boron levels were in sub plot. Experimental plot had 4 rows each row was 4 m long and 70 cm width. The experimental unit area (plot) was 11.2 m<sup>2</sup> and contained 4 rows, with 4 m in length and 0.7 m in width for each row. A guard row was left without planting to separate each two adjacent sub-plots to protect against border effects.

### Agricultural Practices

The experimental sites were prepared by adding 20 m<sup>3</sup> of chicken manure. Later, the soil was cleared, ploughed, harrowed and divided into plots. Seeds of table beet were planted by hand on both sides of the row at a distance of 10 cm between plants under drip irrigation system. Table beet seeds were sown on 23<sup>th</sup> and 25<sup>th</sup> October in the 1<sup>st</sup> and 2<sup>nd</sup> seasons, respectively. All cultural practices (*i.e.* irrigation, weed and pest control) used for the red beet production were performed according to instructions of the Egyptian Ministry of Agriculture.

Soil samples were randomly collected at depth of 0.0–40.0 cm before plantation and then homogenized together in order to determine the physicochemical and chemical characteristics (Jackson, 1973). The soil analysis of the experimental site is illustrated in Table 1.

### Measurements

#### Morphological and yield characters

Table beet plants were harvested after 80 days from germination and number of leaves per plant, leaf area per plant (cm<sup>2</sup>), top fresh weight (g), top dry weight (g), root length (cm), root diameter (cm), root fresh weight (g), root dry matter (%) and total root yield (ton/fed.) were recorded.

#### Biochemical compounds

Total betalains was expressed as mg/100g of fresh weight content was measured spectrophotometrically at 536 nm and 476 nm, using a spectrophotometer (UNICO UV/Visible 2100, USA), according to Von Elbe (2001).

Total sugars were expressed as mg/100g of fresh weight and measured with phenol–sulfuric acid reagents spectrophotometrically using a spectrophotometer (UNICO UV/Visible 2100, USA) at 480 nm according to Dubois *et al.* (1956).

**Table 1. Physical and chemical characteristics of the experimental site in growing seasons**

Soil characteristics	Season 2020/2021	Season 2021/2022
Silt (%)	12.76	12.53
Clay (%)	7.85	7.80
Sand (%)	79.39	79.67
Texture	Sandy	Sandy
PH	8.14	8.10
E.C dsm	1.03	1.01
Organic matter (%)	0.52	0.54
CaCO <sub>3</sub> (%)	5.02	5.05
Available N (mg/kg)	48.90	51.32
Available P (mg/kg)	5.17	5.21
Available K (mg/kg)	134.80	141.42
Soluble cations ((meq/100g)		
K <sup>+</sup>	0.23	0.26
Ca <sup>++</sup>	0.98	0.95
Mg <sup>++</sup>	0.66	0.40
Na <sup>+</sup>	3.14	3.21
Soluble anions (meq/100g)		
CO <sub>3</sub> <sup>--</sup>	-	-
HCO <sub>3</sub> <sup>-</sup>	1.12	1.10
Cl <sup>-</sup>	2.96	2.84
SO <sub>4</sub> <sup>-</sup>	0.93	0.88

Total phenolic content: Total phenolic determination was carried out for roots according to Folin-Ciocalteu method using a spectrophotometer (UNICO UV/Visible 2100, USA), as described by **Sadasivam and Manickam (1991)**. The data were expressed as mg/100g of fresh weight.

Total carbohydrates (%): Carbohydrates content (%): It was determined according to **Mazumdar and Majumder (2003)**.

Total sugars (%) of beet roots were determined by using the phenol-sulphuric acid method (**Dubois et al., 1956**).

Soluble solids content (SSC) (%) was determined using a hand refractometer.

#### **Nitrogen, phosphorus, potassium and boron in leaves and roots**

- 1- Total Nitrogen (mg/g dry weight) was estimated using semi-micro-kjeldahl method as described by **Ling (1963)**
- 2- Phosphorus (mg/g dry weight) was analyzed by chlorostannus reduced molybdophosphoric blue color method, in sulfuric acid system at 660 nm using a Spectro 22 spectrophotometer as described by **Jackson (1973)**.
- 3- Potassium concentrations (mg/g dry weight) were determined using a Perkin-elmer, Flame photometer (**Page, 1982**)
- 4- B (ppm) was determined by method of **Dible et al. (1954)**.

## Statistical Analysis

The collected data were subjected to statistical analysis using two-ways analysis of variance (ANOVA) procedures as applied in Co-Stat Software computer program for statistics. Means for phosphorus levels and borax treatments as well as their interactions were compared according to Duncan's multiple range test at a significance level  $\alpha$  of 0.05.

## RESULTS

### Vegetative Growth of Table Beet

The presented data in Table 2 show the effect of phosphorus and borax as well as their interaction on number of leaves, leave fresh weight, leaves dry weight and leaf area during 2020/2021 and 2021/2022 seasons. These parameters were significantly enhanced by phosphorus treatment at 60 kg/fed as soil fertilization. Also, the results showed that borax at 4 g/L as foliar application resulted in a significant increase in these parameters compared with the other rates. The interaction between P at 60 kg/fed., With borax at 4 g/L gave the highest number of leaves/plant, leave fresh weight, leaves dry weight and leaf area/plant compare with other interactions treatment in both seasons.

### Yield of Table Beet

The results in Table 3 show a significant difference between the treatments during the both seasons. Application of phosphorus as soil fertilization at 60 kg/fed. recorded the highest values of root diameter, root length, root fresh weight, root dry matter and root yield compared with the other rates during the both seasons. Regarding the main effect of borax, the significant highest root diameter, root length, root fresh weight, root dry matter and root yield were observed with 4 g/L as foliar application. However, there are no significant differences between 4 g/L and 6 g/L for root length and root dry matter in the both seasons. The interaction effects between phosphorus and borax treatments are presented in Table 3. Table beet plants which were fertilized with 60 kg/fed., phosphorus and were sprayed with 4 g/L borax had the highest yield parameters and root yield compared with

other combinations. The increasing percentage was approx. 41.34% and 41.23.1% for root diameter, 46.55% and 44.03% for root length, 51.70% and 52.08% for root fresh weight, 74.83% and 83.92% root dry weight and 55.74% and 56.51% root yield in the both seasons, respectively, when table beet plants received 60 kg/fed., P and treated with 4 g/L borax in comparison with 30 kg/fed P with 0 g/L borax.

### Biochemical Compounds of Table Beet Roots

The main effects of phosphorus and borax treatments as well as their interaction on biochemical compounds such as SSC, total carbohydrates, total soluble sugars, total phenolics and betalains of table beet roots during 2020/021 and 2021/2022 seasons are presented in Table 4. With regard to the effect of phosphorus, the application of phosphorus at 60 kg/fed. as soil application gave the highest significant for all parameters under study. With respect to the effect of borax, spraying with 4 g/L of borax gave the highest content of biochemical compounds. Concerning the interaction effect, the results showed that the roots of table beet plants fertilized with phosphorus at a rate of 60 kg/fed., as soil application and spraying with 4 g/L borax gave the highest contents of biochemical compounds in comparison with the other interaction treatments.

### Elements Content of Table Beet Leaves

The results shown in Table 5 indicated that nitrogen, phosphorus, potassium and boron concentration of table beet leaves were significantly affected by phosphorus and borax as well as their interaction during 2020/2021 and 2021/2022 seasons. The results illustrated that the highest nitrogen content of leaves was recorded with 60 kg/fad. P treatment but no significant difference was observed between 60 kg/fad., and 75 kg/fad., in the both seasons. Regarding to the effect of borax as foliar spray on nitrogen content of leaves, spraying with 4 g/L of borax gave the highest content of nitrogen, without significant differences with 6 g/L, while the control treatment gave the lowest content. Concerning the interaction effects on nitrogen content of leaves, sprayed plants with borax at a rate of 4 g/L and fertilized with

**Table 2. Effect phosphorus, borax treatments and their interaction on leaves number, leaves fresh weight, leaves dry weight and leaf area during 2020-2021 and 2021-2022 seasons**

Phosphorus (kg/Feddan)	2020/2021 season					2021/2022 season				
	Borax (g/L)					Borax (g/L)				
	0	2	4	6	Mean	0	2	4	6	Mean
<b>No. of leaves/plant</b>										
<b>30</b>	14.66 h	15.33 gh	15.66 fg	15.66 fg	15.33 D	14.66 i	15.66 gh	16.00 fg	16.00 fg	15.58 D
<b>45</b>	14.66 h	16.33 ef	17.00 de	16.33 ef	16.08 C	15.00 hi	16.66 ef	17.00 de	16.66 ef	16.33 C
<b>60</b>	15.33 gh	18.00 bc	19.00 a	18.66 ab	17.75 A	15.66 gh	18.33 bc	19.33 a	18.66 ab	18.00 A
<b>75</b>	15.00 gh	17.00 de	18.00 bc	17.33 cd	16.83 B	15.66 gh	17.66 cd	18.00 bc	17.66 cd	17.25 B
<b>Mean</b>	14.91 D	16.66 C	17.41 A	17.00 B		15.25 C	17.08 B	17.58 A	17.25 AB	
<b>Top fresh weight (g)</b>										
<b>30</b>	30.20 j	34.48 hi	39.92 fg	36.63 gh	35.31 D	30.90 j	36.12 hi	40.93 fg	38.82 gh	36.69 D
<b>45</b>	31.42 ij	40.05 fg	43.41 ef	42.72 ef	39.40 C	32.53 ij	41.17 fg	46.95 de	43.80 ef	41.11 C
<b>60</b>	34.39 hi	51.46 bc	55.33 a	53.65 ab	48.71 A	35.68 hi	51.66 bc	56.29 a	55.45 ab	49.77 A
<b>75</b>	32.73 ij	46.35 de	50.16 bc	48.43 cd	44.41 B	32.87 ij	47.77 cd	51.63 bc	50.14 cd	45.60 B
<b>Mean</b>	32.18 D	43.08 C	47.20 A	45.36 B		32.99 D	44.18 C	48.95 A	47.05 B	
<b>Top dry weight (g)</b>										
<b>30</b>	4.07 j	4.77 hi	5.34 fg	5.13 gh	4.83 C	4.14 j	4.81 hi	5.36 gh	5.31 gh	4.90 D
<b>45</b>	4.27 ij	5.61 fg	6.22 de	5.85 ef	5.49 B	4.29 ij	5.64 fg	6.27 de	5.97 ef	5.54 C
<b>60</b>	4.57 ij	7.11 bc	7.65 a	7.34 ab	6.66 A	4.63 ij	7.22 bc	7.77 a	7.39 ab	6.75 A
<b>75</b>	4.43 ij	6.58 cd	6.86 bc	6.64 cd	6.13 AB	4.50 ij	6.66 cd	6.91 bc	6.71 cd	6.19 B
<b>Mean</b>	4.33 C	6.02 B	6.52 A	6.24 B		4.39 C	6.08 B	6.58 A	6.34 AB	
<b>Leaf area/plant (cm<sup>2</sup>)</b>										
<b>30</b>	496.04 k	650.22 ij	774.45 gh	699.07 hi	554.94 D	509.73 k	740.74 hi	890.25 g	817.74 gh	739.61 D
<b>45</b>	518.22 k	815.68 fg	958.90 e	900.90 ef	798.42 C	550.97 jk	937.60 fg	1046.81 ef	952.46 fg	871.96 C
<b>60</b>	586.48 jk	274.86 bc	1473.91 a	1315.16 b	162.60 A	675.37 ij	293.21 bc	1555.82 a	1422.57 b	1236.74 A
<b>75</b>	569.37 jk	1094.68 d	1226.86 bc	1193.11 c	1021.01 B	653.04 ij	110.08 de	237.64 cd	205.05 cd	1051.45 B
<b>Mean</b>	542.53 D	958.86 C	1108.53 A	1027.06 B		597.28 D	1020.41 C	1182.63 A	1099.45 B	

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.

**Table 3. Effect of phosphorus and borax treatments and their interaction on root diameter, root length, root fresh weight, root dry matter and root yield during 2020/2021 and 2021/2022 seasons**

Phosphorus (kg/ Feddan)	2020/2021					2021/2022				
	Borax (g/L)					Borax (g/L)				
	0	2	4	6	Mean	0	2	4	6	Mean
<b>Root diameter (cm)</b>										
30	5.66 j	6.10 hi	6.50 fg	6.30 gh	6.14 D	5.70 j	6.40 gh	6.56 fg	6.46 gh	6.28 D
45	5.70 j	6.53 fg	6.80 ef	6.70 ef	6.43 C	5.90 ij	6.61 fg	6.99 de	6.86 ef	6.59 C
60	5.90 ij	7.50 bc	8.00 a	7.63 ab	7.25 A	6.10 hi	7.59 bc	8.05 a	7.71 ab	7.36 A
75	5.80 ij	7.00 de	7.23 cd	7.06 de	6.77 B	5.93 ij	7.06 de	7.33 cd	7.21 de	6.88 B
Mean	5.76 C	6.78 B	7.13 A	6.92 B		5.90 C	6.91 B	7.23 A	7.06 AB	
<b>Root length (cm)</b>										
30	6.23 k	6.93 hi	7.31 gh	7.28 gh	6.94 D	6.36 j	6.96 hi	7.36 gh	7.30 gh	7.00 D
45	6.30 k	7.50 fg	7.86 ef	7.66 fg	7.33 C	6.56 ij	7.53 fg	7.96 ef	7.83 ef	7.47 C
60	6.86 ij	8.56 bc	9.13 a	8.83 ab	8.35 A	6.93 hi	8.70 bc	9.16 a	8.96 ab	8.44 A
75	6.53 jk	8.06 de	8.36 cd	8.26 cd	7.80 B	6.60 ij	8.16 de	8.50 cd	8.43 cd	7.92 B
Mean	6.48 C	7.76 B	8.17 A	8.01 A		6.61 C	7.84 B	8.25 A	8.13 A	
<b>Root fresh weight (g)</b>										
30	102.06 k	112.76 ij	121.54 gh	116.86 hi	113.30 D	102.95 l	116.58 ij	124.89 ghi	119.70 hi	116.03 D
45	105.50 jkl	125.41 fg	131.36 ef	127.06 fg	122.33 C	105.90 kl	128.65 fg	135.45 ef	133.82 ef	125.95 C
60	110.55 ij	146.02 bc	154.82 a	150.93 ab	140.58 A	112.20 jk	147.76 bc	156.57 a	152.88 ab	142.35 A
75	106.37 jkl	135.45 de	144.24 bc	140.08 cd	131.53 B	110.72 jk	137.17 de	146.83 bc	143.56 cd	134.57 B
Mean	106.12 D	129.91 C	137.99 A	133.73 B		107.94 D	132.54 C	140.94 A	137.49 B	
<b>Root dry matter (%)</b>										
30	14.46 h	17.18 fg	18.10 ef	17.45 ef	16.80 C	14.74 i	17.38 gh	18.39 fg	17.73 fg	17.06 D
45	14.99 gh	18.73 ef	19.70 de	19.26 ef	18.17 C	15.01 i	18.81 fg	20.94 de	19.65 ef	18.60 C
60	17.02 fg	23.08 bc	25.28 a	24.15 ab	22.38 A	17.14 gh	24.58 bc	27.11 a	25.66 ab	23.62 A
75	15.18 gh	21.43 cd	22.57 bc	21.81 cd	20.25 B	15.41 hi	21.74 de	23.00 cd	22.60 cd	20.69 B
Mean	15.41 C	20.10 B	21.41 A	20.67 AB		15.57 C	20.63 B	22.36 A	21.41 AB	
<b>Root yield (ton/fed.)</b>										
30	10.10 k	11.25 ij	12.11 gh	11.66 hi	11.28 D	10.14 l	11.53 ij	12.34 gh	11.83 hi	11.46 D
45	10.37 k	12.68 fg	13.34 ef	13.00 ef	12.35 C	10.68 kl	12.93 fg	13.50 ef	13.11 ef	12.56 C
60	11.11 ij	14.98 bc	15.73 a	15.30 ab	14.28 A	11.39 ij	15.02 bc	15.87 a	15.54 ab	14.45 A
75	10.80 jk	13.63 de	14.61 bc	14.30 cd	13.33 B	10.86 jk	13.76 de	14.86 bc	14.41 cd	13.47 B
Mean	10.60 D	13.14 C	13.95 A	13.56 B		10.77 D	13.31 C	14.14 A	13.72 B	

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.

**Table 4. Effect of phosphorus, borax treatments and their interaction on chemical constituents of table beet roots during 2020/2021 and 2021/2022 seasons**

Phosphorus (kg/ Feddan)	2020/2021					2021/2022				
	Borax (g/L)					Borax (g/L)				
	0	2	4	6	Mean	0	2	4	6	Mean
<b>Total betalains (mg/100g)</b>										
30	282.65 l	293.17 ij	298.51 gh	295.08 hi	292.35 D	284.35 l	294.68 ij	300.84 gh	297.45 hi	294.33 D
45	284.26 kl	300.59 fg	305.66 ef	303.43 fg	298.49 C	286.59 kl	301.58 gh	307.59 ef	305.57 fg	300.33 C
60	290.17 ij	316.39 bc	322.27 a	318.85 ab	311.92 A	291.51 jk	317.49 bc	322.61 a	319.90 ab	312.88 A
75	288.19 jk	308.76 de	314.23 bc	311.52 cd	305.67 B	289.38 kl	310.67 de	314.85 cd	312.11 de	306.75 B
Mean	286.32 D	304.73 C	310.17 A	307.22 B		287.96 D	306.10 C	311.47 A	308.76 B	
<b>Total phenols (mg/100g)</b>										
30	121.20 l	128.76 ij	132.44 gh	130.47 hi	128.21 D	122.77 k	130.43 hi	133.05 gh	131.99 gh	129.56 D
45	123.76 kl	133.24 gh	136.92 ef	134.90 fg	132.20 C	124.84 jk	134.46 fg	138.85 de	136.88 ef	133.76 C
60	127.33 ij	144.24 bc	148.05 a	145.80 ab	141.35 A	127.94 ij	145.58 bc	149.95 a	148.49 ab	142.99 A
75	125.85 jk	139.32 de	143.18 bc	141.25 cd	137.40 B	126.34 jk	140.39 de	144.92 bc	141.97 cd	138.41 B
Mean	124.53 D	136.39 C	140.15 A	138.10 B		125.47 D	137.71 C	141.69 A	139.83 B	
<b>Total carbohydrate (mg/g)</b>										
30	84.4 k	95.2 hi	98.3 gh	96.5 hi	93.6 D	87.2 k	99.5 hi	103.7 gh	100.3 hi	97.7 D
45	88.2 jk	102.6 fg	106.4 ef	104.3 ef	100.4 C	91.4 jk	107.3 fg	110.9 ef	108.6 fg	104.6 C
60	92.6 ij	117.3 bc	123.7 a	120.3 ab	113.5 A	96.2 ij	121.6 bc	127.3 a	125.5 ab	117.6 A
75	89.6 jk	109.4 de	114.5 cd	112.4 cd	106.4 B	92.3 jk	114.6 de	118.5 cd	116.7 cd	110.5 B
Mean	88.7 C	106.1 B	110.7 A	108.3 AB		91.8 C	110.8 B	115.1 A	112.8 AB	
<b>Total sugars (mg/g)</b>										
30	56.3k	62.4hi	65.9fg	64.8gh	62.3D	56.4k	62.8hi	66.0gh	65.6gh	62.7D
45	57.6jk	66.9fg	70.4de	68.9ef	65.9C	57.9jk	67.3fg	70.6ef	69.0fg	66.2C
60	60.8ij	74.9bc	80.1a	77.5ab	73.3A	61.0ij	76.2bc	81.3a	79.0ab	74.3A
75	60.1ij	70.5de	74.4bc	73.4cd	69.6B	60.5ij	72.7de	75.5cd	74.5cd	70.8B
Mean	58.7C	68.7B	72.7A	71.1A		59.0C	69.7B	73.3A	72.0A	
<b>Soluble solids content (%)</b>										
30	6.32 k	7.00 hi	7.25 gh	7.10 hi	6.92 D	6.34 l	7.06 ij	7.44 gh	7.25 hi	7.02 D
45	6.50 jk	7.49 fg	7.70 ef	7.63 ef	7.33 C	6.56 kl	7.60 fg	7.94 ef	7.64 fg	7.43 C
60	6.85 ij	8.39 bc	8.79 a	8.52 ab	8.14 A	6.91 ij	8.57 bc	8.95 a	8.77 ab	8.30 A
75	6.61 jk	7.92 de	8.31 bc	8.07 cd	7.73 B	6.72 jk	8.09 de	8.40 cd	8.30 cd	7.88 B
Mean	6.57 C	7.70 B	8.01 A	7.83 B		6.63 C	7.83 B	8.18 A	7.99 B	

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.

**Table 5. Effect of phosphorus, borax treatments and their interaction on N, P, K and B contents of table beet leaves during 2020/2021 and 2021/2022 seasons**

Phosphorus (kg/ Feddan)	2020/2021 season					2021/2022 season				
	Borax (g/L)					Borax (g/L)				
	0	2	4	6	Mean	0	2	4	6	Mean
<b>N (mg/g DW)</b>										
<b>30</b>	21.00i	22.67gh	23.67fg	23.37fg	22.68C	21.10i	22.73gh	23.77fg	23.67fg	22.82C
<b>45</b>	21.33hi	24.40ef	25.37de	25.33de	24.11B	21.63hi	24.47ef	25.57de	25.43de	24.28B
<b>60</b>	22.23ghi	27.13bc	29.00a	28.00ab	26.59A	22.60gh	27.17bc	29.07a	28.13ab	26.74A
<b>75</b>	22.87g	26.30cd	27.83ab	27.23bc	26.06A	23.07g	26.20cd	27.73b	27.13bc	26.03A
<b>Mean</b>	21.86C	25.13B	26.47A	25.98A		22.10C	25.14B	26.53A	26.09A	
<b>P (mg/g DW)</b>										
<b>30</b>	2.73 k	3.05 hi	3.17 gh	3.12 gh	3.02 D	2.80 k	3.07 hi	3.24 fg	3.17 gh	3.07 D
<b>45</b>	2.82 jk	3.24 fg	3.42 de	3.33 ef	3.20 C	2.86 jk	3.27 fg	3.44 de	3.35 ef	3.23 C
<b>60</b>	2.92 ij	3.45 de	3.53 cd	3.50 cd	3.35 B	2.98 ij	3.51 cd	3.63 bc	3.58 cd	3.42 B
<b>75</b>	2.94 ij	3.59 bc	4.01 a	3.70 b	3.56 A	3.03 hi	3.63 bc	4.09 a	3.77 b	3.63 A
<b>Mean</b>	2.85 D	3.33 C	3.53 A	3.41 B		2.92 D	3.37 C	3.60 A	3.47 B	
<b>K (mg/g DW)</b>										
<b>30</b>	35.3 m	40.0 ij	41.2 hi	40.3 hi	39.2 D	35.9 n	40.1 jk	41.7 hi	40.9 ij	39.6 D
<b>45</b>	36.6 lm	41.9 gh	44.2 ef	42.9 fg	41.4 C	37.2 mn	42.6 gh	44.5 ef	43.4 fg	41.9 C
<b>60</b>	38.6 jk	47.3 bc	49.8 a	48.1 b	45.9 A	39.0 kl	47.8 bc	49.9 a	48.4 b	46.3 A
<b>75</b>	37.2 kl	44.6 ef	46.4 cd	45.6 de	43.4 B	38.0 lm	45.4 de	46.8 cd	46.0 de	44.0 B
<b>Mean</b>	36.9 C	43.4 B	45.4 A	44.2 B		37.5 C	44.0 B	45.7 A	44.7 B	
<b>B (ppm)</b>										
<b>30</b>	4.91 k	5.86 hi	6.84 ef	7.81 bc	6.35 D	4.96 k	5.93 hi	6.86 ef	7.78 bc	6.38 C
<b>45</b>	5.17 jk	6.15 gh	7.05 de	7.97 bc	6.58 C	5.23 jk	6.24 gh	7.11 de	8.03 bc	6.65 B
<b>60</b>	5.56 ij	6.54 fg	7.51 cd	8.70 a	7.08 A	5.59 ij	6.59 fg	7.56 cd	8.83 a	7.14 A
<b>75</b>	5.45 ij	6.31 gh	7.20 de	8.23 b	6.80 B	5.48 ij	6.35 gh	7.24 de	8.24 b	6.82 B
<b>Mean</b>	5.27 D	6.21 C	7.15 B	8.18 A		5.31 D	6.28 C	7.19 B	8.22 A	

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.



phosphorus at a rate of 60 kg/fed gave the highest nitrogen content compared the other combinations. With respect to the effect of phosphorus treatments on phosphorus content of leaves, the results showed that phosphorus content increased gradually by increasing the phosphorus level from 30 up to 75 kg/fed as soil application. Concerning borax effect, foliar application of borax at 4 g/L recorded the maximum content of phosphorus in table beet leaves compared with the other rates. The interaction between 75 kg/L phosphorus as soil application and 4 g/L borax as foliar application gave the highest phosphorus content of leaves compared to the other combinations.

Concerning, potassium content of leaves, the effect of phosphorus treatments revealed that the plants received 60 kg/fad., recorded the maximum potassium content of leaves, and sprayed with 4 g/L borax gave the highest potassium content of leaves. The combination of P at 60 kg/fed with borax at 4 g/L recorded the highest potassium content of leaves in the both seasons. Regarding the boron content in leaves, plants fertilized with 60 kg/fed of P recorded the highest concentration of boron, and spraying with boron at 6 g/L gave the highest value of B in leaves in the both seasons. With respect to the interaction treatment, fertilized plants with 60 kg/fed of P and sprayed with 6 g/L increased boron content in leaves in the both seasons.

### Elements Content of Table Beet Roots

Nitrogen, phosphorus, potassium and boron content of table beet roots were significantly affected by phosphorus and boron as well as their interaction during 2020/2021 and 2021/2022 seasons (Table 6). Concerning the main effect of phosphorus treatments, the highest N, K and B content in roots were recorded by the plants which fertilized with 60 kg/fad., of phosphorus, while the highest P content of roots was recorded in plants which fertilized with 75 kg/fad., in the both seasons. With respect to the effect of borax treatments, the highest N, P and K content of roots were found in the plants which sprayed with 4 g/L while the concentration of B in roots increased gradually with increasing the borax levels from 0 up to 6 g/L as foliar application in the both seasons. Concerning the interaction between phosphorus

and borax treatments, the highest N and K content of roots were recorded with the interaction between P at 60 kg/fed and borax at 4 g/L in the both seasons, while the highest P content was found in the roots of plants which fertilized with 75 kg/fad., of P and sprayed with 4 g/L of borax. The interaction between P at 60 kg/fad., as soil application and borax at 6 g/L as foliar application achieved the highest B content of roots.

### DISCUSSION

Plants need essential macro and micro-elements for normal growth, development and formation of fruits and seeds. Phosphorus is an essential macro-element plays a vital role in the physiological processes of plants such as nucleic acid synthesis, energy generation, photosynthesis, carbohydrate metabolism, respiration, glycolysis and nitrogen fixation (Kabir *et al.*, 2013). Boron is an essential micronutrient, plays a role in the metabolism and function of membrane and involved in the reactions of enzymes as well as ions transport, hormones and metabolites, so the deficiency of boron affects the capacity of photosynthetic and photosynthetic products transport. Also, boron deficiency inhibits root elongation by cell division cessation in the apical meristem (Brdar-Jokanovic, 2020). Also, Ahmad *et al.* (2009) reviewed that B deficiency impairs cell wall structure and synthesis, membrane integrity, carbohydrate metabolism, sugar transport, respiration, indole acetic acid metabolism, phenol metabolism and RNA metabolism. In our study, the significant effects of P and borax application were observed regarding number of leaves, leaves fresh weight, leaves dry weight, leaf area and yield of table beet. The application of phosphorus at a rate 60 kg/fed as soil fertilization enhanced the vegetative growth parameters and improved the yield. These results are agreement with Silva *et al.* (2019), who found that the fertilization of phosphorus promoted the growth and yield of four table beet cultivars. The increase in vegetative growth by P might be due to enhance the rate of photosynthetic (Irfan *et al.*, 2019). The results revealed that the concentration of 4 g/L of borax was more effective in improving the vegetative growth and yield of table beet. In the same context, borax foliar application improved

**Table 6. Effect of phosphorus, borax treatments and their interaction on N, P, K and B contents of table beet roots during 2020/2021 and 2021/2022 seasons**

Phosphorus (kg/ Feddan)	2020/2021 season					2021/2022 season					Mean
	0	2	4	6	Mean	0	2	4	6	Mean	
	<b>N (mg/g DW)</b>										
30	15.3 k	17.8 hi	19.0 gh	18.6 gh	17.7 D	15.5 l	18.1 ij	19.2 hi	18.8 hi	17.9 D	
45	15.9 jk	19.8 fg	21.1 de	20.6 ef	19.4 C	16.2 kl	19.9 gh	21.2 ef	20.7 fg	19.5 C	
60	17.0 ij	23.4 bc	25.0 a	24.3 ab	22.4 A	17.4 jk	23.8 bc	25.2 a	24.6 ab	22.7 A	
75	16.6 ij	21.6 de	23.1 bc	22.2 cd	20.9 B	16.7 kl	21.9 ef	23.2 cd	22.3 de	21.0 B	
Mean	16.2 D	20.6 C	22.1 A	21.4 B		16.4 D	20.9 C	22.2 A	21.6 B		
<b>P (mg/g DW)</b>											
30	2.01 k	2.41 hi	2.58 gh	2.54 gh	2.38 D	2.09 k	2.43 hi	2.62 fg	2.55 gh	2.42 D	
45	2.11 jk	2.65 fg	2.81 ef	2.70 fg	2.57 C	2.14 jk	2.71 fg	2.89 de	2.78 ef	2.63 C	
60	2.19 jk	2.94 de	3.09 cd	3.03 cd	2.81 B	2.23 jk	2.95 de	3.13 bc	3.05 cd	2.84 B	
75	2.26 ij	3.18 bc	3.47 a	3.28 b	3.05 A	2.29 ij	3.23 bc	3.49 a	3.31 b	3.08 A	
Mean	2.14 D	2.79 C	2.99 A	2.89 B		2.19 D	2.83 C	3.03 A	2.92 B		
<b>K (mg/g DW)</b>											
30	27.0 l	31.5 ij	33.9 gh	33.1 hi	31.4 D	27.6 k	32.2 hi	34.1 gh	33.2 hi	31.8 D	
45	28.6 kl	35.1 gh	37.5 ef	36.0 fg	34.3 C	28.8 jk	35.7 fg	37.6 ef	36.4 fg	34.6 C	
60	29.8 jk	42.6 bc	45.4 a	43.1 b	40.2 A	31.0 ij	42.7 bc	45.7 a	43.3 b	40.7 A	
75	29.1 kl	39.0 de	41.5 bc	40.5 cd	37.5 B	29.6 jk	39.2 de	41.7 bc	40.8 cd	37.8 B	
Mean	28.6 C	37.0 B	39.5 A	38.2 B		29.2 C	37.5 B	39.8 A	38.4 B		
<b>B (ppm)</b>											
30	3.53 l	4.33 ij	5.23 fg	6.03 cd	4.78 C	3.65 j	4.35 hi	5.27 ef	6.04 cd	4.83 C	
45	3.65 kl	4.54 ij	5.52 ef	6.30 bc	5.00 BC	3.68 j	4.67 gh	5.57 de	6.40 bc	5.08 BC	
60	4.08 jk	5.03 gh	5.82 de	6.97 a	5.47 A	4.09 ij	5.07 fg	5.95 cd	6.99 a	5.52 A	
75	3.84 kl	4.74 hi	5.72 de	6.51 b	5.20 B	3.87 ij	4.77 gh	5.73 de	6.52 b	5.22 B	
Mean	3.77 D	4.66 C	5.57 B	6.45 A		3.82 D	4.72 C	5.63 B	6.49 A		

Means with the same letters are not significantly differed at 5% according to Duncan's multiple range test.

the sugar beet yield (**Armin and Asgharipour, 2012**). This could be attributed to the role of boron in cell division and elongation thereby encouraging the vegetative growth and root yield (**Camacho-Cristóbal et al., 2015**). The interactions between phosphorus and borax had a significant effect on vegetative growth and roots yield. Interestingly, in the previous studies, the combination of P and B enhanced the metabolic function of plants (**Muhlbachova et al., 2017**), and a synergistic relationship between P and B was found (**Irfan et al., 2019**). The current study suggested that 60 kg/fed., of phosphorus and 4 g/L of borax is the best combination for improving the vegetative growth and root yield parameters.

Red beet root is a natural source for biochemical compounds such as betalain pigments, which is permitted as a food ingredient (**Kujala et al., 2002**). Red beet consumption improving and maintaining the human health and helping in the prevention and treatment of various leukaemia, malignancies and the consequences of radiation exposure as well as the regulation of cholesterol, blood pressure and triglycerides (**Bobek et al., 2000**). One of the goals of our study is improvement of the biochemical contents of red beet, the total carbohydrate and total soluble sugar content of roots were enhanced by phosphorus fertilization. This result may be attributed to the role of phosphorus in the bioactivities inside the plants such as energy transformation, where it is a key constituent of adenosine triphosphate (ATP) (**Kabir et al., 2013**). Another factor helps in increasing total carbohydrates and total soluble sugars content of red beet root is boron element, it has a positive role in carbohydrates transportation from source to sink (**Rashid et al., 2004**). Related the interaction between phosphorus and borax on sugars content, the results indicated that the combination of 60 kg/fed P and 4 g/L borax was more effectiveness in increasing the sugar contents in table beet root. Concerning SSC, in the present study, SSC of table beet root was improved, this attributed to increase the total sugars by phosphorus and borax treatments.

Phenolic compounds had a vital role in human health, such as anti-inflammatory, anti-aging, anti-proliferative and antioxidant activities (**Lin et al., 2016**). In our study, total phenolic

increased in beetroot by phosphorus application. This may be attributed to the appropriate conditions for growing table beet. In addition, P is involved in regulating the phenolic compounds synthesis, although its precise mechanism is not completely clear, study suggests that P is a part of the structure of nucleic acid and thus playing an important role in the balancing of synthesis of plant hormones (**Attarzadeh et al., 2020**). In contrast, **Pontigo et al. (2018)** found that phenolic increased under P deficiency. This may be due to the difference plant species or growth conditions. Borax treatments enhanced the total phenolic compounds of table beet, this result indicated that boron have a role in phenolic metabolism, where B induced the activity of phenylalanine ammonia-tyase (PAL), and also phenolics are complexed with B, thereby unavailable for oxidation (**Ruiz et al., 1998**). In dependent on the above, the interaction between phosphorus and borax improved the phenolics content in table beet root by the good synergistic effect between phosphorus and boron.

Increasing phosphorus levels resulted in significant increase in betalains content of table beet roots. This increase could be attributed to the photosynthesis process activity (**Silva et al., 2019**). Betalain pigments are maximized by borax treatments, this result may be due to the role of boron in the physiological processes such as sugars transport and stimulation or inhibition of specific metabolism pathways (**Ahmad et al., 2009**).

Phosphorus and borax treatments resulted in increasing N P K and B content of table beet. This study shows that P fertilization improved nutrient status, which can explain the higher effect on growth of table beet. This may be attributed to the role of phosphorus fertilization in encouraging the plants to take up more nutrients (e.g., N, P, K and B) from the soil (**Graciano et al., 2006**). Borax treatments as foliar application resulted in improving N, P, K and B contents in table beet. These results are in agreement with **Lopez-Lefebvre et al. (2002)** who found that boron fertilization enhanced the N and K contents of tobacco leaves. Also, the application of boron doses caused an increase in N P K and B content of tomato (**Gundes and Sonmez, 2021**). The interaction between P and

borax treatments had a positive effect on N, P, K and B content of table beet plants. These results are in harmony with those reported by **Sinha et al. (2003)** and **Gundes and Sonmez (2021)**.

In general, Synergism was observed between phosphorus and boron when several characteristics were measured. These results are supported by many reports which demonstrated that the reduction in DNA and RNA concentration under phosphorus deficiency became more marked when both phosphorus and boron were deficient together, this may be due to phosphorus is a part of nucleotides, while boron is required for the synthesis of some component of nucleotides (**Bould 1983**). Nucleic acids reduction under phosphorus and boron deficiency probably produces a chain reaction. RNA depression causes a depression in protein which leads to impairs growth and reduces dry weight (**Chatterjee et al., 1990**). In addition, **Long and Peng (2023)**, reviewed that the absorption of B by *Brassica napus* plants was promoted by an appropriate amount of P, perhaps because P can improve water absorption by plants and boost their transpiration and growth, thereby enhance B absorption by improvement of these physiological processes. Also, P can influence the biochemical properties of plant rhizosphere, and hence enhance the B availability in soil.

Collectively all these results indicated that phosphorus at rate of 60 kg/fed as top-dressing and borax at rate of 4 g/L as foliar application promoted the vegetative growth parameters, enhanced root yield and improved the biochemical compound and minerals contents of table beet plants.

## REFERENCES

- Ahmad, W., A. Niaz, S. Kanwal, R. Rahmatullah and M.K. Rasheed (2009). Role of boron in plant growth: A review. *J. Agric. Res.*, 47(3): 329-338.
- Armin, M. and M. Asgharipour (2012). Effect of Time and Concentration of Boron Foliar Application on Yield and Quality of Sugar Beet. *Ame.-Euras. J. Agric. And Environ. Sci.*, 12 (4): 444-448.
- Attarzadeh, M., H. Balouchi, M. Rajaie, M. M. Dehnavi and A. Salehi (2020). Improving growth and phenolic compounds of *Echinacea purpurea* root by integrating biological and chemical resources of phosphorus under water deficit stress. *Ind. Crops and Prod.*, 154 (2020) 112763. <https://doi.org/10.1016/j.indcrop.2020.112763>
- Bobek, P., S. Galbavy and M. Mariassyova (2000). The effect of red beet (*Beta vulgaris* var. rubra) fiber on alimentary hypercholesterolemia and chemically induced colon carcinogenesis in rats. *Nahrung.*, 44(3):184-187.
- Bould, C. (1983). Methods of diagnosing nutrient disorders in plants. Pages 111 136 in J.B.D. Robinson, ed. *Diagnosis of mineral disorders in plants*, Vol. I. Principles H.M.S.O. London, U.K.
- Brdar-Jokanovic, M. (2020). Boron Toxicity and Deficiency in Agricultural Plants. *Int. J. Mol. Sci.* 21, 1424; doi:10.3390/ijms21041424
- Camacho-Cristóbal, J.J., M.T. Navarro-Gochicoa, J. Rexach, A. González-Fontes and M.B. Herrera-Rodríguez (2018). Plant Response to Boron Deficiency and Boron Use Efficiency in Crop Plants. *Plant Micronutrient Use Efficiency*, 109-121.
- Camacho-Cristóbal, J.J., E.M. Martín-Rejano, M.B. Herrera-Rodríguez, M.T. Navarro-Gochicoa, J. Rexach and A. González-Fontes (2015). Boron deficiency inhibits root cell elongation via an ethylene/auxin/ROS-dependent pathway in Arabidopsis seedlings. *J. Exp. Bot.*, 66 (13): 3831-3840.
- Chatterjee, C., P. Sinha and S.C. Acarwala (1990). Interactive effect of boron and phosphorus on growth and metabolism of maize grown in refined sand. *Can. J. Plant Sci.*, 70: 455-460.
- Dible, W.T., E. Truog and K.C. Berger (1954). Boron Determination in Soils and Plants. *Anal. Chem.*, 26(2): 418-421.
- Dubois, M.K.A., J.K. Hamilton, P.A. Rebers and F. Smith (1956). Colorimetric method for determination of sugars and related substances, *Anal. Chem.*, 28: 350-356.
- Epstein, E. and A.J. Bloom (2004). Mineral nutrition of plants: Principles and perspectives (2<sup>nd</sup> Ed.). Sunderland, MA: Sinauer Associates, Inc. 402.

- Graciano, C., J.F. Goya, J.L. Frangi and J.J. Guiamet (2006). Fertilization with phosphorus increases soil nitrogen absorption in young plants of *Eucalyptus grandis*. *Forest Ecol. and Manag.*, 236: 202-210.
- Gundes, F.A. and I. Sonmez (2021). Effect of phosphorus on the alleviation of boron toxicity in the tomato plant. *J. Elem.*, 26(4): 1053-1063. DOI: 10.5601/jelem.2021.26.3.2146.
- Hinsinger, P. (2001). Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: a review. *Plant and Soil*, 237(2):173-195.
- Irfan, M., M. Abbas, J.A. Shah, N. Depar, M.Y. Memon and N.A. Sial (2019). Interactive effect of phosphorus and boron on plant growth, nutrient accumulation and grain yield of wheat grown on calcareous soil. *Euras. J. Soil Sci.*, 8 (1): 17-26. DOI: 10.18393/ejss.484654
- Jackson, M.L. (1973). *Soil Chemical Analysis*. Prentice-Hall of India Private Limited New Delhi, 141.
- Kabir, R., S. Yeasmin, A.K.M.M. Islam and M. D.A.R. Sarkar (2013). Effect of Phosphorus, Calcium and Boron on the Growth and Yield of Groundnut (*Arachis hypogea* L.) *Int. J. Bio-Sci. and Bio-Technol.*, 5 (3): 51-59.
- Kujala, T.S., M.S. Vienola, K.D. Klika, J.M. Loponen and K. Pihlaja (2002). Betalain and phenolic compositions of four beetroot (*Beta vulgaris*) cultivars. *Eur. Food Res. Technol.* 214: 505–510. DOI 10.1007/s00217-001-0478-6
- Lin, D.,M. Mengshi Xiao, J. Zhao, Z. Li, B. Xing, X. Li, M. Kong, L. Li, Q. Zhang, Y. Liu, W. Chen Qin, H. Wu. and S. Chen (2016). An Overview of Plant Phenolic Compounds and Their Importance in Human Nutrition and Management of Type 2 Diabetes. 21, 1374; doi:10.3390/molecules 21101374
- Ling, E.R. (1963). Determination of total nitrogen by semimicrokjeldahl method. *Dairy Chem.*, 11: 23-84.
- Long, Y. and J. Peng (2023). Interaction between Boron and Other Elements in Plants. *Genes* 14, 130. <https://doi.org/10.3390/genes14010130>
- Lopez-Lefebvre, L.R., R.M. Rivero, P.C. Garcia, E. Sanchez, J.M. Ruiz and L. Romero (2002). Boron effect on mineral nutrients of tobacco. *J. Plant Nutr.*, 25(3): 509-522. DOI: 10.1081/PLN-120003379
- Marinkovic, B., J. Crnobarac, G. Jaćimovic, D. Marinkovic, D.V. Mircov and M. Rajici (2008). Importance of increasing amounts of NPK nutrients on sugar beet yield. *Res. J. Agric. Res.*, 40 (2): 99-104.
- Mazumdar, B.C. and K. Majumder (2003). *Methods on Physico-Chemical Analysis of Fruits*. Daya Publishing House, Delhi-110035, 162-163.
- Mekdad, A.A.A. (2015). Sugar beet productivity as affected by nitrogen fertilizer and foliar spraying with boron. *J. Curr. Microbiol. App. Sci.*, 4 (4): 181-196.
- Muhlbachova, G., P. Cermak, R. Vavera, M. Kas, M. Pechova, K. Markova, H. Kusa, P. Ruzek, J. Hlusek and T. Losak, (2017). Boron availability and uptake under increasing phosphorus rates in a pot experiment. *Plant, Soil and Environ.*, 63 (11): 483-490.
- Ninfali, P. and D. Angelino (2013). Nutritional and Functional Potential of *Beta vulgariscicla* and *Rubra*. *Fitoterapia*, 89: 188-199. <https://doi.org/10.1016/j.fitote.2013.06.004>
- Page, A.L. (1982). *Methods of soil analysis*. 2<sup>nd</sup> Ed. Part 1, Soil Sci. Soc. Amer. Madison Wisc. USA.
- Pontigo, S., M. Ulloa, K. Godoy, N. Nikolic, M. Nikolic, M.L. Mora and P. Cartes (2018). Phosphorus efficiency modulates phenol metabolism in wheat genotypes. *J. Soil Sci. and Plant Nutr.*, 18 (3): 904-920.
- Raish, M., A. Ahmad, M.A. Ansari, K.M. Alkharfy, A. Ahad, A. Khan, N. Ali, M.A. Ganaie and M.A.A. Hamidaddin (2019). Beetroot juice alleviates isoproterenol-induced myocardial damage by reducing oxidative stress, inflammation, and apoptosis in rats. *3 Biotech*. 2019 Apr., 9 (4):147. doi: 10.1007/s13205-019-1677-9. Epub 2019 Mar 23. PMID: 30944794; PMCID: PMC6430824.

- Rashid, A., M. Yasin, M. Ashraf and R.A. Mann (2004). Boron deficiency in calcareous soil reduces rice yield and impairs grain quality. *Int. Rice Res. Notes*, 29: 58-60.
- Reddy, M.K., R.L. Alexander-Lindo and M.G. Nair (2005). Relative Inhibition of Lipid Peroxidation, Cyclooxygenase Enzymes, and Human Tumor Cell Proliferation by Natural Food Colors. *J. Agric. Food Chem.*, 53 (23): 9268–9273.
- Ruiz, J.M., G. Bretones, M. Baghour, L. Ragala, A. Belakbir and L. Romero (1998). Relationship between boron and phenolic metabolism in tobacco leaves. *Phytochem.*, 48 (2): 269-272.
- Sadasivam, S. and A. Manickam (1991). *Biochemical Methods for Agricultural Sciences*. Wiley.
- Seadh, S.E. (2012). Maximizing sugar beet yield with decreasing mineral fertilization pollution. *Int. J. Agric. Sci.*, 4 (7): 293-298.
- Silva, G.A., L.C. Grangeiro, V.F.L. Sousa, L.R. R. Silva, P.M.M. Jesus and J.L.A. Silva (2019). Agronomic performance of beet cultivars as a function of phosphorus fertilization. *R. Bras. Eng. Agríc. Ambiental*, 23 (7): 518-523. DOI: <http://dx.doi.org/10.1590/1807-1929/agriambi.v23n7p518-523>
- Sinha, P., B.K. Dube and C. Chatterjee (2003). Phosphorus stress alters boron metabolism of mustard, *Comm. Soil Sci. Plant Anal*, 34(3-4): 315-326. DOI: 10.1081/CSS-120017823
- Sreekanth, D., M.K. Arunasree, K.R. Roy, T.C. Reddy, G. V. Reddy and P. Reddanna (2007). Betanin a betacyanin pigment purified from fruits of *Opuntia ficus-indica* induces apoptosis in human chronic myeloid leukemia Cell line-K562, *Phytomedicine*, 14 (11): 739-746. <https://doi.org/10.1016/j.phymed.2007.03.017>.
- Subba, S.K., R.K. Yambem, R.K. Asha, A. Das, S.B. Chattopadhyay and P. Choudhuri (2016). Effect of potassium and boron on quality parameters of carrot (*Dacus carota* L.). *Int. Quality J. Environ. Sci. Special Issue*, IX: 487-490
- Tripathi, D.K., S. Singh, S. Singh, S. Mishra, D.K. Chauhan and N.K. Dubey (2015). Micronutrients and their diverse role in agricultural crops: advances and future prospective. *Acta physiol. Plant*, 37(7): 139.
- Von Elbe, J.H. (2001). *Betalains. Spectrophotometric determination of betacyanins and betaxanthins. Current Protocols in Food Analytical Chemistry F3.1.1-F3.1.7*, New York: Wiley.
- Winkler, B.W.C., K. Schroecksnadel, H. Schennach and D. Fuchs (2005). In vitro effects of beet root juice on stimulated and unstimulated peripheral blood mononuclear cells. *Ame. J. Biochem. Biotechnol.*, 1:180-185. doi: 10.3844/ajbbsp.2005.180.185.
- Zapata, F. and A.R. Zaharah (2002). Phosphate availability from phosphate rock and sewage sludge as influenced by addition of water soluble phosphate fertilizers. 2002. *Nutrient Cycling in Agroecosystems*, 1 (63):43-48.

## تحسين نمو ومحصول وجودة جذور نباتات بنجر المائدة بالتسميد الفوسفاتي والرش الورقي بالبوراكس تحت ظروف الوادى الجديد

محمد علي<sup>1</sup> - إبراهيم ناصف<sup>2</sup>

1- قسم البساتين - كلية الزراعة - جامعة الوادى الجديد- مصر

2- قسم البساتين - كلية الزراعة - جامعة قناة السويس - مصر

أجريت تجربتين حقليتين خلال موسمي 2021/2020 و 2022/2021م فى مزرعة كلية الزراعة جامعة الوادى الجديد بمحافظة الوادى الجديد جمهورية مصر العربية؛ بهدف بحث التسميد الفوسفاتي والرش الورقي بالبوراكس على النمو والمحصول والمكونات الكيميائية والعناصر المعدنية فى بنجر المائدة. تم تطبيق أربعة مستويات من الفوسفور: 30 و 45 و 60 و 75 كجم/الفدان كتسميد أرضي و كذلك أربعة مستويات من البوراكس: 0 و 2 و 4 و 6 جرام/لتر رش ورقي وذلك فى المساحات المستصلحة حديثاً، وبالأخص محافظة الوادى الجديد كمساحات واعدة فى توسع الزراعة فى مصر. بينت النتائج أن تطبيق الفوسفور بمعدل 60 كجم/الفدان حسن النمو الخضري وصفات الجذر ومحتوى السكريات والمواد الصلبة الذائبة والفينولات وصبغات البيتاينات والعناصر المعدنية فى بنجر المائدة. أيضاً، كشفت الدراسة أن الرش الورقي بالبوراكس بمعدل 4 جرام/ لتر حسن النمو الخضري والمحصول والمركبات البيوكيميائية مقارنة بالتركيزات الأخرى. إضافة إلى ذلك، التفاعل بين الفوسفور بمعدل 60 كجم/فدان والبوراكس بمعدل 4 جم/لتر كان أكثر تأثيراً على بنجر المائدة عن باقى التوليفات ، وكان تأثيره معنوياً على النمو والمحصول وجودة بنجر المائدة.

المحكمون:

1- أ.د. السيد أبو الخير

2- أ.د. عبد الله برديسي أحمد

أستاذ بمعهد بحوث البساتين - مركز البحوث الزراعية - الجيزة.

أستاذ الخضر المتفرغ - كلية الزراعة - جامعة الزقازيق