

## Processing Potato Growth Performance as Affected by Foliar Application of Seaweed Extract and Boron

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**ABSTRACT:** Potato (*Solanum tuberosum* L.) is a leading staple food in the diet of the world population and providing of regular caloric requirements for human and deliver many essential elements, and vitamins including K, P, Mn, Mg, foliate, vit. C, and vit. B<sub>6</sub>. Increasing its potential yield could be hypothesized *via* environmental friendly agricultural supplements as seaweed extracts (SWEs) instead of mineral fertilization, and certain micronutrients as boron (B). Therefore, two field experiments were carried out during both seasons of 2016 / 2017 and 2017 / 2018, in a private farm, at El-Nobaria region, El-Behiera Governorate, Egypt, under open field conditions in sandy soil to investigate the effects of two independent variable as SWE (control, 1000 and 2000 mg/l), and B (control, 25, 50 and 75 mg/l) and their combinations on the growth performance (i.e. vegetative growth-related attributes and the yield) of 'Caruso' potato cultivar. Both conducted experiments were factorial experiments laid out in randomized complete blocks design (RCBD), with three replicates. Each replicate included 12 treatments. All determined treatments were distributed randomly within each block. Foliar application of SWE × B at 2000 × 75 mg / l; brought about the highest mean values of the studied vegetative growth attributes (plant height [cm] and number of main stems / plant) compare with the other treatments during both seasons. Likewise, pertaining the tuber yield, the same combination; led to the highest mean values for number of tubers / plant, tuber fresh weight / plant (g), total yield / feddan, as compared with control treatment during both seasons. Hence, the above-mentioned combination is the appropriate for both tested independent variables for the best growth performance of the tested dependent variable (i.e., vegetative and yield attributes of the given cultivar). Nevertheless, applying SWE at 2000 mg / l × B at 50 mg / l; brought about the best potato for processing.

**Key words:** Foliar application, seaweed extract (SWE), boron (B), potato (*Solanum tuberosum* L.), vegetative growth attributes, yield attributes.

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## INTRODUCTION

Potato (*Solanum tuberosum* L.) is a member of the family Solanaceae. It is a staple food prevailing worldwide with obvious large-scale production, consumption and affordability with easy availability in the market. It is one of the most remunerative and cost-effective crops for the farmers due to its higher yield capacity within a short time - course (Sati *et al.*, 2017).

Nowadays, there is a high demand for good environment friendly agriculture practices as seaweed extracts (SWEs) and certain micronutrients as boron for the high production of quality and healthy food as potatoes to nourish the increasing population (Jayasinghe *et al.*, 2016).

Seaweed extracts are, mostly, rich in natural plant promoting substances such as auxins and cytokinins, vitamins, and some macro-and micronutrients,

lipids, proteins, carbohydrates, amino acids, osmo-protectants, antimicrobial compounds and minerals. The benefits of seaweed application in agricultural field are numerous and diverse such as increase agricultural production rather than the use of chemical fertilizers (Cassan *et al.*, 1992). Seaweed extracts (SWEs) have been used as a foliar application to increase growth, yield and quality, nutrient uptake, photosynthetic pigments and resistance to stress factors of many crops including potato (Arafa *et al.*, 2011, 2012, 2013; Calvo *et al.*, 2014).

It is known that the Egyptian soils have low organic matter content and high soil pH levels, and are, generally, of low in moisture contents, high in lime content and fine-textured, which decreases the boron uptake by plants (Dursun *et al.*, 2010). Many investigators are in favor of foliar application of boron (B) in addition to essential major elements, which can play a distinct role in increasing the yield of potato.

Also, reclaimed land is usually not rich in fertility and structure, which negatively affects the growing crops. In addition, the nutrients in the soil of the Nile valley have been depleted due to the applied intensive agricultural systems. Therefore, a precise fertilization program has to be designed and applied to each type of soil in order to produce a better crop potentials.

Boron (B) plays an important role in physiological and biochemical events that occur in plants (Saleem *et al.*, 2011), Also, Boron (B) plays a crucial roles in cell wall synthesis, sugar transport, cell division, cell development, auxin metabolism, good pollination and fruit set, seed development, synthesis of amino acids and proteins, nodule formation in legumes and regulation of carbohydrate metabolism (El-Dissoky and Abdel-Kadar, 2013).

Therefore, developing good management practices of both independent variables (*i.e.* seaweed extract and boron and their interaction) for potato growers was selected and undertaken in the present research to: 1) evaluate the response of potato cultivar 'Caruso' to the both tested independent variable levels, and 2) examine the interaction effect between SWE and boron levels on the growth performance of potato plant 'Caruso' cultivar (*i.e.*, vegetative, yield and quality).

## **MATERIALS AND METHODS**

Two field experiments were carried out during both seasons of 2016 / 2017 and 2017 / 2018, in a private farm, at El-Nobaria region, El-Behiera Governorate, Egypt, under open field conditions in sandy soil as given in Table (1). The experimental field was ploughed and pulverized. Then, the soil was ridged into rows 0.80 m width and divided to plots. The potato seeds of 'Caruso' cultivar were derived from summer season and stored under cold conditions (4 °C and R.H. 95%) were used in this study.

**Table (1). Some physical and chemical properties of the experimental site during both seasons of the experimentation (2016 / 2017 and 2017 / 2018)**

Soil properties	Season	
	2016/2017	2017/2018
<b><u>Mechanical Analysis:</u></b>		
Clay (%)	3.00	3.50
Silt (%)	00.00	00.00
Sand (%)	97.00	96.50
Textural class	Sandy	Sandy
<b><u>Chemical analysis:</u></b>		
pH (1:2), water suspension)	7.50	7.450
EC (extract) at 25 (dS/m)	1.34	1.50
<b><u>Soluble cations in (1:5) soil: water extract (meq/l)</u></b>		
Ca <sup>++</sup>	1.60	1.70
Mg <sup>++</sup>	4.88	4.60
K <sup>+</sup>	3.25	3.35
Na <sup>+</sup>	6.98	7.00
<b><u>Soluble anions in (1:5) soil: water extract (meq/l)</u></b>		
HCO <sub>3</sub> <sup>-</sup>	3.00	3.36
Cl <sup>-</sup>	3.35	3.45
SO <sub>4</sub> <sup>-</sup>	10.36	9.84
CaCO <sub>3</sub> (%)	3.30	3.25
Available N (mg/kg soil)	82.66	85.50
Available P (mg/kg soil)	7.00	8.25
Available K (mg/kg soil)	157	160
Boron (mg/kg soil)	1.50	1.60

### The experimental treatments and statistical design

The outcome treatments of the various tested combinations were consisted of both two factors (two independent variables) as foliar applicants, *i.e.*; three concentrations of seaweed extract (SWE) as control, 1000, and 2000 mg / l and four concentrations of boron (B) as control, 25, 50, and 75 mg / l either individually or in combinations. Control plants were sprayed with tap water. Seaweed extract coined as 'Oligo-x' was used in this study. It is a mixed from *Ascophyllum*, *Laminaria*, *Sargassum*, *Fucus* spp. It was obtained from Union for Agricultural Development Company having the following composition: oligosaccharides 3%, alginic acid 5%, phytin 0.003%, menthol 0.001%, natural growth regulators (Cytokinin 0.001%, indoleacetic acid 0.0002%), pepsin 0.02 % and minerals (potassium oxide 12%, phosphorus oxide 0.5%, N1%, Zn 0.3%, Fe 0.2% and Mn 0.1%).

Boron as boric acid (H<sub>3</sub>BO<sub>3</sub>) [MW= 61.83] contained 17% B was purchased from Algomhoria Company for Chemicals, Alexandria, Egypt.

Both conducted experiments were factorial experiments laid out in a randomized complete block design (RCBD), with three replicates. Each replicate included 12 treatments. All determined treatments were randomly distributed within each block. The experimental plot consisted of two ridges with 7.00 m long and 0.80 m width; making an area of 11.20 m<sup>2</sup>.

Potato plants were sprayed with the allocated or assigned treatments twice, the first one was executed after 55 days of planting, the second application was achieved after 15 days of the first one. The recommended agricultural practices were followed.

### Experimental data collections

#### 1-Vegetative growth – related characters included:

- Number of main stems per plant
- Plant height (cm)

#### 2-Yield and its component measurements included:

- Number of tubers per plant
- Tuber fresh weight (g)
- Average of tuber yield per plant (g)
- Total tubers yield per feddan (ton)

#### 3- Tubers Quality included:

- **Potato yield accepted for processing:** The suitable tubers for processing per plot were selected, weighted and converted into tons/fed, then calculated as percentage from total yield per feddan.

- **The number of tubers / 10 kg**, it was determined by taking a random sample of 10 kg of tubers from the yield of each treatment and then counted. Number of potato tubers / 10 kg is a character of the processing Companies to receive potatoes. The accepted range of the number of tubers / 10 kg is 72 – 112 tubers (Frito lay company, 1999), more than this numbers means small tubers and consequently small slides of chips which reduce the chip quality. If it was less than that range it means the presence of over-size large tubers, which may comprises hallow hart and cracks. Such defects may cause the rejection of the chips after processing.

- **Specific gravity**, was determined using the method described by Dinesh *et al.* (2005) and calculated from equation of Smith (1977) as follows:

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of tuber in air} - \text{Weight of tuber under water}}$$

- **Tuber under size (< 35 mm, %)**, was determined using a micrometer (caliper) to measure all tubers under size (> 35 mm) per plot and counted, then calculated as a percentage of the total number of harvested tubers / plot.

- **Tubers dry matter (%)** was carried out *via* randomly tuber samples of 100 g of fresh weight which were dried in an electrical oven at 70 °C till the constant weight, then the obtained value of tuber dry matter was calculated as percentage.
- **Chips defect evaluation**, was calculated by showing the size limits (1/2 cm) for sugar browning and defects using chip–check chart method to determine the internal, external and undesirable color defects and dividing the defects to three categories; the first green from 0 - 8% defects are acceptable potato chips, the second yellow 8 - 15 % defects are acceptable potato chips but with discarding the percentage over 8% and the third red > 15% defects are rejected and not suitable for processing according to (Frito Lay Company, 1999).

### **Statistical Analysis:**

All obtained data of the present study were, statistically, analyzed according to the design used by the MSTAT-C computer software program (Bricker, 1991) and were tested by analysis of variance. The least significant difference test at 0.05 level of probability was used to compare the differences among the means of the various treatment combinations as illustrated by Gomez and Gomez (1984).

## **RESULTS AND DISCUSSIONS**

### **A. Vegetative growth-related characters**

Generally, Results presented in Table (2), reveal that the main effects of both SWE and B exhibited a direct proportional relationship with both tested traits, during both seasons, for the vegetative growth- related characters significantly ( $p \leq 0.05$ ).

The foliar application of potato plants with SWE especially at 2000 mg/l; accounted for recording the highest average values compare with control treatment (foliar application with tap water). The increment percentages as an average of both seasons compare to control plants were 42.29 and 24.38% for number of main stems/plant and plant height characters, consecutively. These results are in agreement, more or less, with those of Demir *et al.* (2006) on tomato, pepper and eggplant plants, Abdurraheem (2009) on cucumber, Prasad *et al.* (2010) and Spinelli *et al.* (2010) on strawberry. Sridhar and Rengasamy (2012) on chilli pepper, Marhoon and Abbas (2015) on two sweet pepper cultivars, whereas the authors attributed this result due to the mode of action of cytokinins involved in SWE. Also, this finding may be taken place owing to break the apical dominance; hence accelerated the outgrowth of axillary branches and /or the ratio of cytokinin/auxin, which regulates the growth and development all the other vegetative-related characters (George *et al.*, 2008 a and b).

Likewise, they enhance plants' resistance to biotic and abiotic stresses due to their direct effect on metabolic pathways; resulting in formation antioxidant molecules in plant cells (Thirumaran *et al.*, 2009 a, b).

**Table (2).Average values of some vegetative growth-related characters of potato plants cv. 'Caruso' as affected by foliar application with seaweed extract (SWE), Boron (B) and their combinations during the winter seasons of 2016/2017 and 2017/2018**

Treatments	No. of main stems/plant		Plant height (cm)		
	2016/2017	2017/2018	2016/2017	2017/2018	
<b>SWE (main effect)</b>					
Control	3.69 c	3.83 c	55.05 c	55.88 c	
1000 mg.l <sup>-1</sup>	5.04 b	5.08 b	66.94 b	67.94 b	
2000 mg.l <sup>-1</sup>	5.33 a	5.37 a	68.88 a	69.10 a	
<b>B (main effect)</b>					
Control	3.99 d	4.15 d	59.61 d	60.88 d	
25 mg.l <sup>-1</sup>	4.42 c	4.40 c	62.16 c	62.59 c	
50 mg.l <sup>-1</sup>	4.98 b	5.04 b	64.57 b	64.58 b	
75 mg.l <sup>-1</sup>	5.37 a	5.44 a	68.16 a	69.18 a	
<b>Combinations effects</b>					
<b>SWE (mg.l<sup>-1</sup>)</b>		<b>B (mg.l<sup>-1</sup>)</b>			
Control	Control	3.10 i	3.42 f	51.85 h	53.81 g
	25	3.40 h	3.53 f	54.43 g	54.54 g
	50	4.10 g	4.10 e	55.62 g	55.23 g
	75	4.17 g	4.27 e	58.32 f	59.92 f
1000	Control	4.20 g	4.30 e	62.40 e	63.14 e
	25	4.90 e	4.80 d	65.42 cd	66.44 d
	50	5.23 d	5.32 c	67.33 c	68.82 bc
	75	5.83 b	5.90a b	72.62 ab	73.35 a
2000	Control	4.66 f	4.73 d	64.59 d	65.69 d
	25	4.97 e	4.86 d	66.62 cd	66.77 cd
	50	5.60 c	5.70 a	70.77 b	69.67 b
	75	6.10 a	6.17 a	73.55 a	74.27 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using L.S.D. test at 0.05 level of probability.

With regard to the main effect of B, it is clear also that there is a direct progressive relationship between B concentrations and the dependent variable characters; whereas, foliar application of B at 75 mg / l, exerted a significant ( $p \leq 0.05$ ) effect on both tested traits, which brought about the highest average values of all tested traits compare to control plants, but intermediate values were recorded between both extreme levels. The increment percentages of both seasons compare to control plants were 32.80 and 13.98% for number of stems/plant and plant height characters, each in turn.

These results are in parallel with those of El-Banna and Abd El-Salam, 2005; El-Dissoky and Abdel-Kadar, 2013; Farouk, 2015; Muthanna *et al.*, 2017; Tantawy *et al.*, 2017; Alkharpotly *et al.*, 2018; Ramesh *et al.*, 2019.

Number of stems/plant and plant height increments could be accounted for the physiological promotive effects mode of action of B, which enhance plant photosynthetic activity and concomitant vigour plant growth. Also, B has profound roles in cell wall synthesis, cell division, cell development, auxin metabolism and activation of different enzymes (Jafari-Jood *et al.*, 2013). Likewise, B is an important agent for maintaining the structural integrity of cell wall and cell membranes (Zhang *et al.*, 2014). Boron, also, helps in water and nutrient transportation from roots to shoots (Ziaeyan and Rajaie, 2012).

In terms of the first order interaction between both independent variables on vegetative-growth characters, it exerted significant ( $p \leq 0.05$ ) effect on various tested traits. Generally, it is obvious that under any concentration of SWE with B, more or less, the maximum average value of both studied traits compare to control plants was obvious. The interaction between SWE at either 1000 or 2000 mg / l with B at 75 mg / l, exhibited clear differences among tested treatments as number of main stems/plant and plant height as compared to control plants.

#### **B) Yield characters and its components:**

Concerning the results of Table (3), the average values of most tested yield characters were affected significantly ( $p \leq 0.05$ ) due to the main effects of both independent variables compare to their control treatments except for the number of tubers / plant character, which showed insignificant ( $p > 0.05$ ) differences in its responses to main and interaction effects of both independent variables during both seasons.

With respect to the main effect of SWE, most tested traits were affected significantly ( $p \leq 0.05$ ) during both seasons. However, foliar application of SWE at 1000 or 2000 mg / l; recorded the highest average values of tuber fresh weight, total yield / plant (g), total yield / feddan (ton) and the accepted yield for processing percentage compared to control plants during both seasons of the study. Whereas, control plants (sprayed with tap water) expressed the lowest significant average values of all tested yield characters during both seasons.

**Table (3). Averages values of some yield characters of potato plants cv. 'Caruso' as affected by foliar application with seaweed extract (SWE), Boron (B) and their combinations during the winter seasons of 2016/2017 and 2017/2018.**

Treatments	No. of tubers/plant		Tuber fresh weight (g)		Total yield/plant (g)		Total yield/feddan (ton)		
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	
<b>SWE (main effect)</b>									
Control	5.83 a	5.17 a	73.34 b	75.14 b	427.55 b	388.45 b	8.98 b	8.16 b	
1000 mg.l <sup>-1</sup>	5.67 a	6.00 a	85.80 a	87.76 a	486.50 a	526.53 a	10.22 a	11.06 a	
2000 mg.l <sup>-1</sup>	6.00 a	6.33 a	87.68 a	89.64 a	526.08 a	567.45 a	11.05 a	11.92 a	
<b>B (main effect)</b>									
Control	5.33 a	5.67 a	77.02 d	78.87 d	410.53 c	447.19 c	8.62 c	9.39 c	
25 mg.l <sup>-1</sup>	4.89 a	5.22 a	80.74 c	82.64 c	394.83 c	431.37 c	8.29 c	9.06 c	
50 mg.l <sup>-1</sup>	5.44 a	5.78 a	84.15 b	86.07 b	457.76 b	497.48 b	9.61 b	10.45 b	
75 mg.l <sup>-1</sup>	6.00 a	6.33 a	87.76 a	89.72 a	526.53 a	567.92 a	11.06 a	11.93 a	
<b>Combinations effects</b>									
<b>SWE ( mg.l<sup>-1</sup> ) B (mg.l<sup>-1</sup>)</b>									
<b>Control</b>	<b>Control</b>	5.33 a	5.67 a	69.60 l	71.35 l	370.99 f	404.54 g	7.79f	8.50g
	<b>25</b>	5.67 a	5.50 a	72.15 k	73.93 k	409.09 e	406.64 g	8.59e	8.54g
	<b>50</b>	5.50 a	5.33 a	74.27 j	76.08 j	408.49 e	405.50 g	8.58e	8.52g
	<b>75</b>	5.33 a	5.67 a	77.15 i	78.99 i	411.20 e	447.88 f	8.64e	9.41f
<b>1000</b>	<b>Control</b>	5.67 a	5.00 a	79.64 h	81.51 h	451.53 d	407.55 g	9.48 d	8.56 g
	<b>25</b>	5.70 a	5.67 a	83.52 f	85.45 f	476.06 c	484.49 e	10.00 c	10.17 e
	<b>50</b>	6.00 a	6.33 a	87.82 d	89.78 d	526.93 b	568.34 c	11.07 b	11.94 c
	<b>75</b>	6.67 a	7.00 a	91.75 b	93.76 b	611.96 a	656.30 a	12.85 a	13.78 a
<b>2000</b>	<b>Control</b>	5.00 a	5.33 a	81.37 g	83.27 g	406.86 e	443.83 f	8.54 e	9.32 f
	<b>25</b>	5.67 a	6.00 a	85.92 e	87.87 e	487.19 c	527.24 d	10.23 c	11.07 d
	<b>50</b>	6.33 a	6.67 a	89.52 c	91.51 c	566.67 b	610.35 b	11.90 b	12.82 b
	<b>75</b>	7.00 a	7.33 a	93.41 a	95.43 a	653.84 a	699.48 a	13.73 a	14.69 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using L.S.D. test at 0.05 level of probability.

The increment percentages of tested characters treated with 2000 mg/l (as an average of both seasons) compare to control plants were 19.42, 34.01, 34.01 and 5.2% for tuber fresh weight, total yield / plant (g), total yield / feddan (ton) and accepted yield for processing percentage, respectively. While, the increment percentages of tested characters treated with 1000 mg/l (as an average of both seasons) compare to control plants were 16.89, 24.15, 24.15 and 4.40% for tuber fresh weight, total yield/plant (g), total yield / feddan (ton) and accepted yield for processing percentage, in series.

These results are in parallel with those of Awad *et al.* (2006); Sarhan (2011); Muhammad *et al.* (2012); Al-Bayati and Al-Quraishi (2019) on potato plants.

With regard to the main effect of B, it is clear that there is a direct proportional relationship between B concentrations and the dependent variable characters except for the number of tubers/plant character upon foliar application of B at 75 mg/l., compare with control plants (sprayed with tap water), which



expressed the lowest significant values for tuber fresh weight (g) and accepted yield for processing characters percentage.

The increment percentages of both seasons compare to control plants were 13.85, 27.60, 27.65 and 4.47% for tuber fresh weight, total yield / plant (g), total yield / feddan (ton) and accepted yield for processing percentage, each in turn.

These results are in parallel with those of El-Dissoky and Abdel-Kadar (2013); Farouk (2015); Tantawy *et al.* (2017); Alkharpotly *et al.* (2018); Manjunath *et al.* (2018); Sarkar *et al.* (2018 a,b); Singh *et al.* (2018) on potato plants.

In terms of the first order interaction between both independent variables on potato yield characters, it exerted significant ( $p \leq 0.05$ ) effect on various tested traits. Generally, it is obvious that under any concentration of SWE with B, more or less; caused the highest average values of the studied traits compare to control plants except for number of tubers / plant character. The interaction between SWE at either 1000 or 2000 mg / l with 50 or 75 mg / l B; exhibited clear differences on total yield / plant (g), total yield / feddan (ton) and accepted yield for processing percentage during both seasons compare to other tested treatments. About the average tuber fresh weight character (g), the interaction between SWE at 2000 mg / l  $\times$  75 mg / l B; brought about the highest significant average values compare to other tested treatments during both seasons.

The increment percentages of 2000 mg/l SWE  $\times$  75 mg / l B as an average of both seasons compare to control plants were 33.98, 74.50, 74.46 and 9.64% for tuber fresh weight, total yield / plant (g), total yield / feddan (ton) and accepted yield for processing percentage, each in turn.

The increment percentage points may be taken place due to applying a combination of 1000 mg / l SWE  $\times$  75 mg / l B as an average of both seasons compare to control plants were 63.53, 73.47 and 9.07% for total yield / plant (g), total yield / feddan (ton) and accepted yield for processing percentage, each in turn.

These results are in parallel with those of Abd El-Gawad and Osman (2014) on eggplant; whereas they reported that the highest values of yield and its components were achieved owing to foliar application of 1000 and 2000 ppm seaweed extract and B at 50 ppm.

The increments of yield characters could be accounted for synchronization both applied independent variable levels, which may release phytohormones that stimulated plant growth and photosynthetic processes which enhanced vegetative growth characters as reported earlier, then caused increasing yield characters.

### C) Tuber quality

Results presented in Table (4) declare that both independent variable levels and their interactions affected significantly ( $p \leq 0.05$ ) the studied physical tuber quality traits of potato plants under the study.

Regarding the main effect of SWE levels, applying SWE at any real levels; decreased significantly ( $p \leq 0.05$ ) both number of tubers/10 kg and percentage of tubers under size ( $< 35$  mm) compare to the control treatment plants (*i.e.* plants treated with SWE produced tubers with the largest size) during both seasons. On the contrary, applied SWE at either 1000 or 2000 mg/l; produced tubers with higher specific gravity average values (1.10 and 1.10) [without significant difference] compare with untreated plants (1.08), *i.e.* untreated plants; produced tubers with lower specific gravity during both seasons. Similar trend of results were noticed for accepted yield for processing (%).

Regarding the main effect of SWE independent variable, in general, showed a direct proportional relationship with tuber dry matter (%), potato chips defect characters during both seasons of the study. In other words, as SWE foliar applied concentration increased; the average values of the studied traits increased progressively compare to control plants, especially at SWE level 2000 mg / l. untreated plants showed the lowest significant values for all studied characters during both seasons.

The increment percentage points of the above-mentioned traits (an average of the highest tested concentration of both seasons *versus* control treatment) were as follows: 16.06 for tuber dry matter and 117.71 for potato chips defect percentages.

Tuber containing high dry matter is desirable for processing for a number of reasons: recovery (yield of processed product per unit of raw potatoes) is higher (Smith, 1977), the texture and flavor of the finished product is more desirable (Klienschmidt *et al.*, 1984) and the cost of processing is low due to faster frying and less oil absorption (Gould, 1988). Many processing contracts after incentive to growers for delivering high specific gravity (high dry matter content) tubers. Tubers with high dry matter content require less energy input during frying or dehydration to remove water; they have greater product yield per unit fresh weight than tubers with lower solid content and absorb less oil during frying (Burton *et al.*, 1992).

Potatoes with dry matter content of 20 – 24% are acceptable for making French fries and crisps while those with dry matter content up to 24% are ideal for preparing crisps (Kabira and Berga 2003). Kabira and Berga (2003) justified that potato tubers containing 20 – 24% dry matter produce fried products with high yields, less oil absorption and having better texture than those with lower solids. High dry matter has a direct effect on crisps and French fry yield as the weight of

the processed product depends directly on the amount of dry matter present per quantitative weight of fresh potatoes (Burton *et al.*, 1992).

These findings may be related to several direct and indirect mechanisms of SWE, including the stimulation of enzymatic activities related to carbon, nitrogen, metabolism, Krebs cycle, and glycolysis. Such use may also induce activity similar to hormones and improve the nutrition status of treated plants with SWE foliar application.

In terms of the main effect of Boron (B) levels, the obtained results demonstrate that its foliar application at various levels; decreased significantly ( $p \leq 0.05$ ) number of tubers /10 kg and tuber under size ( $< 35$  mm) especially at 75 mg / l B compare to control plants, which recorded the highest average values for both characters, but the contrary was true for tuber specific gravity when potato plants treated with B at either 50 or 75 mg / l during both seasons compared to either control or plants treated with 25 mg / l B.

These findings could be accounted the role of SWE and B on the incidence of phenotypic changes in both directions of the tuber (longitudinally and dimensionally) and produced tubers with bigger size. Also, boron plays an active role in cell wall synthesis, cell division, cell development and activation of different enzymes which finally increased tuber size. The improved vegetative growth of plant and yield attributing characters due to SWE and boron application has a key function-as reported earlier- and direct relation in improvement tuber development and increase in tuber yield of medium and large size, *i.e.*, the strong source-sink relationship.

Specific gravity of raw potatoes is widely accepted by the potato processing industry as a measure of total solids, starch concentration, and other qualities (Fitzpatrick *et al.*, 1969). High and uniform specific gravity tubers have better quality and lower oil absorption when utilized for crisps (Kunkel *et al.*, 1951 and Lana *et al.*, 1970).

In the case of specific gravity, Khan *et al.* (2009) mentioned that potatoes with high specific gravity are preferred for preparation of chips and French fries, but potatoes with very high specific gravity (1.10) may not be suitable for French fries production, where they become hard or biscuit like products. The gained results showed that all tuber specific gravity values less than (1.10) were, more or less, recorded except that of either 1000 or 2000 mg / l SWE in combination with 75 mg / l B treatment during both seasons of the study. As for accepted yield for processing (%) trait, the obtained results elicited that this trait positively affected with increasing B concentration up to 75 mg / l.

Likewise, these findings could be accounted for the SWE mode of action which could contribute to break down the polysaccharides of the cell wall,

especially during maturing, and increasing sugars levels within tuber tissues, concomitant with the lowering of acidity inversely.

Plants treated with B at the highest level (75 mg / l); showed the highest significant values for accepted yield for processing, tuber dry weight and potato chips defect percentages compare to control, which gave rise to the lowest significant values during both seasons. The increment percentage points compare to control plants (as an average of values of the highest level *versus* the control average values of both seasons) were 4.48% for accepted yield for processing, 11.50 % for tuber dry matter and 89.17 % for potato chips defect.

Regarding the first order interaction between both independent variables, tabulated results showed that dependent variable characters were affected significantly ( $p \leq 0.05$ ) due to the tested combinations.

Regarding the first order interaction between both independent variables, various tested combinations denoted to significant decreases between the control level of B variable under various levels of SWE; led to the highest average values of both number of tubers /10 kg and percentage of tubers under size (< 35 mm) characters (*i.e.* tubers with smallest size), during both seasons of the study.

Notably, at any tested level of SWE under the presence of B at 75 mg / l, in general; led to the lowest index values (*i.e.* tubers with bigger size) compare to their control plants. However, tuber specific gravity index behaved oppositely to the above - mentioned characters; whereas, SWE at either 1000 or 2000 mg/l and the presence of B especially at either 50 or 75 mg / l; give rise to the highest values of the given trait compare to its absence.

As for all of studied traits, direct proportional relationships were noticed at any levels of both independent variable levels. In other words, at any level of SWE, as B level increased; the average values of tested traits increased, especially at 75 mg / l B *versus* control level of B at any level of SWE. Meanwhile, intermediate average values were significantly different from each other and from control treatments. These findings could be taken place due to the appropriate balance or ratio between cytokinins either added exogenously *via* seaweed extract or *in vivo* biosynthesized, in addition to exogenously applied B may stimulate various physiological processes, including those related to plant growth and development (Horgan, 1992; Strnad, 1997; Sakakibara, 2006; Frébort *et al.*, 2011). Thus, each change in the level of applied SWE is concomitant with the endogenous cytokinins, affects the growth of entire plant attributes (Stirk and Van Staden, 2010; Zalabák *et al.*, 2013).

In the review of literature of most published articles, most of plant responses that treated with biostimulant's as foliar application, especially seaweeds, were, most probably, derived from the presence of compounds of the category of plant

hormones as cytokinins (Panda *et al.*, 2012). Also, Korasick *et al.* (2013) concluded that auxins have a profound effect on many important stages of physiological growth in life cycle of plants. In other words, these findings could be taken place because of the higher constituents of SWE biostimulants as plant phytohormones (*i.e.* auxins, cytokinins, GAs, *etc.*) and other macro-and micronutrients which affected significantly the vital prerequisites for plant growth and development (Masny and Zurawicz, 2004; Zodape *et al.*, 2011; Mohammed, 2013).

This investigation provides the most appropriate findings to enhancement the growth performance of such processing potato cultivar "Caurso" grown at El-Nobarria region, El-Behiera Governorate, Egypt, under open field conditions in clay loam soil *via* foliar application a combination of SWE at 2000 mg / l plus B at 75 mg / l., for yield. Nevertheless, applying SWE at 2000 mg / l × B at 50 mg /l; brought about the best combination for potato processing.

**Table (4). Averages values of some physical quality characters of potato tubers cv. 'Caruso' as affected by foliar application with seaweed extract (SWE), Boron (B) and their combinations during the winter seasons of 2016/2017 and 2017/2018**

Treatments	Accepted yield for processing (%)		Number of tubers/ 10 kg.		Tuber under size (> 35 mm) (%)		Tuber specific gravity		Tuber dry matter(%)		Potato chips defect (%)		
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	
<b>SWE (main effect)</b>													
Control	88.62b	90.96b	136.36 a	133.09 a	5.73a	6.01a	1.08b	1.08b	20.40c	20.70c	4.70c	4.73c	
1000 mg.l-1(SWE)	93.01a	94.47a	116.55 b	113.95 b	2.31b	2.63b	1.10a	1.10a	23.50b	23.70b	8.58b	8.94b	
2000 mg.l-1(SWE)	93.47a	95.44a	114.05 b	111.55 b	2.02c	2.37c	1.10a	1.10a	23.70a	24.00a	10.09a	10.44a	
<b>B (main effect)</b>													
Control	89.51d	91.58d	129.83 a	126.79 a	4.66 a	5.03 a	1.08 c	1.09 c	21.10d	21.50d	5.64c	5.72c	
25 mg.l-1(B)	91.13c	93.10c	123.85 b	121.01b	3.58 b	3.91b	1.09 b	1.09 b	22.10c	22.40c	6.79c	7.07bc	
50 mg.l-1(B)	92.43b	94.36b	118.84 c	116.18 c	2.91bc	3.24bc	1.09 a	1.10 a	23.20b	23.40b	8.27b	8.35b	
75 mg.l-1(B)	93.74a	95.45a	113.95 d	111.46 d	2.26 c	2.50 c	1.10 a	1.10 a	23.60a	23.90a	10.47a	11.02a	
<b>Combinations effects</b>													
<b>SWE (mg.l-1) B ( mg.l-1)</b>													
Control	Control	86.40f	89.65i	143.67a	140.16a	7.67a	7.81a	1.07 g	1.08 g	17.50k	20.10h	2.67g	2.81h
	25	88.48e	90.52hi	138.60b	135.26b	6.00b	6.34ab	1.08 f	1.08 f	19.90j	20.10h	4.67fg	4.58gh
	50	89.37de	91.36hi	134.64c	131.44c	4.90bc	5.24bc	1.09 e	1.09 e	21.70i	22.10g	5.57ef	5.63fg
	75	90.22de	92.31gh	129.62d	126.60d	4.33cd	4.66cd	1.09 de	1.09 de	22.10h	22.40f	5.90ef	5.91e-g
1000	Control	90.76c d	91.75 gh	125.57e	122.69e	3.23de	3.57d-f	1.09 c-e	1.09 c-e	22.70g	23.20e	6.87d-f	6.97d-g
	25	92.30b c	94.17 d-f	119.73g	117.03g	2.63ef	2.96e-g	1.09 b-d	1.10 b-d	23.20e	23.60d	7.70de	8.23c-e
	50	93.60 ab	95.34 b-d	113.87i	111.38i	2.07e-g	2.39e-h	1.10 a-c	1.10 a-c	23.70c	24.00c	8.57cd	8.72cd
	75	95.38 a	96.63 ab	108.99j	106.66j	1.30g	1.60gh	1.10 ab	1.10 a	24.10b	24.30a	11.20b	11.85b
2000	Control	91.37 cd	93.33 e-g	122.89f	120.09f	3.07de	3.72de	1.09 c-e	1.09 b-d	22.90f	23.20e	7.40de	7.38d-f
	25	92.59 bc	94.62 c-e	116.38h	113.80h	2.10e-g	2.42e-h	1.10 a-c	1.10 a-c	23.50d	23.60d	8.00de	8.39c-e
	50	94.32 ab	96.40 a-c	111.71i	109.28i	1.77fg	2.09f-h	1.10 a-c	1.10 ab	23.70c	24.20b	10.67bc	10.70bc
	75	95.61 a	97.42 a	107.06j	104.79j	1.13g	1.24h	1.10 a	1.10 a	24.30a	24.30a	14.30a	15.29a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's Multiple Range Test at 0.05 level of probability.

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### الملخص العربي

## سلوك نمو بطاطس التصنيع تأثراً بالرش الورقي بمستخلص الطحالب البحرية و البورون

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تعتبر البطاطس محصول غذائي هام للعشيرة الإنسانية ويقدم الاحتياجات الغذائية الضرورية للإنسان ويقدم العديد من العناصر الغذائية الضرورية والفيتامينات مثل بوتاسيوم، فوسفور، منجنيز، مغنسيوم ، الفوليوت، فيتامين ج ، فيتامين ب6. زيادة القدرة الإنتاجية لمحصول البطاطس عبر مستخلصات الطحالب البحرية بدلا من التسميد المعدني وبعض المغذيات الصغرى مثل البورون من أجل زيادة الإنتاجية كماً ونوعاً وصحياً لتحسين تغذية زيادة السكان. ولذلك أجريت تجربتان حقليةتان أثناء موسمي الزراعة ٢٠١٦/٢٠١٧ وكذلك ٢٠١٧/٢٠١٨ في مزرعة خاصة بالنوبارية، محافظة البحيرة، مصر، تحت ظروف الحقل المكشوف في تربة طينية لدراسة تأثير الرش الهوائي

للأوراق بمستويات مختلفة من مستخلص الطحالب البحرية (كنترول، ١٠٠٠، ٢٠٠٠ ملجم/لتر) والبورون (كنترول، ٢٥، ٥٠، ٧٥ ملجم/لتر) وكذلك توليفاتهما علي صفات النمو الخضري وإنتاجية البطاطس صنف كاروسو 'Caruso'. كانت كلتا التجريبتين المنفذتين تجارب علمية موضوعة أضمن التصميم الإحصائي القطاعات العشوائية الكاملة بثلاث مكررات. تضمنت كل مكررة اثني عشر معاملة، وكل معاملة كانت قد وزعت عشوائياً داخل كل قطاع فتوليفة الرش

الورقي لكل من مستخلص الطحالب البحرية والبورن عند تركيز ٢٠٠٠ × ٧٥ ملجم/لتر، قد أدت إلي أقيم قيم متوسطات صفات النمو الخضري (كطول النبات وعدد الأفرع/نبات مقارنة مع المعاملات الأخرى خلال موسمي النمو. أيضاً، أدي الرش الورقي لنباتات البطاطس تحت التجربة بنفس التوليفة من متغيري الدراسة المستقلين إلي أعلى متوسطات قيم كل من عدد الدرنات/نبات ، متوسط وزن الدرنة (جم)، والإنتاج الكلي/ نبات (جم)، والإنتاج الكلي للبدان(بالطن)، النسبة المئوية للمحصول القابل للتصنيع ، الكثافة النوعية ، النسبة المئوية للمادة الجافة في الدرنات ، عيوب التصنيع في الشيبسي (%) مقارنة مع معاملة المشاهدة (الكنترول) أثناء موسمي الزراعة. وفي النهاية، فإن التوليفة المذكورة أعلاه هي التوليفة المناسبة لكل من متغيري الدراسة المستقلين بالنسبة لصفات النمو الخضري ، وأدت للحصول على أعلى محصول وجودة درنات لصنف البطاطس كاروسو . غير أن التوليفة من مستخلص الطحالب البحرية بتركيز ٢٠٠٠ مجم / لتر × ٥٠ مجم / لتر من البورن كانت الأمثل لإنتاج بطاطس التصنيع .