

Effect of Exogenous Application of Boric Acid and Seaweed Extract on Growth, Biochemical Content and Yield of Eggplant

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Abstract: There is no adequate literature on the effects of boron (B) and seaweed extract on the physiological responses of eggplant plants as well as yield. In the present study, the field experiment was carried out during the two growing seasons of 2012 and 2013, at the Experimental Farm, Faculty of Agriculture, Ain Shams University, to study the effect of separate and combined foliar applications of boric acid and seaweed extract at different levels on growth and yield of eggplant Suma hybrid. Seaweed extract was used at four concentrations, 0, 500, 1000 and 2000 ppm. Boric acid was used at three concentrations, 0, 50 and 100 ppm. The results indicated that foliar application with boric acid significantly stimulated many growth aspects as plant height, leaf number, leaf area, haulm fresh and dry weight as compared with the control treatment. Respecting the foliar application of seaweed extract, the obtained data indicated that the foliar application of 1000 and 2000 ppm seaweed extract, generally, increased vegetative growth characteristics. In the two tested seasons, the differences detected for the foliar application of boric acid were insignificant in all leaf chemical components, but responded positively to foliar application of 1000 and 2000 ppm seaweed extract. The highest values of yield were recorded by the foliar application of 1000 and 2000 ppm seaweed extract and boric acid at 50 ppm, but the foliar applications of boric acid individually had an insignificant increase on yield and its components.

Key words: Eggplant • *Solanum melongena* • Seaweed extract • Boric acid • Boron • Growth • Yield

INTRODUCTION

Currently, the demand for eggplant (*Solanum melongena* L.) in the world has increased. In Egypt, eggplant is considering one of the most important crops grown in the summer season. The varieties of *Solanum melongena* L. show a wide range of fruit shapes and colors, ranging from oval or egg-shaped to long club-shaped; and from white, yellow, green through degrees of purple pigmentation to almost black. Eggplant fruits contain a considerable amount of carbohydrates, proteins and some minerals and it's known for being low in calories and having a mineral composition beneficial for human health. They are also a rich source of potassium, magnesium, calcium and iron. The hybrids of eggplant have many advantages compared with open-pollinated cultivars in terms of yield and disease resistance. The yield depends upon several production factors. Among these proper, balanced nutrition plays a significant role.

Boron is an essential micronutrient and plays a major role in plant growth, cell wall structure, membrane stability, sugar transportation, phenol and carbohydrate metabolism [1, 2]. In commercial plant production, providing a sufficient B supply is particularly important for yield development and fruit quality [3 - 5]. Boron deficiency in crops is more wide spread than the deficiency of any other micronutrients [6]. The foliar application with micronutrients especially boron not only have major effects upon flower formation, carbohydrate and protein metabolism, but also increase pollen germination, pollen tube growth and yield [7]. Study of Asad *et al.* [8] revealed that B deficiency affects the reproductive yield more than biomass yield, even in the absence of any visible sign of deficiency symptoms and therefore the requirement of B for reproductive development appears to be more for reproductive development than for vegetative growth.

Studies on B nutrition of eggplant are very limited while much more research has been conducted on related solanaceous species. Leaf-tip yellowing has been reported as a result of poor B supply of eggplant [9].

Growers have always sought new methods to control the growth of plants. Seaweed appears to have some of the qualities of efficient plant growth regulators, which would justify its use as a soil additive. The use of seaweed in agriculture is not new, since ancient Greeks, Chinese and Viking applied seaweed mulches to the soil. Although seaweed has been used as mulch for certain crops for centuries, investigation into the response of plants in growth and development have been initiated only in recent years, seaweed liquid fertilizers were found superior than chemical one because of the presence of high levels of organic matter, thus accounting a reduction of 50% cost for chemical fertilizer [10]. Seaweed concentrates are known to cause many beneficial effects on plants as they contain growth promoting hormones (IAA, IBA and Cytokinins), trace elements (Fe, Cu, Zn, Co, Mo, Mn and Ni), vitamins and amino acids [11]. On faba beans, all the crude extracts of seaweed increased protein content in shoot systems, total soluble sugars and chlorophyll content in leaves [12]. Kumar and Sahoo [13] demonstrated that seaweed liquid extract could serve as an alternative bio-fertilizer as is eco-friendly, cheaper, deliver substantial economic and environmental benefits to farmers. Therefore, the present study aimed to use foliar spray with boric acid and seaweed extract on eggplant plants to increase growth and the final yield.

MATERIALS AND METHODS

The field experiment was carried out during the two growing seasons of 2012 and 2013, at the Experimental Farm, Faculty of Agriculture, Ain Shams University, Cairo, Egypt, in order to investigate the effect of using foliar application of boric acid and seaweed extract on growth

and yield of eggplant. The experimental soil was clay loam and its chemical analysis results according to A.O.A.C. [14] are shown in Table (A).

Imported eggplant seeds, hybrid Suma (Syngenta Company), fruits white and long shape, were sown in the shading screen nursery, using foam trays (209 eyes) on the 1st of March 2012 and 2013 seasons. Thirty five days after seed sowing, transplants were set up in the field (3-4 leaf stage). The area of the experimental plot was 14 m² and consisted of five rows, each row was 4 m length and 0.7 m width. The plant distance was 50 cm apart on one side.

Calcium super-phosphate (15 % P₂O₅) at 300 kg / feddan was applied at two times, the first (200 kg) was added during the soil preparation and the second one (100 kg) was carried out after one month from transplanting. Ammonium nitrate (33% N), at 300 kg / feddan, was applied as soil application in three portions, the first addition (100 kg) was added during the soil preparation, the second one (100 kg) was carried out after one month from transplanting and the third one (100 kg) was added one month later. Potassium sulfate (48 % K₂O) was applied at a rate of 150 kg per feddan at two times. The first portion took place one month from transplanting, whereas, the second part was added one month later. Cultural management, disease and pest control programs were followed according to the recommendations of the Egyptian Ministry of Agriculture.

The Experimental Design and Treatments: Boric acid [(B(OH)₃ with 17% boron] was used as a source of boron and applied as a foliar application at 35, 65, 95, 125 and 155 days from transplanting. Boric acid was used at three levels, i.e. 0 (control, sprayed with tap water), 50 and 100 ppm. Seaweed extract was used at four concentrations, i.e. 0 (control, sprayed with tap water), 500, 1000 and 2000 ppm, applied after 20, 50, 80, 110 and 140 days from transplanting as a foliar application. The used seaweed

Table A: The Chemical analysis of the experimental soil during 2012 and 2013 seasons

Seasons	Macro elements(ppm)			Micro elements (ppm)						
	N	P	K	Fe	B	Zn	Mn	Cu		
2012	30	71	752	5.2	4.1	3.5	12	4.7		
2013	50	88	488	5.4	4.4	3.6	12	5.0		
				Soluble anions (meq/L.)			Soluble cations (meq/L.)			
	pH	CaCO ₃ %	E.C ds/m	HCO ₃ ⁻	SO ₄ ⁻²	Cl ⁻	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺
2012	7.5	2	0.93	2.6	2.56	1.5	6.6	0.6	1.63	1.29
2013	7.4	1	1.09	2.4	5.53	2.0	4.2	1.8	2.33	1.60

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Table B: Chemical and biochemical analyses of seaweed extract, according to UAD®Company.

Organic component		Growth regulators		Macro elements		Micro elements	
Total amino acid	6.11 %	IAA	0.024%	Organic (N)	2.83 %	Fe	0.0162 %
Carbohydrates	35.02 %	Cytokinins	0.018%	P ₂ O ₅	2.60 %	Zn	0.0057 %
Alginic acid	8.50 %	----	----	K ₂ O	4.47 %	Mn	0.0012 %
Mannitol	4.23 %	----	----	Ca	0.28 %	B	0.0046 %
Betaines	0.037 %	----	----	S	3.00 %	----	----
----	----	----	----	Mg	0.65 %	----	----

extract (powder form) was produced by U.A.D. Co. Egypt (Table B). All treatments were applied as a foliar spray on plants using hand operated compressed air sprayer at the rate of 10 liter/plot. The previous treatments in this experiment will be described as follows: individual treatment for single application of boric acid or seaweed extract, combination treatment for interaction between boric acid and seaweed extract and finally mean effect of the treatment for the average of the treatment under all levels of the other studied factor.

The experiment was laid out in a split plot design with three replicates. The applied foliar applications of boric acid were assigned in the main plots and foliar applications of seaweed extract were distributed in the sub-plots.

Studied Characteristics:

Vegetative Characteristics: Five plants were chosen at random from plot (from the inner rows) at 100 days from transplanting to record plant height, leaf number, leaf area, fresh and dry weight per plant. Leaf area was determined using the recent full expanded fourth leaf from the plant top as a relation between unit area and leaf fresh weight [15].

$$\text{Leaf area (cm}^2\text{)} = \frac{\text{Disk area} \times \text{No. disks} \times \text{Leaf f.w.}}{\text{Disk f.w.}}$$

Leaf Bio-Chemical Components: The dried fourth leaf, at 100 days after transplanting was used for bio-chemical analysis. Total nitrogen concentration was determined by using the micro-Kjeldahl method as described by Horneck and Miller [16]. Crude protein = total nitrogen X 6.25 [14]. Phosphorus was determined colorimetrically by the molybdenum blue method according to the method of Bernhart and Wreath [17]. Potassium concentration was determined by flame photometer according to Horneck and Hanson [18]. Total carbohydrates concentration was determined by using phenol-sulfuric acid method described by DuBois *et al.* [19].

Leaf chlorophyll reading (SPAD) was determined using the recent full expanded mature upper leaf of 6 plants in the middle row per plot. A digital chlorophyll meter, Minolta SPAD-502, (Minolta Company, Japan) was used.

Fruit Set Percentage: Flowers were counted at full bloom with two week intervals to determine the fruit set. Fruits formed after two weeks of full bloom were counted and fruit setting determined by the following formulae:

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruit}}{\text{Total number of flowers}} \times 100$$

Treatment-Control Fruit Set Ratio (Fruit Set Sharing %): Sharing percentage of the treatment in fruit set was calculated by the following formulae:

$$\text{Fruit set sharing \%} = \left(\frac{\text{Fruit set \% of treatment}}{\text{Fruit set \% of control}} - 1 \right) \times 100$$

Fruit Physical Characters: Ten fruits from each plot were taken at various intervals; fruit diameter and length were measured.

Yield: Eggplant fruits were harvested every 4 days. Estimated total yield per plant and feddan were recorded.

Statistical Analysis: Data of the two seasons were arranged and statistically analyzed using MSTAT-C package [20]. The comparison among means of the different treatments was determined, as illustrated by Snedecor and Cochran [21].

RESULTS AND DISCUSSION

Vegetative Characteristics: Data presented in Tables (1-2) show the influence of foliar application of boric acid and seaweed extract on plant height, leaf number, leaf area, haulm fresh and dry weight of eggplant in the two seasons (2012 and 2013). In general, the vegetative growth of eggplant responded positively to foliar application of boric acid. Boron is vital to plant health, due to its role in forming and strengthening cell walls [1]. Although the significance test between the means of the individual treatment of boric acid was insignificant, the individual treatment of boric acid at 50 ppm recorded the highest values for all vegetative characteristics comparing with 100 ppm concentration of

Table 1: Effect of foliar application of boric acid and seaweed extract on plant height, leaf number and leaf area of eggplant in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	1 st season				2 nd season			
Plant height (cm)								
0	69.53 f	72.52 ef	71.41 f	71.15 C	67.35 e	68.13 e-d	67.70 e	67.72 C
500	72.95 d-f	77.51 cd	73.38 d-f	74.62 B	70.28 e-c	72.65 d-a	71.14 e-b	71.36 B
1000	76.83 c-e	83.22 ab	79.90 a-c	79.98 A	72.99 c-a	76.25 a	75.49 ab	74.91 A
2000	79.02 bc	83.80 a	81.47 a-c	81.43 A	74.80 c-a	74.90 c-a	73.65 a-c	74.45 AB
Mean	74.58 C	79.26 A	76.54 B	----	71.35 B	72.98 A	71.99 B	----
Leaf No. / plant								
0	77.9 f	80.9ef	79.7 f	79.5 C	73.8 c	74.6 bc	74.2 bc	74.2 C
500	81.3 d-f	85.9 cd	82.0 d-f	83.1 B	76.8 a-c	79.5 a-c	77.6 a-c	78.0 B
1000	85.2 c-e	91.6 ab	88.6 c-a	88.4 A	79.5 a-c	82.7 a	83.3 a	81.8 A
2000	87.4 bc	92.1 a	89.8 a-c	89.8 A	81.2 ab	81.4 a	79.8 a-c	80.8 AB
Mean	83.0 B	87.7 A	85.1 AB	----	77.67 A	79.67 A	78.83 A	----
Leaf area (cm ²)								
0	92.69 d	98.16 b-d	102.75 bc	97.87 B	90.75 d	96.96 cd	94.52 cd	94.08 B
500	97.52 cd	104.27 b	101.10 bc	100.96 B	97.75 c	100.43 c	94.68 cd	97.62 B
1000	118.18 a	124.21 a	123.42 a	121.94 A	112.16 b	119.88 a	118.0 ab	116.70 A
2000	120.28 a	119.46 a	121.60 a	120.45 A	116.32 ab	120.06 a	117.93 ab	118.10 A
Mean	107.2 B	111.5 A	112.2 A	----	104.2 B	109.3 A	106.3 B	----

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

Table 2: Effect of foliar application of boric acid and seaweed extract on fresh and dry weight of eggplant in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	-----1 st season-----				-----2 nd season-----			
	Haulm f.w. (g)							
0	479.1 fg	491.8 ef	468.2 g	479.7 D	459.2 f	485.4 ed	452.2 f	465.6 D
500	497.8 e	527.7 d	505.3 e	510.3 C	465.6 f	499.9 d	483.9 e	483.1 C
1000	550.6 c	602.9 a	569.4 b	574.3 B	490.1 de	552.9 ab	536.7 c	526.6 B
2000	584.1 b	616.2 a	607.4 a	602.5 A	544.7 bc	560.4 a	566.0 a	557.1 A
Mean	527.9 B	559.7 A	537.6 B	----	489.9 C	524.7 A	509.7 B	----
Haulm d.w. (g)								
0	49.70 f	52.52 e	50.96 f	51.06 D	47.15 g	48.66 f	46.92 g	47.58 D
500	55.36 d	57.67 c	52.72 e	55.25 C	50.34 e	52.71 d	50.46 e	51.17 C
1000	58.51 c	61.92 a	60.56 b	60.33 B	54.57 c	55.27 bc	56.12 ab	55.32 A
2000	60.53 b	61.66 ab	61.96 a	61.38 A	52.20 d	55.25 bc	56.32 a	54.59 B
Mean	56.03 B	58.44 A	56.55 B	----	51.06 B	52.97 A	52.45 A	----

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

boric acid or comparing with control (untreated plants). Plant requirements for boron nutrient are lower than the requirements for all other nutrients except molybdenum and copper [22]. Despite the chemical analysis of experimental soil (Table A) indicated that, the soil has sufficient amount of boron for plant growth. Control without boric acid foliar application recorded the lowest growth values. This result suggests that the amount of boron supply via roots from soil is not the optimum amount for plant growth. This might be referred to the alkaline nature of the experimental soil, which reduce the

amount of free boron. So, plant uptake of boron is reduced by increasing the soil pH [23]. Low boron levels lead to poor growth of fast growing tissues and plant development, which in turn recorded the lowest values. Foliar application may be used to supply boron to a crop when B demands are higher than can be supplied via the soil. Maximum growth level in plant height, leaf number and leaf area registered for foliar application with 50 ppm boric acid. This might refer to the role of boron in cell wall formation, cell development and elongation [22]. Decreasing growth levels after foliar application with 100

ppm boric acid, after increasing with the 50 ppm application, suggest that 100 ppm boric acid is more than enough for plant growth, or may have some toxic effects as the range of optimal and toxic level of B in crop plants is very low [22]. The mean effect of boric acid treatment at 50 and 100 ppm gave the highest values of plant height, leaf number, leaf area, haulm fresh and dry weight in the two seasons, except for leaf number in the second season which showed an insignificant increase.

Respecting the foliar application of seaweed extract, the obtained data reveal that the individual treatment or mean effect of seaweed extract at 1000 and 2000 ppm increased significantly plant growth, i.e. plant height, leaf number and leaf area, in the two seasons as compared with the other studied foliar application of seaweed extract treatments. However, foliar application of 2000 ppm seaweed extract was more superior for improving haulm fresh in the two tested seasons. The growth enhancing potential of seaweed might be attributed to the presence of growth regulators and macro elements. Seaweed extracts are known to enhance the growth of vegetables, fruits and other crops as they are reported to contain growth regulators such as auxins (IAA and IBA), gibberellins, cytokinins, betaines and major macronutrients [13]. The results obtained by Sridhar and Rengasamy [24] assure our result, the groundnut treated with brown seaweed *Sargassum wightii* as seaweed liquid fertilizers showed increase in physical parameters like shoot height, total fresh and dry weight, number of branches and leaf area of third young leaf. They attributed this to that the seaweed extract contained a maximum amount of K compared to the other macro nutrient N and P. These results might be attributed to the beneficial effect of seaweed extracts contain naturally occurring supplying nutrients, plant growth hormones (auxins, cytokines and gibberellins) as well as other plant bio stimulants; e.g. amino acids, vitamins that could maintain photosynthetic rates, improve plant resistances, delay plant senescence and control cell division.

The interaction between foliar application of boric acid and seaweed extract with all concentrations gave the highest values of growth parameters (plant height, leaf number, leaf area, fresh and dry weight) during the two growing seasons as compared with either individual foliar application or control plants. The maximum stimulatory effect was existed in plants treated with 1000 or 2000 ppm seaweed extract and boric acid at 50 ppm followed by 100 ppm as a foliar application during the two seasons. The toxic effect of individual treatment with boric acid at 100 ppm was vanished when combined with seaweed extract.

This could be due to the reason that seaweed extract contained adequate amount of calcium (0.28 %), which involved along with boron in cell wall structure. In this regard, Sotiropoulos *et al.* [25] mentioned that the important determining factor for B toxicity in kiwifruit seems to be the ratio of Ca/B in a particular tissue. At the highest Ca concentration (12 mM), the Ca/B ratio in leaves was significantly high and no toxicity symptoms were observed.

Leaf Chemical Components: Data presented in Tables (3-4) indicate an insignificant effect of foliar application of boric acid mean effect on all leaf chemical components (total nitrogen, phosphorus, potassium, crude protein, total carbohydrates and leaf chlorophyll reading). This may be attributed to two reasons, first that effects of individual applications of boric acid always have values lower than individual applications of seaweed extract, this fact would seem to indicate that seaweed extract has a greater effect than boric acid on plant growth and development, the second reason could be due to quasi-effects of seaweed concentrations (particularly at 1000 and 2000 ppm) under different boric acid concentrations, which in turn gave values close to others, finally reflect on significance level. But, the closer look to the individual applications of B revealed that, most measured chemical components of leaf affected by B application. The individual application of boric acid at 100 ppm recorded a significant increase in nitrogen concentration in both seasons and phosphorus concentration at the second season, while an insignificant increase was recorded with 50 ppm boric acid for nitrogen, phosphorus, potassium and protein concentration. These effects of B on uptake of ions are mediated by direct or indirect effects of B on membrane structure and hence function of various membrane transport processes including plasma membrane-bound H^+ -pumping ATPase [26]. The partitioning of nitrogen into soluble components (nitrate, ammonium and amino acids) of broccoli (*Brassica oleracea* var. botrytis L.) was dependent on boron and plant organ. Boron deficiency enhance the proportion of inorganic nitrogen, particularly nitrate concentration as well as corresponding decreases in nitrate reductase activity [27]. In this connection, foliar application of B could enhance the activity of nitrate reductase and synthesize more amino acids, which may reflect on protein content. This hypothesis confirmed with Broadley *et al.* [1], who mentioned that, foliar applications of B in soybean improved nitrate reductase and nitrogenase activities of plants and improved

Table 3: Effect of foliar application of boric acid and seaweed extract on nitrogen, phosphorus and potassium concentration of eggplant leaves in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	1 st season				2 nd season			
Nitrogen (mg / g d.w.)								
0	25.9 d	29.0 cd	30.2 c	28.4 B	25.1 d	28.6 cd	30.0 c	27.9 B
500	33.4 bc	34.6 ab	37.3 a	35.1 AB	33.4 bc	37.9 ab	38.0 ab	36.5 A
1000	38.4 a	39.7 a	40.3 a	39.5 A	38.7 ab	40.5 a	39.4 ab	39.5 A
2000	40.5 a	40.2 a	41.4 a	40.7 A	36.7 ab	40.7 a	41.0 a	39.4 A
Mean	34.5 A	35.8 A	37.2 A	----	33.4 A	36.9 A	37.1 A	----
Phosphorus (mg / g d.w.)								
0	4.8 a	5.7 a	5.3 a	5.3 B	4.5 e	4.9 cd	4.7 d	4.7 C
500	5.6 a	5.4 a	5.6 a	5.5 AB	5.0 bc	4.8 cd	4.9 cd	4.9 BC
1000	5.7 a	5.9 a	6.2 a	6.0 A	5.0 bc	5.1 b	5.8 a	5.3 B
2000	5.7 a	5.9 a	5.9 a	5.9 A	5.8 a	5.8 a	5.8 a	5.8 A
Mean	5.4 A	5.7 A	5.7 A	----	5.0 A	5.1 A	5.3 A	----
Potassium (mg / g d.w.)								
0	25.6 c	27.1 c	28.7 bc	27.2 B	27.2 b	27.8 b	29.0 ab	28.0 C
500	33.0 ab	34.7 a	34.9 a	34.2 A	31.4 ab	33.0 ab	33.3 ab	32.6 B
1000	35.3 a	34.9 a	36.3 a	35.5 A	33.1 ab	35.2 a	34.9 a	34.4 A
2000	36.2 a	35.8 a	35.1 a	35.7 A	34.3 a	34.8 a	35.1 a	34.7 A
Mean	32.5 A	33.1 A	33.7 A	----	31.5 A	32.7 A	33.1 A	----

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

Table 4: Effect of foliar application of boric acid and seaweed extract on protein, carbohydrates concentration and chlorophyll reading of eggplant leaves in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	-----1 st season-----				-----2 nd season-----			
Protein (mg / g d.w.)								
0	162.2 d	181.2 cd	188.6b-d	177.3 B	156.7 d	178.9 cd	187.6b-d	174.4 B
500	208.7a-d	216.2a-d	233.0a-c	219.3AB	208.5a-d	237.2a-c	237.8a-c	227.8 A
1000	240.1a-c	248.0 ab	251.6 a	246.6 A	241.9 ab	253.1 a	246.4 ab	247.1 A
2000	253.3 a	251.2 a	258.9 a	254.5 A	229.1a-c	254.4 a	256.1 a	246.5 A
Mean	216.1 A	224.2 A	233.1 A	----	209.1 A	230.9 A	232.0 A	----
Total carbohydrates (mg / g d.w.)								
0	330 a	331 a	326 a	329 C	321 f	323 ef	322 f	322 C
500	341 a	355 a	335 a	344 B	339 de	347b-d	332 d-f	339 B
1000	363 a	362 a	375 a	367 A	359 a-c	364 a	370 a	364 A
2000	373 a	364 a	358 a	365 A	344 cd	372 a	363 ab	360 A
Mean	352 A	353 A	348 A	----	341 A	351 A	347 A	----
Chlorophyll reading (SPAD)								
0	49.51 f	49.64 f	51.93ef	50.36 C	49.93 a	48.98 a	50.30 a	49.73 C
500	54.60ab	53.27cd	52.06 e	53.31 B	53.25 a	54.44 a	53.13 a	53.61 B
1000	52.73de	54.77 a	55.39 a	54.30 A	52.88 a	53.99 a	52.64 a	53.17 A
2000	52.31 e	55.48 a	53.73bc	53.84AB	51.45 a	54.32 a	51.65 a	52.47AB
Mean	52.29 A	53.29 A	53.28 A	----	51.88 A	52.93 A	51.93 A	----

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

concentrations of seed proteins. The total carbohydrates concentration and chlorophyll reading were not affected by boric acid applications. This may be attributed to that the B content of the soil is enough to the needs of the plants at that stage during the two seasons (Table A), or could refer to that boron had no effect on sugar translocation from source to sink. So, there is no accumulation for sugars in leaves as expected with B treatment according to literature [22]. In this respect, Liakopoulos *et al.* [28] found that sucrose export from eggplant leaves was notably higher in developing leaves compared to young fully expanded and mature leaves while it was unaffected by B treatment and sugar-alcohols which interact with B (specifically myo-inositol, mannitol, or sorbitol) were not detected in the phloem samples.

Respecting the foliar application of seaweed extract in Tables (3-4), foliar application of 1000 and 2000 ppm concentrations for either mean effect or individual applications resulted in the highest values of total nitrogen, phosphorus, potassium, crude protein, total carbohydrates and leaf chlorophyll reading as compared with the other studied concentrations. The chemical analysis of seaweed extract (Table B) has revealed a wide range of substances such as N, P_2O_5 and K_2O with percentage values 2.83, 2.6 and 4.47 %, respectively, which absorbed by plant leaves, hence, it could be the source of the additional amounts of N, P and K in eggplant analyzed leaves. Other researchers suggest that seaweed extract improved nutrient uptake from root as seaweed products such as growth regulators promote root growth and development, so, the formed healthy root could uptake more nutrients which reflect on N, P and K content [11, 29]. Rising values of protein concentration in Table 4 under seaweed extract treatments led to hypotheses that seaweed extract has substances responsible for that increasing. The chemical analysis data in (Table B) show that seaweed extract has amino acids and zinc. Zinc is present in enzymes of all six enzyme classes, including oxido-reductases, transferases, hydrolases, lyases, isomerases and ligases [1]. In this connection, Osman and Abd El-Gawad [30] reported that, zinc play an important role in protein synthesis from amino acids. Present leaf chlorophyll reading results confirmed previously results on tomato by Zodape *et al.* [31] that leaf chlorophyll reading was significantly enhanced by foliar application with seaweed extract particularly, under 1000 and 2000 ppm concentrations for mean effect and 50 ppm for individual application which recorded maximum significant increase (10.28 % over the control) when comparing with the other individual

applications. This increase in chlorophyll content was a result of reduction in chlorophyll degradation, which might be caused in part by betaines in the seaweed extract [11]. The total carbohydrates concentration significantly increased with seaweed extract applications for mean effect in two seasons and individual treatments in the second season, particularly, under 1000 and 2000 ppm concentrations. This may be attributed to more than one reason. First, this increase could refer to the existing content of carbohydrate (35 %) and mannitol (4.23 %) in seaweed extract. Second, this increase could refer to the stimulatory effect of seaweed extract on plant root and shoot growth, thereby plants were able to mine more nutrients even from distant places and deeper soil horizons, in balanced proportion. Besides, seaweed extract regulated plant bio-physiological activities, which collectively resulted in maintaining higher photosynthetic activities [32]. Third, according to Genard *et al.* [33] glycine betaine delays the loss of photosynthetic activity by inhibiting chlorophyll degradation during storage conditions in isolated chloroplasts, so, betaine in seaweed extract could responsible for enhancing eggplant photosynthetic activity, which reflect leaf carbohydrates content.

The interaction between foliar application of boric acid and seaweed extract with all concentrations gave the highest values of chemical components during the two growing seasons as compared with either individual foliar application or control plants, except for phosphorus and total carbohydrates in the first season. The maximum stimulatory effect was existed in plants treated with boric acid and 1000 ppm or 2000 ppm of seaweed extract as a foliar application during the two seasons. This stimulation could refer to beneficial addition of B on carbohydrates and protein metabolism and to the stimulatory effect of seaweed extract on many physiological functions, which energize plant metabolism to the maximum levels [34]. In this regard, Choularas *et al.* [35] found that the additional application of B (150 g borax per tree) and seaweed extract (0.5% v/v) increased K in olive leaves compared to the corresponding treatments without seaweed extract.

Fruit Setting: As shown in Table 5, either individual application or mean effect of boric acid recorded the maximum significant values over control for fruit set percentage. This increase suggests that reproductive tissues require high amount of B which are not well supplied via root. This is supported by observations that foliar application of B to developing reproductive tissues can increase reproductive success even in the presence of

Table 5: Effect of foliar application of boric acid and seaweed extract on fruit set percentage and sharing percentage in fruit set over control of eggplant in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	1 st season				2 nd season			
Fruit set (%)								
0	31.02 f	33.99 d	33.32de	32.78 C	31.30 g	36.49 d	33.55 f	33.78 C
500	32.83 e	38.75 b	36.71 c	36.10 B	34.80 e	39.63 b	39.29bc	37.91 B
1000	37.24 c	40.03 a	39.84 a	39.04 A	38.53 c	41.13 a	40.94 a	40.20 A
2000	36.99 c	39.57ab	39.80 a	38.78 A	38.54 c	41.38 a	41.17 a	40.36 A
Mean	34.52 B	38.09 A	37.42 A	----	35.79 B	39.66 A	38.73 A	----
Fruit set sharing %								
0	-	9.6	7.4		-	16.6	7.2	
500	5.8	24.9	18.3		11.2	26.6	25.5	
1000	20.1	29.0	28.4		23.1	31.4	30.8	
2000	19.2	27.6	28.3		23.1	32.2	31.5	

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

soil B sufficient for vegetative growth [5]. It is clear that reproductive tissues have a high requirement for B due to their rapid growth rates and pectin-rich cell walls [1].

Foliar application of seaweed extract recorded the highest significant effects on the fruit set percentage for either mean effect or individual applications, particularly at 1000 and 2000 ppm concentrations. Eggplant treated with seaweed extract had more flowers than untreated plants. As flower initiation and development is related to the physiological age of plants, seaweed extract may have promoted flowering by encouraging more vigorous plant growth. However, many plants subjected to environmental stress are known to shift towards reproductive growth as a survival strategy. As experimental plants receiving seaweed extract showed no signs of stress, it can be assumed that early flower set was elicited either by improved plant growth or possibly by some endogenous component in the product [36]. Cytokinins and auxins in addition to boron are all known to affect flowering [37, 38]. The sharing percentage in fruit set over control (Table 5) reveal that there is no difference between the individual application of seaweed extract at 1000 or 2000 ppm, which suggest that the endogenous content (cytokinins, auxin and B) of seaweed extract at 1000 ppm which recorded the maximum stimulatory effect for fruit set, reach the highest levels in the stimulation fruit set. Hence, application of 2000 ppm seaweed extract, which in turn duplicate the endogenous content of cytokinins, auxin and B, did not lead to any increase in fruit set. It was observed also that, the maximum increase in the fruit set percentage recorded with seaweed extract at 1000 ppm was 20%, while with boric acid application at 50 ppm was 9.6% at the first season. The priority of seaweed extract than boric acid in fruit set may be referred

to the multiple stimulatory content of seaweed (cytokinins, auxin and B), while boron has a single effect on the fruit set percentage. This hypothesis was confirmed by interaction data.

The combination between treatments recorded the highest value in fruit set comparing with individual treatments or control. The maximum increase achieved by interaction between 50 ppm boric acid and 1000 or 2000 ppm seaweed extract. For instance, individual application of seaweed extract at 1000 ppm and boric acid at 50 ppm gave 20% and 9.6% increase in fruit set over control, respectively, while the interaction between them recorded a 29% increase in fruit set over control. This observation recommended that boron content in seaweed extract must be increased to maximize fruit set percentage.

Yield and its Components: In most plants, fruit yield is dependent on the percentage of flowers that reach maturity. Data presented in Tables (6-7) show that there were statistically insignificant effects of foliar application of boric acid on fruit length, fruit diameter and yield per plant and per feddan of eggplant plant in the two seasons (2012 and 2013). This result may be attributed that B has a little effect on fruit growth. In this connection, Singh *et al.* [39] found that B has not influenced the individual strawberry weight. On the contrast, the little increase in yield under individual application of boric acid is parallel to the increase in fruit set % (Table 5), so the increase in yield refers to increase in fruit number. In this connection, Pandey and Gupta [40] reported that foliar spray of boron in black gram increased the yield parameters.

In the two tested seasons, the foliar application of 1000 or 2000 ppm seaweed extract increased significantly fruit yield per plant and per feddan in the two

Table 6: Effect of foliar application of boric acid and seaweed extract on fruit length and diameter of eggplant in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	-----1 st season-----				-----2 nd season-----			
	Fruit length (cm)							
0	13.09 ab	13.16 ab	12.94 b	13.06 A	12.21 b	12.57 ab	12.59 ab	12.46 A
500	13.29 ab	13.73 ab	12.98 b	13.33 A	12.79 ab	13.07 ab	12.84 ab	12.90 A
1000	13.24 ab	13.91 a	13.53 ab	13.56 A	12.90 ab	12.76 ab	12.97 ab	12.88 A
2000	13.14 ab	13.47 ab	13.50 ab	13.37 A	13.24 ab	13.77 a	12.88 ab	13.30 A
Mean	13.19 B	13.57 A	13.24AB	----	12.78 A	13.04 A	12.82 A	----
	Fruit diameter (cm)							
0	3.69 b	3.60 b	3.81 ab	3.70 A	3.72 a	3.70 a	3.71 a	3.71 A
500	3.56 b	3.73 ab	3.64 b	3.64 A	3.72 a	3.79 a	3.87 a	3.81 A
1000	3.48 b	4.31 a	3.81 ab	3.87 A	3.41 a	3.62 a	3.87 a	3.64 A
2000	3.89 ab	3.89 ab	3.96 ab	3.91 A	3.79 a	3.63 a	3.54 a	3.65 A
Mean	3.65 A	3.88 A	3.80 A	----	3.66 A	3.68 A	3.75 A	----

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

Table 7: Effect of foliar application of boric acid and seaweed extract on yield per plant and feddan of eggplant in the two seasons (2012 and 2013)

Seaweed extract concentration (ppm)	Boric acid concentration (ppm)							
	0	50	100	Mean	0	50	100	Mean
	1 st season				2 nd season			
	Yield (kg / plant)							
0	2.55 d	2.84 cd	2.68 cd	2.69 C	2.46 c	2.55 c	2.51 c	2.51 C
500	2.93 bc	3.19 ab	3.35 a	3.16 B	2.99 b	3.13 ab	3.14 ab	3.09 B
1000	3.45 a	3.54 a	3.29 a	3.43 A	3.29 ab	3.33 a	3.25 ab	3.29 A
2000	3.24 ab	3.33 a	3.36 a	3.31 AB	3.16 ab	3.29 ab	3.18 ab	3.21AB
Mean	3.04 A	3.23 A	3.17 A	----	2.98 A	3.08 A	3.02 A	----
	Yield (ton / feddan)							
0	26.52 d	29.51cd	27.84cd	27.96 C	25.57 c	26.48 c	26.09 c	26.05 C
500	30.48bc	33.16ab	34.84 a	32.83 B	31.07 b	32.55ab	32.56ab	32.06 B
1000	35.79 a	36.78 a	34.15 a	35.57 A	34.13 a	34.54 a	33.73ab	34.13 A
2000	33.69ab	34.59 a	34.93 a	34.40AB	34.14 a	32.77ab	32.98ab	33.30 A
Mean	31.62 A	33.51 A	32.94 A	----	31.23 A	31.58 A	31.34 A	----

Means followed by different letters are significantly different at $P \leq 0.5$ level; Duncan's multiple range test.

seasons as compared with the other studied foliar applications of seaweed extract treatments. This increase in fruit yield may be attributed to two reasons, first, the increase in yield refers to increase in fruit number, second, the stimulatory effect of seaweed extract on growth enhanced eggplant fruit weight. As the onset and development of flowering and the number of flowers produced are linked to the developmental stage of plants, seaweed extracts probably encourage flowering by initiating robust plant growth. Yield increases in seaweed-treated plants are thought to be associated with the hormonal substances present in the extracts, especially cytokinins. Cytokinins in vegetative plant organs are associated with nutrient partitioning, whereas in reproductive organs, high levels of cytokinins may be linked with nutrient mobilization. Fruit ripening generally

causes an increase in transport of nutrient resources within the developing plant and the fruits have the capacity to serve as strong sinks for nutrients [11].

The interaction between foliar application of boric acid and seaweed extract with all concentrations gave the highest values of yield and its components (fruit length, fruit diameter and yield per plant and per feddan) during the two growing seasons as compared with either individual foliar application or control plants. The maximum stimulatory effect was existed in plants treated with boric acid and 2000 ppm seaweed extract as a foliar application during the two seasons. The previously obtained results on yield and its components (Tables 6-7) could be attributed to the stimulating effect of boric acid and seaweed extract on vegetative growth (Tables 1-2), leaf chemical composition (Tables 3-4) and fruit set

(Table 5). In this respect, Chouliaras *et al.* [35] found that the additional application of borax and seaweed extract increased the productivity and oil content and accelerated maturation of the olive fruits.

CONCLUSION

The foliar application treatments of this experiment, especially foliar application of 1000 ppm seaweed extract with 50 ppm boric acid should be recommended for the studied eggplant, in order to increase plant productivity and improve their nutrition status and various yield parameters.

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