

Impact of Foliar Feeding With Alga Extract and Boron on Yield and Quality of Sugar Beet Grown in Sandy Soil

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TWO FIELD experiments were conducted at Wadi El-Natron, El-Bahira Governorate, (latitude of 30.48⁰ N and longitude of 30.50⁰ E) during 2013/2014 and 2014/2015 seasons to study the impact of foliar application with alga extract (*Spirulina platensis*) and boron on yield and quality of sugar beet (*Beta vulgaris* var. *saccharifera*, L.) planted in a sandy soil under sprinkler irrigation system. The present work included sixteen treatments, represented the combinations of four alga extract levels (without; 1.5; 2.5 and 3.5 g / liter) sprayed twice at 4-6 and 6-8 leaf stages as well as four concentrations of boron (without; 50; 100 and 150 ppm/liter/fad, as boric acid 17% boron) which, sprayed twice at 6-8 and 10 leaf stages. The treatments were arranged in a strip plot design in three replicates. The vertical plots were occupied with four levels of alga extract and the horizontal plots were devoted to the four levels of boron.

The Results indicated that foliar application of alga extract using 2.5 g/l or 3.5 g/l produced significantly higher values of photosynthetic pigments (chlorophyll a, b and carotenoides), vegetative growth traits of sugar beet plants (root diameter, root and foliage fresh weight), (root and top dry weight/plant), extractable sugar %, quality index %, nitrogen, phosphorus, potassium, boron contents in leaves and root, top and sugar yields/fad, as well as the lowest content of sodium in roots in both seasons.

Higher values of root diameter, fresh weight/plant, root, top and sugar yields/fad, sucrose, extractable sugar, quality index percentages and boron contents in leaves and roots, at harvesting time, were obtained with spraying boron at 100 ppm/fad in both seasons.

The interaction between alga extract and boron levels significantly affected chlorophyll (a), root fresh weight/plant in both seasons; chlorophyll (b), and root yield/fad in 1st one. The combination of 3.5 g/l alga extract along with 100 ppm boron can be recommended to get the maximum root yield/fad (27.13 t/fad) in 1st season, which showed an integrative role between fertilization using the alga extract and boron.

Keywords: *Spirulina*, Boron, Sandy soil, Sugar beet.

Sugar beet is one of the most imperative cash crops in the world. The continued production of this important commodity requires more crop management

techniques. In addition the broad-leaved crop increases soil fertility, especially in newly cultivated soils which, characterized with low of organic matter and water holding capacity as well as high nutrient losses by leaching; which leads to show deficiency symptoms of macro and micro nutrients (Shafeek *et al.*, 2013). Algae extract being organic and bio-degradable in nature is considered as an important source of nutrition for sustainable agriculture especially in the newly reclaimed soil. Chemical analysis of algae extract and have revealed the presence of a wide variety of plant growth regulators such as auxins and cytokinins in varying amounts (Zhang & Ervin, 2004). Thus, algae extract stimulate root establishment, root elongation and promote vegetative growth of plants. Foliar application of algae extract has been reported to induce many positive effects, where spraying plants had led to improve crop yield and quality, increase nutrient uptake, resistance to frost and stress conditions. Algae were early considered as an important group of microorganisms capable of fixing atmospheric nitrogen, as well as it causes significant increase in root growth, fresh and dry weights of roots, total biomass, yield component, photosynthetic pigments and growth promoting hormones (Ghalab & Salem, 2001). As a result of the functional activity, there is an increase of photosynthetic apparatus through raising the contents of total carbohydrates, starch, amino acids and protein (Raupp & Oltmanns, 2006 and Yassen *et al.*, 2007). *Spirulina platensis* is a rich source of potassium and contains considerable amounts of Ca, Cu, Fe, Mg, Mn, P and Zn, hence it increases uptake and accumulation of these elements in plants. This in turn explains the significant increase of vegetative growth and yield and its components as well as content of nitrogen, phosphorus and protein in leaves also leaf chlorophyll content for most crops especially those grown under semi arid and desert conditions (Abd El-Mawgoud *et al.*, 2010 and Marrez *et al.*, 2014).

Boron is by far the most important trace element needed by sugar beet because without an adequate supply, the yield and quality of roots is very depressed (Cooke & Scott, 1993). Its plays a key role in higher plants by facilitating the short-and long-distance transport of sugar via the formation of borate-sugar complexes. In addition, boron may be of importance for maintaining the structural integrity of plasma plant cells membranes. This function is likely related to stabilization of cell membranes by boron association with some membrane constituents (Brown *et al.*, 2002). Foliar spraying with boron have the advantage that they enable an existing deficiency problem to be treated rapidly. Several studies showed the beneficial effect of boron on the sugar beet, such as Kristek *et al.* (2006). They studied the effect of foliar fertilization with 1.0 kg B/ha on root yield and quality of sugar beet compared with the control. They found that higher values of root, sugar yields/fad and sucrose % was obtained with the previous concentration mentioned of boron. Enan (2011) showed that higher values of root diameter, fresh weight/plant, root, top and sugar yields/fad, sucrose% and boron concentration in root and leaves were obtained with increasing boron application up to 200 ppm/fad. Armin & Asgharipour (2012) indicated that highest root yield/fad and sucrose% were obtained by spraying with 12% boric acid, furthermore decreasing potassium,

sodium, alpha amino-N contents and sugar lost to molasses compared with the control treatment. Abbas *et al.* (2014) showed that application of boron showed significant increase in most traits where, increasing boron fertilizer up to 0.20 g/l resulted in highest sucrose, sugar recovery percentages, recoverable sugar yield/fad and purity % compared to check treatment.

This study aiming to evaluate the effect of alga extract as a source of bio-stimulator on sugar beet, which is considered as an important strategic crop and has extensively growth potential in reclaimed soils with possibility to select the optimum dose of the alga extract and of boron levels for maximizing yield and quality under sprinkler irrigation system in sandy soil.

Materials and Methods

Two field experiments were conducted at Wadi El-Natrun, El-Bahira Governorate, (latitude of 30.48⁰ N and longitude of 30.50⁰ E) during 2013/2014 and 2014/2015 seasons to study the impact of foliar application with alga extract (*Spirulina platensis*) and boron on yield and quality of sugar beet (*Beta vulgaris* var. *saccharifera*, L.) planted in a sandy soil under sprinkler irrigation system. The present work included sixteen treatments, represented the combinations of four alga extract levels (without; 1.5, 2.5 and 3.5 g/l/350 liter water/fad) sprayed twice at 4-6 and 6-8 leaf stages as well as four concentrations of boron (without; 50, 100 and 150 ppm/450 liter water/fad, as boric acid 17% boron) which, sprayed twice at 6-8 and 10 leaf stages. The treatments were arranged in a strip plot design in three replicates. The vertical plots were occupied with four levels of alga extract while, the horizontal plots were devoted to the four levels of boron. The plot area was 21.60 m² including 12 rows of 4-m in length and 45-cm between them, with 17-cm hill spacing filled with one seed per hill. Phosphorus fertilizer was applied in the form of calcium super phosphate (15 % P₂O₅) at the rate of 200 kg/fad at seed bed preparation. Nitrogen fertilizer was applied as ammonium nitrate at the rate of 100 kg N/fad, which was split as follows: 10 kg N/fad at age of 20 days after sowing, followed by 10 kg N/fad, two doses of 25 kg N/fad were added twice as a soil application after hoeing, 20 kg N/fad at age of 80 days after sowing and 10 kg N/fad at 100 days from sowing. Potassium fertilizer was added in the form of potassium sulphate (48% K₂O) with irrigation water at the rate of 48 kg/fad before canopy closer. Sugar beet was sown mechanically under sprinkler irrigation system. Sowing of sugar beet variety mono-germ "GENIO" took place during the 1st week of October, while harvesting was done 7 months later in both seasons.

Algal extract preparation

The early isolated blue green alga *Spirulina platensis* from Wadi El-Natrun, El-Bahira Governorate was scaled up to massive scale at Algal Biotechnology Unit, National Research Centre within three open ponds (75 m³ of a final capacity). Continuous centrifugation (Westifalia Separator) was employed for harvesting algal bulk which contains 75-80 % moisture and then after freeze for 48 h at -25⁰ C. Prior centrifugation, algal slurry was drastically stressed by hyper

nutritional doses to meet obligatory nutrient accumulation within algal cells. The frozen bulk was then re-melted at the room temperature, homogenized and an aerobically fermented 72 h. The fermented biomass was then homogenized and filtered till it used. Major components of the used alga extract are shown in Table 1.

TABLE 1. Chemical composition of some macro and micro-nutrients of alga bio-fertilizer.

Elements	N	P	K	Mg	Na	Ca	Fe	Zn	Mn	Cu
Conc.	%						ppm			
	11.2	1.65	0.88	0.22	0.01	0.33	1936	21	68	18

Some soil physical properties were analyzed using the procedure described by Black *et al.* (1981). Soil chemical analysis was determined according to the method of Jackson (1973). Physical and chemical analyses of the soil (the upper 60-cm) of the experimental site are given in Table 2.

TABLE 2. Particle size distribution and some chemical properties of a representative soil sample of the experimental site for 2013-2014 and 2014-2015 seasons.

Soil properties	2013/2014 season	2014/2015 season
Particle size distribution:		
Coarse sand %	30.89	27.95
Fine sand %	61.01	64.00
Silt	6.20	6.00
Clay	1.90	2.05
Texture class	Sandy	Sandy
Organic Matter %	0.37	0.41
Available Nitrogen mg/kg soil	11.50	12.60
Available P ₂ O ₅ mg/kg soil	3.65	4.00
Available K ₂ O mg/kg soil	75.3	80.1
Available boron mg/kg soil	0.12	0.15
pH at (1:2.5) soil : water suspension	7.94	8.01
E.C dS./m ⁻¹	0.45	0.35
Soluble Cations (meq./l ⁻¹)		
K ⁺	1.50	1.14
Na ⁺	0.80	0.76
Mg ⁺⁺	1.20	0.90
Ca ⁺⁺	0.89	0.75
Soluble Anions (meq./l ⁻¹)		
SO ₄ ⁼	1.39	0.89
Cl ⁻	2.1	1.80
HCO ₃ ⁻	0.90	0.86
CO ₃ ⁼	-	-

The recorded data

After 105 days from sowing, random samples of five sugar beet plants were taken from each sub plot to determine chlorophyll a, b and carotenoides (mg/g leaf fresh weight) according to the method of Wettstein (1957).

At harvest time, the following traits were estimated:

Yield components

1. Root length and diameter (cm).
2. Root and top fresh weight (g/plant).
3. Root and leaves dry weights as g/plant which were determined as follows: 100 g of the fresh leaves and minced fresh roots were oven dried at 70 °C to a constant weight, then the dry matter percentages of these two portions were multiplied by their fresh weight/plant.

Chemical and quality characteristics

4. Sucrose percentage (Pol%) was estimated in fresh samples of sugar beet roots, using Saccharometer according to the method described in A.O.A.C. (2005).
5. Sugar lost to molasses percentage (SLM %) was calculated by the following formula, according to Devillers (1988):

$$\text{SLM}\% = 0.29 + (\text{Na} + \text{K}) 0.343 + 0.094 (\alpha\text{-amino N}).$$
6. Juice quality percentage (QZ %) was calculated according to Cooke & Scott (1993) using the following equation:

$$\text{QZ}\% = (\text{extractable sugar}\% \times 100) / \text{Pol}\%.$$
7. Impurities%: K, Na and α -amino N contents were estimated as meq/100 g beet according to the procedure of sugar company using an Automated Analyzer as described in Cooke & Scott (1993).
8. Extractable sugar % was calculated using the following equation according to Cooke & Scott (1993):

$$\text{Extractable sugar}\% = (\text{Pol}\% - 0.29) - 0.343 (\text{K} + \text{Na}) - \alpha\text{- amino N} (0.0939).$$
 where: K, Na and α -amino N were determined as meq/100 g beet.

9. Foliage contents of N, P, K and B: The dry matter of leaves was digested using an acid mixture consisting of nitric, perchloric and sulfuric acids in the ratio of 8:1:1 (v/v), respectively (Chapman & Pratt, 1978). Nitrogen (N) was determined using micro-Kjeldahl method, using boric acid modification described by Ma & Zuazaga (1942) and distillation was done using Gerhardt apparatus. Phosphorus was spectro-photometrically determined using the molybdate-vanadate method according to Jackson (1973). Potassium was measured using Dr. Lang-M8D Flame-photometer. Boron was extracted with hot water and determined colourimetrically using azomethine-H according to the method described by Wolf (1974).

Root, top and sugar yields/fad (t/fad)

Plants of six guarded rows were uprooted, topped and weighed to determine the following parameters:

10. Top yield (fad).
11. Root yield (fad).

12. Sugar yield (fad), which was calculated according to following equation:
 Sugar yield (fad) = roots yield (fed) x sugar recovery%.

All data statistically analyzed according to the technique of analysis of variance (ANOVA) for the strip plot design as published by Gomez & Gomez (1984) by means of "MSTAT-c" computer software package. Least significant differences between treatment means at 5% level of probability as described by Snedecor & Cochran (1980).

Results and Discussion

Photosynthetic pigments, root diameter, root and foliage fresh weights/plant

Data in Table 3 manifest that a significant effect of *Spirulina* extract on photosynthetic pigments, root diameter, root and foliage fresh weights/plant, in both seasons. Spraying beet plants with 2.5 or 3.5 g/l *Spirulina* extract resulted in higher values of photosynthetic pigments and root thickness as well as fresh weight of leaves and roots as compared to the other levels (*i.e.*; control and 1.5 g/l). There were significant difference between 2.5 and 3.5 g/l *Spirulina* extract in their effect on root fresh weight/plant and root diameter in both seasons concerning foliage fresh weight in 1st season and root diameter in 2nd season. The appreciable influence of alga extract may be attributed to its effect in increasing cell membrane permeability and promoting plant efficiency in the absorption of nutrients such as nitrogen, which has a direct relation with leaf chlorophyll concentration. Moreover, algae extract may play a role through its content of cytokinins in delaying the aging of leaves by reducing the degradation of chlorophyll. In addition, alga extract as a bio-regulator affecting the balance between photosynthesis and respiration processes in plants (Raupp & Oltmanns, 2006 and Yassen *et al.*, 2007).

TABLE 3. Photosynthetic pigments (mg/g fresh weight), root diameter (cm), root and foliage fresh weight (g/plant) as affected by foliar application of *Spirulina* extract concentrations in 2013/2014 and 2014/2015 seasons.

Alga extract conc. (g/l)	Photosynthetic pigments (mg/g f.w.)			Root diameter (cm)	Root fresh weight (g/plant)	Foliage fresh weight (g/plant)
	Chl. a	Chl. b	Carotenoids			
2013/2014 seasons						
Without alga extract	1.33	0.71	0.51	8.13	550.0	221.9
1.5	1.77	1.01	0.71	8.98	670.0	287.3
2.5	2.37	1.22	0.87	9.56	709.6	296.3
3.5	2.67	1.35	0.89	9.97	776.5	364.0
LSD at 0.05% level	0.42	0.27	0.13	1.05	66.10	0.63
2014/2015 seasons						
Without alga extract	1.98	0.60	0.36	7.11	552.1	230.4
1.5	2.09	1.07	0.54	7.86	619.5	304.6
2.5	2.64	1.21	0.73	8.52	637.5	330.0
3.5	2.83	1.45	0.64	9.20	719.5	353.8
LSD at 0.05 %level	0.52	0.39	0.16	0.62	69.43	0.69

Concerning the effect of boron levels, data in Table 4 cleared that fertilizing sugar beet with 100 ppm of boron led to the positive effects of boron on root diameter, foliage and root fresh weights/plant and carotenoids in both seasons, whilst insignificant differences between boron levels in their impact on chlorophyll (a) in both seasons and also in their effect on chlorophyll (b) in 1st season only. This result may be due to role of boron element in cell elongation where, in case of boron deficiency the leaves are smaller, stiff and thick also its role for the formation of new leaves. Moreover it has an active role in translation of assimilation product of the leaves and roots. Similar results were reported by Kristek *et al.* (2006), Enan (2011) and Abbas *et al.* (2014).

TABLE 4. Photosynthetic pigments (mg/g fresh weight), root diameter (cm), root and foliage fresh weight (g/plant) as affected by foliar application of boron fertilization in 2013/2014 and 2014/2015 seasons.

Boron treatments (ppm)	photosynthetic pigments (mg/g f.w)			Root diameter (cm)	Root fresh weight (g/plant)	Foliage fresh weight (g/plant)
	Chl. a	Chl. b	Carotenoids			
2013/2014 season						
Without boron	1.81	1.00	0.67	8.72	595.7	251.7
50	2.00	1.09	0.74	9.23	679.4	286.6
100	2.21	1.15	0.82	9.45	739.2	317.6
150	2.11	1.06	0.76	9.25	691.8	313.6
LSD at 0.05% level	NS	NS	0.06	0.13	45.8	21.0
2014/2015 season						
Without boron	2.07	0.93	0.44	7.88	600.8	280.0
50	2.34	1.06	0.54	7.99	636.3	303.8
100	2.61	1.19	0.69	8.72	662.9	327.1
150	2.50	1.17	0.58	8.10	628.6	307.9
LSD at 0.05% level	NS	0.11	0.10	0.55	27.3	20.0

The interaction between *Spirulina* extract and boron fertilization levels had a significant effect on chlorophyll (a) and root fresh weight/plant in both seasons as well as chlorophyll (b) in 1st season (Tables 3 and 4).

Effect of interactions

Chlorophyll (a) was significantly affected by the interaction between *Spirulina* extract and boron fertilization levels in both seasons. The results in Table 5 showed that chlorophyll (a) was responded to the increase of foliar applied *Spirulina* extract level, but was highly magnituded by adding 100 ppm boron. Therefore the highest value of leaf tissue content of chlorophyll (a) was recorded by 2.5 and/or 3.5 g/l alga extract without significant differences between them when plants received 100 ppm boron in 1st and 2nd season. This

finding may be due to algae extract contains cytokines which induce the physiological activities and increase total chlorophyll in plants which, reflects on the activity of photosynthesis and the synthesized materials which will positively reflects on the growth characteristics (Ghalab & Salem, 2001).

TABLE 5. Chlorophyll (a) as affected by the interaction between *Spirulina* extract and boron fertilization levels in 2012/2013 and 2013/2014 seasons.

Boron	2013/ 2014 seasons				2014/ 2015 seasons			
	Without boron (control)	50 ppm	100 ppm	150 ppm	Without boron (control)	50 ppm	100 ppm	150 ppm
Alga extract								
Without alga extract	1.23	1.26	1.45	1.36	1.88	1.96	2.09	1.99
1.5 g/l	1.68	1.70	1.88	1.81	1.89	2.10	2.25	2.11
2.5 g/l	1.85	2.41	2.69	2.54	2.02	2.69	3.00	2.84
3.5 g/l	2.47	2.64	2.82	2.74	2.50	2.61	3.13	3.07
LSD at 0.05% level	0.23				0.29			

Data in Table 6 clear that the difference in chlorophyll (b) content in leaf tissue of sugar beet fertilized with 1.5 and 2.5 g/l alga extract/fad was significant, when plants received 100 ppm boron whilst, the difference between these two levels of alga extract under the other levels of boron was insignificant. Application of 2.5 and/or 3.5 g/l alga extract/fad combined with 100 ppm boron/fad gave the highest value for content of chlorophyll (b), in 2013/2014 season.

TABLE 6. Chlorophyll (b) as affected by the interaction between *Spirulina* extract concentration and boron fertilization levels in 2013/2014 season.

Boron	2013/ 2014 seasons			
	Without boron (control)	50 ppm	100 ppm	150 ppm
Alga extract conc.				
Without alga extract	0.40	0.81	0.84	0.79
1.5 g/l	0.99	1.05	0.97	1.00
2.5 g/l	1.17	1.19	1.33	1.16
3.5 g/l	1.32	1.33	1.47	1.28
LSD at 0.05 % level	0.20			

Data in Table 7 show that the difference in root fresh weight/plant between beets which received 50 ppm boron and those untreated with boron was insignificant when sugar beet was unfertilized with alga extract, fertilized with 1.5 and 3.5 g/l alga extract/fad. However, the difference in this trait between those two levels of boron was significant under fertilized with 2.5 g/l alga extract in 1st season. In the 2nd one, the difference in this trait between those two levels of boron was significant under those fertilized with 2.5 and/or 3.5 g/l alga extract/fad. Application of 3.5 g/l alga extract + 100 ppm boron/fad gave the highest value for root fresh weight/plant, in both seasons.

TABLE 7. Root fresh weight (g/plant) as affected by the interaction between *Spirulina* extract concentration and boron fertilization level in 2012/2013 and 2013/2014 seasons.

Alga extract conc.	Boron	2013/ 2014 seasons				2014/ 2015 seasons			
		Without boron (control)	50 ppm	100 ppm	150 ppm	Without boron (control)	50 ppm	100 ppm	150 ppm
Without alga extract		485.0	501.7	576.7	516.7	531.7	561.7	563.3	551.7
1.5 g/l		585.0	620.0	686.7	668.3	606.7	626.7	645.0	599.7
2.5 g/l		630.0	713.3	768.3	726.7	573.3	636.7	690.0	650.0
3.5 g/l		758.3	778.3	821.7	751.7	681.7	720.0	753.3	723.0
LSD at 0.05% level		39.96				31.0			

Root, top dry weight/plant, nitrogen, phosphorus, potassium and boron contents in leaves (mg/100 g plant)

Root and top dry weight of sugar beet plants recorded higher values by spraying beets with 2.5 or 3.5 g/l *Spirulina* extract, without significant difference between them, in both seasons (Table 8). Increasing the applied level of alga extract up to 2.5 g/l resulted in a gradual and significant increases in N, P and B contents in sugar beet leaves in both seasons. Meantime, the highest K content was recorded when beets received 3.5 g/l of alga extract, without significant variance with 2.5 g/l of alga extract in both seasons. These results may be due to that alga extract is considered a source of high protein which split into natural amino acids involved directly in the metabolism (Marrez *et al.*, 2014). It also contains some essential macronutrients for growth and development of the plant as N, P and K. In addition, algae extract affect the nutrients uptake by plant roots (Abd El-Mawgoud *et al.*, 2010).

TABLE 8. Root (g/plant), top dry weight (g/plant); nitrogen, phosphorus, potassium and boron contents in leaves (mg/100 g plant) as affected by foliar application of *Spirulina* extract concentration level in 2013/2014 and 2014/2015 seasons.

Alga treatments concentration g/l	Root dry weight (g/plant)	Top dry weight (g/plant)	N content (mg/100 g plant)	P content (mg/100 g plant)	K content (mg/100 g plant)	Boron content (mg/100 g plant)
2013/2014 season						
Without alga	135.9	25.73	298.7	24.42	359.7	0.55
1.5	186.7	28.29	538.4	43.11	521.1	0.74
2.5	213.3	29.25	753.8	62.84	584.9	0.93
3.5	200.8	31.71	724.9	60.62	666.2	0.86
LSD at 0.05 %level	46.0	2.75	210.0	18.0	119.5	0.12
2014/2015 season						
Without alga	145.0	21.7	305.9	28.64	342.3	0.36
1.5	178.3	26.0	419.2	49.39	479.8	0.62
2.5	225.0	28.6	596.0	74.05	633.1	0.95
3.5	215.0	27.9	528.2	68.45	591.9	0.81
LSD at 0.05% level	37.5	4.0	161.0	22.0	0.97	0.15

The results in Table 9 reveal that sprayind beets with 100 or 150 ppm boron recorded higher values of root and top dry weights/plants without significant difference between them in root dry weight/plant, boron content in leaves in both seasons and top dry weight/plant in 2nd season. Feeding sugar beet with 100 ppm boron/fad led to significant effect on top dry weight/plant in 1st season compared with the rest of the levels used. Phosphorus content was not affected by levels of boron in both seasons. Similarly, leaf potassium content was insignificantly influenced by boron levels, in the 2nd season. These results may be due to differential absorption of these nutrients in the presence of boron, which enhance some elements on the account of others in the bio-accumulation of nitrogen (Hellal *et al.*, 2009), especially in sandy soil which contain low of organic matter and micronutrients such as boron (Table 2).

The interaction between *Spirulina* extract and boron fertilization levels had insignificant effect on the above-mentioned traits (Tables 8 and 9).

Sucrose %, (*potassium, sodium, alpha-amino contents meq/100 g beet*), *sugar lost to molasses and extractable sugar percentages*

Data in Table 10 show that sucrose %, potassium and alpha-amino-N in both seasons, as well as sugar lost to molasses (in 1st season) and extractable sugar percentages (in 2nd season) were insignificantly influenced by the applied alga extract concentrations. Meantime, the fertilization with 2.5 g/l and/or 3.5 g/l alga extract led to higher values of extractable sugar percentage in 1st season. Feeding beet plants with 3.5 g/l reduced sodium content amounted to 22.36% and 39.06% in the 1st and 2nd seasons respectively, as well as reduced sugar lost to molasses% amounted to 6.80% in the 2nd season, as compared to that gained by fertilizing beets with 2.5 g/l alga extract.

TABLE 9. Root, top dry weight/plant, nitrogen, phosphour, potassium and boron contents in leaves (mg/100 g plant) as affected by foliar application of boron fertilization levels in 2013/2014 and 2014/2015 seasons.

Boron treatments (ppm)	Root dry weight%	Top dry weight%	N content in leaves (mg/100 g plant)	P content in leaves (mg/100 g plant)	K content in leaves (mg/100 g plant)	Boron content in leaves (mg/100 g plant)
2013/2014 season						
Without boron	168.8	27.75	539.1	45.39	444.4	0.68
50	175.5	28.63	558.4	49.13	534.6	0.74
100	194.2	29.50	604.4	49.53	589.6	0.83
150	198.3	29.11	613.8	46.94	563.3	0.82
LSD at 0.05% level	12.0	0.32	39.0	NS	44.0	0.07
2014/2015 season						
Without boron	176.7	25.4	396.4	52.14	471.7	0.48
50	187.5	25.8	443.1	55.31	515.9	0.66
100	197.5	26.4	502.3	57.98	529.6	0.78
150	201.7	26.7	507.5	55.10	529.8	0.84
LSD at 0.05 %level	10.0	0.80	0.23	NS	NS	0.11

TABLE 10. Sucrose %, potassium, sodium, alpha-amino content (meq/100 g beet), sugar lost to molasses and extractable sugar (%) as affected by *Spirulina* extract concentration in 2013/2014 and 2014/2015 seasons.

Alga treatments conc. (g/l)	Sucrose %	Potassium (meq/100 g beet)	Sodium (meq/100 g beet)	Alpha amino-N (meq/100 g beet)	Sugar lost to molasses %	Extractable sugar %
2013/2014 season						
Without alga	15.96	3.95	2.11	1.81	2.55	13.41
1.5	16.38	3.77	2.06	1.62	2.45	13.94
2.5	16.49	3.73	1.97	1.44	2.39	14.10
3.5	16.65	3.69	1.61	1.40	2.25	14.40
LSD at %0.05 level	NS	NS	0.35	NS	NS	0.57
2014/2015 season						
Without alga	15.54	3.75	2.05	1.39	2.42	13.13
1.5	15.62	3.70	1.89	1.34	2.34	13.28
2.5	15.81	3.63	1.78	1.23	2.20	13.61
3.5	15.90	3.49	1.28	1.32	2.06	13.84
LSD at 0.05% level	NS	NS	0.50	NS	0.25	NS

Data in Table 11 show that sucrose %, sodium, potassium contents in roots, sugar lost to molasses and extractable sugar percentages were significantly affected by the spraying beet plants with boron levels, while alpha-amino N failed to reach the level of significance in both seasons. Fertilizing beet plants with 100 ppm of boron recorded highest values of sucrose and extractable sugar %, in addition to lowest quantities of sodium, potassium contents and sugar lost to molasses% compared to other treatments. Adding boron at the rate of 100 ppm achieved an increase in sucrose amounted to 1.16, 1.00 and an increase in extractable sugar amounted to 1.56, 1.35 over those unfertilized in 1st and 2nd season, respectively. Meantime, the significant lowest quantities of sodium and sugar lost to molasses% was recorded by supplying 100 ppm boron application compared with the check treatment, 50 and 150 ppm boron/fad. These results may be due to that boron levels significantly increased glucose levels in phloem sap and the balance in sodium uptake and nitrogen consumption. As well as the borate ion react with hydroxyl rich substances such as sugar to produce legends which were then transported more rapidly across membranes than un-dissociated free sugar, which led to boron gave more facilities to sugar movement from the leaves to roots. These finding are in agreement with that mentioned by Javaheripour *et al.* (2005) who stated that increasing the amount of boric acid to a certain extent can reduce molasses sugar as a result of decreasing in impurities in terms of Na, K and alpha-amino nitrogen content in beet roots.

The interaction between *Spirulina* extract and boron fertilization levels failed to reach the level of significance in their effect on the above-mentioned traits in both seasons (Tables 10 and 11).

TABLE 11. Sucrose %, (potassium, sodium, alpha-amino contents meq/100 g beet), sugar lost to molasses and extractable sugar percentages as affected by boron fertilization levels in 2013/2014 and 2014/2015 seasons.

Boron treatments (ppm)	Sucrose %	Potassium (meq/100 g beet)	Sodium (meq/100 g beet)	Alpha amino-N (meq/100 g beet)	Sugar lost to molasses %	Extractable sugar %
2013/2014 season						
Without boron	15.76	4.06	2.22	1.56	2.59	13.16
50	16.33	3.67	1.95	1.52	2.37	13.96
100	16.92	3.58	1.58	1.47	2.21	14.72
150	16.48	3.84	2.00	1.72	2.46	14.02
LSD at 0.05 % level	0.51	0.26	0.19	NS	0.14	0.53
2014/2015 season						
Without boron	15.16	3.94	1.89	1.41	2.43	12.73
50	15.63	3.72	1.73	1.25	2.28	13.34
100	16.16	3.29	1.55	1.25	2.08	14.08
150	15.93	3.62	1.62	1.37	2.22	13.71
LSD at 0.05 % level	0.30	0.37	0.23	NS	0.16	0.38

Quality index%, root, top and sugar yields/fad

Data in Table 12 indicate a significant effect on root, top and sugar yields/fad due to the fertilization with *Spirulina* extract levels in both seasons. Feeding sugar beet plants with 2.5 or 3.5 g/l alga extract/fad without significant difference between them gave higher values of these traits compared with check treatment and those that received 1.5 g/l alga extract, while there was insignificant difference between beets fertilized with 2.5 and 3.5 g/l. Application of 3.5 g/l alga extract led to an increase in root, top and sugar yields/fad amounted to 3.05, 1.57 and 0.67 tons/fad, compared that gained by check treatment in 1st season, respectively. In the 2nd one, the increase in these traits amounted to 2.52, 1.92 and 0.50 tons/fad respectively, compared to the untreated treatment with alga extract. The augmentation in root, top and sugar yields/fad may be due to the increase in plant growth parameters (Tables 3 and 8), which in turn is reflected on root, top yields/fad depending on the theory of the source and downstream. As for the quality index, it turned out to be significantly affected by adding 2.5 and/or 3.5 g/l alga extract without significant differences between them in the 1st season. In the 2nd one, the variance in this trait between alga extract concentrations used was insignificant.

TABLE 12. Quality index, root, top and sugar yields/fad as affected by foliar application of *Spirulina* extract concentration in 2013/2014 and 2014/2015 seasons.

Alga treatments conc. g/l	Quality Index	Root yield t/fad	Top yield t/fad	Sugar yield t/fad
2013/2014 season				
Without alga extract	83.97	23.53	8.46	3.76
1.5	85.02	25.17	9.20	4.13
2.5	85.45	25.78	9.90	4.25
3.5	86.54	26.58	10.03	4.43
LSD at 0.05% level	1.48	1.50	0.67	0.21
2014/2015 season				
Without alga extract	85.47	22.82	7.48	3.54
1.5	86.07	24.09	8.24	3.77
2.5	84.80	24.64	8.55	3.90
3.5	85.26	25.34	9.40	4.04
LSD at 0.05 %level	NS	1.25	0.71	0.17

Quality index, root, top and sugar yields/fad in Table 13 increased significantly when boron level was raised from zero up to 100 ppm boron/fad in both seasons. Supplying sugar beet with 100 ppm boron resulted in a positive effect surpassing the level of 150 ppm boron on quality index% in both seasons and top yield/fad in 1st season, while there was insignificant difference between 100 and 150 ppm boron on root, sugar yields/fad in both seasons and top yield/fad in 2nd season. This increase in root, top, sugar yields/fad and quality index accompanying boron may be due to the increase in root diameter, root, top fresh weights/plant and sucrose% as mentioned before (Tables 4 and 11). These

results are in harmony with those obtained by Kristek *et al.* (2006), Enan (2011) and Armin & Asgharipour (2012)

The interaction between *Spirulina* extract and boron fertilization levels had insignificant effect on the above-mentioned traits, with the exception of root yield/fad in 1st season (Tables 12 and 13).

TABLE 13. Quality index, root, top and sugar yields/fad as affected by foliar application of *Spirulina* extract concentration in 2013/2014 and 2014/2015 seasons.

Boron treatments (ppm)	Quality index	Root yield t/fad	Top yield t/fad	Sugar yield t/fad
2013/2014 season				
Without boron	83.43	24.41	9.08	3.85
50	85.47	25.19	9.35	4.11
100	86.97	25.94	9.74	4.40
150	85.11	25.52	9.44	4.21
LSD at 0.05% level	0.87	0.74	0.21	0.20
2014/2015 season				
Without boron	84.79	23.27	8.13	3.53
50	84.96	24.13	8.38	3.77
100	86.50	24.95	8.61	4.03
150	85.35	24.54	8.55	3.91
LSD at 0.05% level	1.00	0.70	0.14	0.13

Interaction effect

Root yield/fad was significantly affected by the interaction between *Spirulina* extract concentrations and boron levels in 2013/2014 season. The results in Table 14 show that the differences in root yield/fad between beets sprayed with 50 ppm and those unfertilized with boron were insignificant, in the case of plants unfertilized with *Spirulina* extract, plants fad with 1.5 and 3.5 g/l *Spirulina* extract. The differences in root yield/fad between beets sprayed with 100 ppm and those that sprayed with 50 ppm were insignificant in the case of plants fertilized with 1.5 and 3.5 g/l *Spirulina* extract. Based on that spraying beet plants with 100 ppm boron/fad resulted in a higher value of root yield/fad, when beets was fad with 2.5 and/or 3.5 g/l *Spirulina* extract without significant differences between them.

TABLE 14. Root yield/fad as affected by the interaction between *Spirulina* extract and boron fertilization levels in 2013/2014 season.

Alga extract conc.	2013/ 2014 season			
	Without boron (control)	50 ppm boron	100 ppm boron	150 ppm boron
Without alga extract	22.88	23.01	24.18	24.06
1.5 g/l	24.60	25.13	25.76	25.17
2.5 g/l	23.85	25.70	26.85	26.72
3.5 g/l	26.30	26.76	27.13	26.15
LSD at 0.05% level	1.09			

Conclusion

Spirulina extract when applied as a foliar application, can contribute to the supply of plant nutrients and substitute nutrients. On the results of this study, it can be recommended to spray sugar beet with 2.5 or 3.5 g/l of *Spirulina* extract along with 100 ppm boron for maximum yields of root and sugar under sandy soil conditions.

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تأثير التغذية الورقية بمستخلص الطحالب والبورون على إنتاجية وجودة بنجر السكر المنزرع في الأراضي الرملية

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أقيمت تجربتان حقليتان في وادى النطرون- محافظة البحيرة (دائرة عرض ٣٠,٤٨ ° شمالاً و خط طول ٣٠,٥٠ ° شرقاً) في موسمي ٢٠١٣/٢٠١٤ و ٢٠١٤/٢٠١٥ م لدراسة تأثير أربعة تركيزات من مستخلص الطحالب هي: ١- الرش بالماء بدون مستخلص الطحالب (مقارنة) ، ٢- الرش بمستخلص الطحالب تركيز ١,٥ جرام/لتر ، ٣- الرش بمستخلص الطحالب تركيز ٢,٥ جرام/لتر ٤- الرش بمستخلص الطحالب تركيز ٣,٥ جرام/لتر/فدان تم إضافتهم رشاً على دفعتين (بعد تكوين ٤-٦ ورقات و بعد تكوين ٦-٨ ورقات حقيقية) ، وأربعة تركيزات من البورون تم إضافتهم رشاً على دفعتين حسب العمر الفسيولوجي للنبات (بعد تكوين ٦-٨ ورقات و بعد تكوين ١٠ ورقات حقيقية) وهي:

- ١- الرش بالماء بدون بورون (مقارنة).
- ٢- الرش بمحلول ٥٠ جزء في المليون بورون.
- ٣- الرش بمحلول ١٠٠ جزء في المليون بورون.
- ٤- الرش بمحلول ١٥٠ جزء في المليون بورون ، باستخدام حمض البوريك ١٧% بورون وذلك لدراسة تأثيرها على بعض صفات النمو وحاصل وجودة بنجر السكر.

تم استخدام تصميم الشرائح المتعامدة في ثلاث مكررات ، حيث احتلت مستويات مستخلص الطحالب الشرائح الرأسية بينما وزعت مستويات البورون في الشرائح الأفقية.

أوضحت النتائج ما يلي:

١- أعطى التسميد الورقي بمستخلص الطحالب بتركيز ٢,٥ جرام/لتر أو ٣,٥ جرام/لتر زيادة معنوية في متوسطات الكلوروفيل (أ) ، (ب) ، والكاروتينيدات، وقطر ووزن الجذور والأوراق الطازجة والمادة الجافة بالجذور والأوراق/نبات. ، كما زاد محتوى الأوراق من النيتروجين و البوتاسيوم والفوسفور والبورون ، والممتص من البورون في الجذور، فضلاً عن زيادة السكر المستخلص ومؤشر دليل الجودة مقارنة بالكنترول في كلا الموسمين.

٢- دلت النتائج على أن الرش بإضافة ١٠٠ جزء في المليون/بورون قد نتج عنه زيادة معنوية في قطر ووزن الجذور الطازجة والنسبة المئوية للسكر والسكر المستخلص بالجذور ، وكذلك حاصل الجذور والأوراق والسكر/فدان ، فضلاً عن زيادة محتوى البورون في أوراق وجذور بنجر السكر.

٣- أظهر التفاعل بين التسميد بمستخلص الطحالب ومستويات البورون تأثيراً معنوياً على صبغات البناء الضوئي (كلوروفيل أ) ، ومتوسط وزن الجذور/نبات في الموسمين ، وكذلك حاصل الجذور في الموسم الأول فقط ، حيث أدت التوليفة المكونة من ٣,٥ جرام/ لتر مستخلص طحالب مع ١٠٠ جزء في المليون بورون للحصول على أعلى القيمة من حاصل الجذور/ فدان (٢٧,١٣ طن/ فدان). وقد لوحظ من تداخل التفاعل بين عوامل الدراسة على هذه الصفات دوراً تكاملياً بين التسميد بمستخلص الطحالب والبورون.

وبناءً عليه توصي هذه الدراسة بتسميد بنجر السكر باستخدام التسميد الورقي بتركيز ٢,٥ أو ٣,٥ جرام/لتر من مستخلص الطحالب مع البورون بتركيز ١٠٠ جزء في المليون تحت ظروف التربة الرملية المروية بالرش.