Menoufia J. Plant Prod., Volume 9 Issue 4 (2024): 211– 228

MENOUFIA JOURNAL OF PLANT PRODUCTION

https://mjppf.journals.ekb.eg/

ALLEVIATION OF SALT STRESS ON SUGAR BEET BY NITROGEN, *SPIRULINA* ALGAE EXTRACT AND POTASSIUM SILICATE

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Received: Apr. 3 , 2024 Accepted: Apr. 20, 2024

ABSTRACT: A field experiment was conducted at Gelbana district, Sahl El-Tina (latitude of 30.57º N and longitude of 32.20º E), North Sinai Governorate, Egypt, in 2021/2022 and 2022/2023 to find out the optimal level of nitrogen fertilization and some combinations of *Spirulina platensis* extract and potassium silicate on growth, yield, and quality of sugar beet. This work included 21 treatments of three nitrogen levels and seven foliar combinations of *Spirulina* extract and potassium silicate. A complete block design in a split-plot arrangement with three replicates was used. Results indicated that fertilizing beets with 288.0 kg N ha^{-1} increased proline content, root diameter, fresh weight, root impurities, and sugar lost to molasses. Enriching beets with 230.4 and/or 288.0 kg N ha^{-1} gave the highest leaf area index, photosynthetic pigments, sucrose, extracted sugar percentages, quality index, root and sugar yields ha^{-1} in both seasons. Spraying beet tops with (3.60 g L^{-1} ha^{-1} *Spirulina* extract combined with a fixed dose of potassium silicate) resulted in a significant increase in leaf area index, photosynthetic pigments, root diameter, fresh weight, α-amino-N content, yields of root and sugar ha^{-1}. However, proline, potassium, and sodium content decreased compared to other single doses of algal extract. Application of 230.4 kg N ha^{-1} and spraying beet tops with a combination of (3.60 g L^{-1} algal extract and 7.20 cm^3 L^{-1} potassium silicate) led to a significant increase in sucrose %, quality index, root and sugar yields ha^{-1} with a reduction in sodium and potassium contents.

Key words: *Spirulina platensis* algae extract, nitrogen rates, saline soil, potassium silicate, sugar beet.

INTRODUCTION

Sugar beet is a member of the Amaranthaceae family. It is well-suited for growth in a wide range of soil types and is cultivated in newly reclaimed soils in Egypt. It can naturally tolerate salinity levels up to an electric conductivity of 7.0 dS/m in growth media without a considerable yield reduction, and each additional EC unit causes a 5.9% yield loss (Grieve *et al.*, 2012). However, it is relatively sensitive to soil salinity during the early stages of germination and seedling growth (Skorupa *et al.*, 2019). Salinization is projected to destroy up to 30% of the world's cultivated land by 2050. This will lead to reduced agricultural productivity and significant losses in economic crops. Furthermore, as highlighted by Mostafazadeh-Fard *et al.*, (2007), approximately 20% of irrigated areas globally are impacted by different degrees of salinity and sodium levels. Mineral nutrition with nitrogen and supplementation with plant-growth regulators may be one of the best-suited strategies to improve the tolerance potential of a plant to salinity. Nitrogen plays a critical role in photosynthesis and is essential for protein manufacturing in plants. In this concern, Abdou and Badawy (2014) observed that increasing nitrogen levels from 70 to 90 and 110 kg N/fed significantly increased root fresh weight, root dimensions, and root and sugar yields/fed. They added that high N availability late in the season increases foliage growth and impurities in beet plants. The highest sucrose% was recorded with 90 kg N/fed, whereas sugar

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yield was the highest with 110 kg N/fed. Additionally, El-Shal, (2016) stated that increasing the N-level to 357 kg N ha^{-1} attained a significant increase in root yield of sugar beet sown in ~~a~~ salt-affected soil. Wael *et al*., (2017) showed that increasing the N rate up to 120 kg N/fed significantly increased root fresh weight and impurities contents as well as root yield/fed and white sugar yield/fed. They added that excessive N application decreased sucrose, purity and extracted sugar percentages. At the same trend, increased shoot and root fresh weight. Elwan and Helmy (2018) revealed that raising nitrogen fertilization levels from 80 to 100 and 120 kg N/fed resulted in gradual and significant increases in root diameter, fresh weight, sugar lost to molasses%, root and corrected sugar yields/fed. Nonetheless, the quality index was decreased. The highest sucrose and corrected sugar percentages were recorded by applying 100 kg N/fed.

Potassium silicate is a source of highly soluble potassium and silicon. Silicone is favorable for plants, but it is not considered necessary. It plays a very important role in the reduction of the plant's vulnerability to biotic and abiotic environmental stress (Sacała, 2009). Aly *et al*., (2014) reported that the application of K-fertilizer at 24 kg K_2O/fed and/or 48 kg K_2O/fed as soil-side dressing of K-sulphate, along with the foliar application of K-silicate at 3 cm^3 L^{-1} were more effective and significantly increased root yield/fed by (8.19 and 10.24 % tons/fed), and sugar yield by (8.83 and 13.85% tons/fed), respectively compared to the soil application of potassium sulphate without spraying silicates. El-Kalawy, (2021) indicated that the combination between fertilizing sugar beet with 24 kg K_2O/fed and spraying with silicon at 200 ppm gave the highest values of chlorophyll a, b and total (a+b) in leaf tissues, root diameter, root fresh weight/plant and root yield/fed.

Spirulina platensis algae extract is a rich source of nitrogen and potassium, in addition to considerable amounts of Ca, Cu, Fe, Mg, Mn, P and Zn. It increases the uptake and accumulation of these elements in plants, explaining the significant increase in vegetative growth and yield components, as well as the contents of nitrogen, phosphorus, and leaf chlorophyll for most crops, especially those grown under semi-arid and desert conditions (Abd El-Mawgoud *et al*., 2010). In this regard, Enan *et al*., (2016) manifested that foliar application of alga extract using 2.5 g L^{-1} produced significantly higher values of photosynthetic pigments, *i.e.* chlorophyll a, b and carotenoids, vegetative growth traits of sugar beet plants root diameter, root and foliage fresh weights/plant, extractable sugar %, quality index, root and sugar yields/fed with a decrease in sodium content in roots.

This work aimed to investigate the effects of nitrogen fertilization in combination with spraying *Spirulina* extract and potassium silicates in mitigating salt stress, which may negatively affect the growth and quality characteristics of sugar beet grown in Gelbana, Sahl El-Tina.

MATERIALS AND METHODS

A field experiment was conducted at Gelbana district, Sahl El-Tina (latitude of 30.57º N and longitude of 32.20º E), North Sinai Governorate, Egypt, in 2021/2022 and 2022/2023 seasons to find out the optimal level of nitrogen fertilization and some combinations of *Spirulina platensis* with potassium silicate on growth, yield and quality of sugar beet (*Beta vulgaris var.* saccharifera, L.) grown in a saline soil. This work included twenty-one treatments, represent the combinations of three nitrogen levels (100%, 80%, and 60% of the recommended nitrogen requirements in this region, *i.e.* 120 kg N/fed), which is equivalent to (288.0, 230.4 and 172.8 kg N ha^{-1}) and seven combinations of *Spirulina platensis* extract (SE) with potassium silicate (KS), as follows:

1. without spraying SE or KS.
2. 1.20 g L^{-1} SE
3. 1.20 g L^{-1} SE + 7.2 cm^3 L^{-1} KS .

4. 2.40 g L^{-1} SE .
5. 2.40 g L^{-1} SE + 7.2 cm^3 L^{-1} KS .
6. 3.60 g L^{-1} SE .
7. 3.60 g L^{-1} SE + 7.2 cm^3 L^{-1} KS.

The combinations of algal culture filtrate (SE) and potassium silicates (KS) were sprayed on beet canopies thrice: after thinning and the other two ones were applied every 25-day interval.

A complete block design in a split-plot arrangement with three replications was used, where the main plots were assigned to the three levels of nitrogen, while the seven foliar combinations of SE and KS were allocated at random in the sub-plots. The sub-plot area was 25.2 m^2 including 7 ridges of 6 m in length and 60 cm in width, with 20 cm between hills. Seeds of the multi-germ sugar beet variety *viz* "Meralda" were soaked in water for 1-2 hours in a cloth bag, which was hang overnight to moisten them and enhance their germination. Then, seeds were sown in the lower part of ridges, to avoid the negative influence of salts that may appear on the top of ridges on the germinated sugar beet seedlings. Sowing seeds took place in 2nd week of September while harvesting beets was done at the age of 210 days, in both seasons. Plants were thinned twice: at age of 15 days and the appearance of 4-true leaves, to ensure one plant per hill. The studied nitrogen fertilizer levels were applied into four split-equal doses as follows: the 1st dose was added after thinning, followed by three doses given at two-week intervals after the first one in the form of (a mixture of ammonium nitrate, 33.5% N + ammonium sulphate 20.6% N) at the ratio of 50:50), as mentioned by (Enan, 2014) for fertilizing the saline soil. Potassium silicate, which contains 11% silicon and 60% K_2O, was applied as a foliar spray at a fixed rate of 3 cm^3 L^{-1}. This is equivalent to 180 g K_2O/fed or 432 g K_2O ha^{-1}, which is equal to 7.2 cm^3 ha^{-1}.

Phosphorus fertilizer was applied in the form of calcium super phosphate (15 % P_2O_5) at the rate of 480 kg ha^{-1}at seedbed preparation. Potassium fertilizer was added to the soil as potassium sulfate 48% K_2O at the rate of 60 kg ha^{-1} in two equal doses: at seedbed preparation and the other one was given with the second dose of N-fertilizer. Other recommended agricultural practices were followed as advised by the Sugar Crops Research Institute.

Algal extract preparation

The early isolated blue-green alga *Spirulina platensis* from Wadi El-Natrun, El-Beheira Governorate was scaled up to a massive scale at the Algal Biotechnology Unit, at the Algae Production Station of the National Research Centre (El-Sayed, 2004), within three open ponds (75 m^3 of a final capacity). Continuous centrifugation (Westfalia Separator) was employed for harvesting algal bulk, which contains 75-80 % moisture and then after freezing for 48 h at 25^o C., before centrifugation, the 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 room temperature, homogenized and aerobically fermented for 72 h. The fermented biomass was then homogenized and filtered till it was used. Major components of the used alga extract are shown in Table 1.

Table 1. Chemical composition of some macro and micro-nutrients of *Spirulina platensis* extract

Element	N	P	K	Mg	Ca	Na	Fe	Zn	Mn	Cu
concentration	%						mg/kg			
	11.2	1.68	1.1	0.22	0.35	0.01	1930	65	67	19

Soil samples at (0-30 cm depth) were collected from the experimental site to determine their physical and chemical properties using the method described by (AOAC, 1990), as shown in Table 2

Table 2. Particle size distribution and chemical soil properties of the experimental site in 2021/2022 and 2022/2023 seasons

Physical characteristics	Particle size distribution				Soil texture	Available nutrients (mg kg^{-1} soil)			O.M.%	*SAR %	*ESP %
	Coarse sand	Fine sand	Silt	Clay		N	P	K			
2021/2022	66.20	8.95	11.86	12.99	Sandy loam	33.0	4.40	170	0.43	13.32	15.66
2022/2023	67.30	9.00	10.30	13.40		35.0	5.10	180	0.46	15.49	17.90

Chemical characteristics	pH	EC (dS/m)	Soluble Cations (mmolc L^{-1})				Soluble Anions (mmolc L^{-1})		
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{3-}	Cl^{-}	SO_4^{2-}
2021/2022	8.10	8.01	13.79	16.00	49.50	0.81	8.93	50.50	20.67
2022/2023	7.97	8.09	11.69	15.00	53.50	0.71	9.90	52.50	18.50

* Sodium Adsorption Ration (SAR) =Na/SQRT (Ca^{+2} + Mg^{+2})/2 according to (Richards, 1954).

* Exchangeable sodium percentage (ESP%) = 1.95 + 1.03 SAR

Studied traits

Five plants were randomly collected from the middle ridges of each sub-plot at 110 days from sowing to determine the following:

1. Leaf area index (LAI): Leaf area was measured using the disk method according to Watson (1958), and then the following equation was used:

LAI = Leaf area per plant (cm^2)/plant ground area (cm^2)

2. Photosynthetic pigments *i.e.*, chlorophyll a, b, and carotenoids (mg/g leaf fresh weight) were determined according to the method described by Wettstein (1957), where:

Chlorophyll a (mg/g fresh leaf) = 9.784 (A 662) - 0.99 (A 644), Chlorophyll b (mg/g fresh leaf) = 21.426 (A 644) - 4.65 (A 662) and Carotenoids (mg/g fresh leaf) = 4.695 (A 440)- 0.268 (chl. "a"+ chl. "b").

3. Proline content in sugar beet leaves, expressed in (µg. g leaf fresh weight^{-1}) was determined using the method of Bates *et al*., (1973).

At harvest, a random sample of ten guarded plants was taken from the middle ridges of each sub plot to determine the following traits:

1. Root diameter/plant (cm).
2. Root fresh weight/plant (g).

Quality analysis was done on fresh samples of sugar beet roots at the Laboratory of Canal Sugar Company, Egypt, including the following characteristics:

3. Sucrose percentage (Pol %) was determined in fresh macerated root according to the method of Le-Docte (1927).
4. Sugar lost to molasses percentage (SLM%) was calculated according to the equation of Devillers (1988): SLM = 0.14 (Na + K) + 0.25 (α–amino N) + 0.5
5. Extracted sugar percentage (EX %) was calculated by the following equation of Dexter *et al*., (1967): EX% = sucrose % - SLM % - 0.6
6. Quality index (QI) % was calculated using the equation of Cooke and Scott (1993) as follows:
   QI = (extracted sugar % / sucrose %) x 100

Yields

1. Root yield ha^{-1} (megagram).
2. Sugar yield ha^{-1} (megagram) was calculated according to the following equation:

Sugar yield ha^{-1} (megagram) = Root yield ha^{-1} (megagram) x Extracted sugar %.

Statistical analysis

The obtained data were statistically analyzed using “Co-STATC” computer software package, to estimate the analysis of variance (ANOVA) for the split plot design as published by Gomez and Gomez (1984). The least significant difference (LSD) method was used to test the differences between treatment means at the 5% level of probability as described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

1. Leaf area index and photosynthetic pigments

The results in Table 3 show that fertilizing sugar beet plants sown in saline soil with 288.0 and or 230.4 kg N ha^{-1} significantly resulted in higher values of leaf area index (LAI), photosynthetic pigments concerning chlorophyll a, chlorophyll b and carotenoids, compared to those received 172.8 kg N ha^{-1} in both seasons. These results may be due to the role of nitrogen element in building up and enhancing plant foliage i.e. leaves area, which intercepted and utilized efficiently the solar radiation. These results are consistent with those reported by (Nemeat Alla *et al.*, 2023).

Table 3. Leaf area index and photosynthetic pigments (mg/g fresh weight) of beets as affected by nitrogen fertilizer levels, spraying a combination of algae extract and potassium silicate in the 2021/2022 and 2022/2023 seasons

Treatments	Leaf area index (LAI)		Photosynthetic pigments (mg/g f.w.)					
			Chlorophyll a		Chlorophyll b		Carotenoids	
	1st Season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
(A): Nitrogen fertilization levels (kg ha^{-1})								
172.8	2.49	2.18	3.44	3.54	1.25	1.30	0.51	0.60
230.4	2.73	3.18	4.17	4.48	1.75	1.63	0.86	0.95
288.0	2.93	3.42	4.28	4.57	1.89	1.77	0.98	0.99
LSD at 0.5%	0.24	0.22	0.21	0.18	0.23	0.32	0.23	0.12
(B): *Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)								
Without SE or KS	2.17	2.43	3.62	3.78	1.31	1.13	0.53	0.55
1.20 SE	2.38	2.58	3.69	3.92	1.40	1.29	0.64	0.65
1.20 SE + 7.20 KS	2.46	2.73	3.89	4.09	1.51	1.44	0.68	0.80
2.40 SE	2.65	2.95	4.01	4.26	1.63	1.63	0.77	0.89
2.40 SE + 7.20 KS	2.81	2.98	4.07	4.32	1.70	1.72	0.86	0.93
3.60 SE	3.12	3.08	4.14	4.43	1.81	1.80	0.96	1.02
3.60 SE + 7.20 KS	3.42	3.73	4.33	4.59	2.07	1.97	1.07	1.10
LSD at 0.5%	0.13	0.11	0.18	0.15	0.18	0.14	0.10	0.11
A x B	**	**	NS	NS	NS	NS	NS	NS

Leaf area index and photosynthetic pigments increased significantly when beets were sprayed with *Spirulina* algae extract (SE) either alone or in combination with potassium silicate (KS). Spraying beet plants with SE at the rate of 3.60 g L^{-1} resulted in higher values of (LAI), chlorophyll a, b and carotenoid contents compared to the other individual doses of (SE). Nevertheless, supplying beet canopy with a combination of 3.60 g L^{-1} (SE) ha^{-1} and 7.20 cm^3 (KS) ha^{-1} attained more distinguished and appreciable influence on these traits than the other individual or combined treatments in both seasons. The noticeable effect of (SE) on sugar beet can be attributed to its ability to increase the permeability of cell membrane, which improves the plant's efficiency in absorbing nutrients such as nitrogen, which are directly related to delaying leaf senescence by reducing the degradation of chlorophyll, as reported by (Enan *et al*., 2016). The positive effect of the foliar application of K-silicate might be associated with the role of silicon in increasing the activities of photosynthetic enzymes and chlorophyll content. Moreover, the accumulation of silicon in leaves causes their erection, which facilitates light penetration. Also, it may be due to that potassium and silicon elements, involved in K-silicate, attained a salinity mitigating effect by improving osmolytes and strengthening the enzymatic and non-enzymatic (proline and glycine betaine) antioxidant defense systems as mentioned by (Muhammad *et al*., 2014).

Interaction effect

Data in Table 4 reveal that the LAI of sugar beet plants was significantly affected by the interaction between nitrogen levels and the combination of SE and KS in both seasons. In the first one, there were insignificant differences in LAI of plants fertilized with 288.0 kg and/or 230.4 kg N ha^{-1}, when they were sprayed with (2.40 g L^{-1} SE alone), (2.40 SE+7.20 cm^3 KS), (3.60g L^{-1} SE alone) and/or left without spraying. However, when beets were sprayed with (3.60 SE+ 7.20 cm^3), (1.20 SE+7.20 cm^3 KS) and/or (1.20 g L^{-1} SE alone), fertilizing beets with 288.0 kg N ha^{-1} markedly resulted in higher records of LAI than that attained by 230.4 kg N ha^{-1}. In the second season, the differences between the same two nitrogen levels were insignificant when beets received a combination of (2.40 SE+7.20 cm^3 KS) and (3.60g L^{-1} SE alone). Nevertheless, beets sprayed with (1.20 g L^{-1} SE alone), (1.20 SE+7.20 cm^3 KS), (2.40 g L^{-1} SE alone), (3.60 SE+ 7.20 cm^3) and/or left without spraying attained the highest values of LAI when beets fertilized with 288.0 kg N ha^{-1}.

Table 4. A significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on leaf area index in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	***Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)**						
	1st season						
	Without SE and KS	**1.20 SE**	**1.20 SE+ 7.20 KS**	**2.40 SE**	**2.40 SE+ 7.20 KS**	**3.60 SE**	**3.60 SE+ 7.20 KS**
172.8	2.08	2.16	2.26	2.35	2.46	2.97	3.16
230.4	2.24	2.32	2.40	2.69	2.90	3.21	3.36
288.0	2.19	2.65	2.74	2.91	3.08	3.18	3.73
LSD at 0.5%	0.23						
2nd season							
172.8	1.78	1.99	2.11	2.23	2.29	2.39	2.47
230.4	2.61	2.65	2.88	3.21	3.29	3.38	4.22
288.0	2.91	3.09	3.19	3.41	3.35	3.48	4.52
LSD at 0.5%	0.19						

2. Proline content, root diameter and fresh weight/plant

Results revealed that proline content, root diameter and fresh weight/plant were significantly affected by different nitrogen fertilizer levels in both seasons (Table 5). Raising nitrogen fertilization levels to 230.4 and 288.0 kg N ha^{-1} supplied to sugar beet resulted in a gradual increase in proline content, compared to those fertilized with 172.8 kg N ha^{-1}. This finding suggests that the accumulation of proline in leaves is associated with tolerance to osmotic and salt stress, or that a higher nitrogen supply leads to an increase in proline content (Wang *et al.*, 2004). A Similar trend was observed concerning root diameter and fresh weight/plant, with increases amounting to (1.52 cm and 1.59 cm in root diameter) and (156.28 g and 118.45 g in root fresh weight) in comparison to that fertilized with 172.8 kg N ha^{-1}, in the 1st and 2nd season, successively. These results are mainly due to the role of N as an essential structural element in building plant organs and stimulating the meristematic growth activity, which relates to the increase in the number of cells and their enlargement, thereby increasing root diameter and fresh weight/plant (El-Sharnoby *et al.*, 2021).

Table 5. Proline content, root diameter, fresh weight/plant of beets as affected by nitrogen fertilizer levels, spraying a combination of algae extract and potassium silicate in the 2021/2022 and 2022/2023 seasons

Treatments	Proline content (µg. g leaf fresh weight^{-1})		Root diameter (cm)		Root fresh weight/plant (g)	
	1st season	2nd Season	1st Season	2nd Season	1st season	2nd season
(A): Nitrogen fertilization levels (kg ha^{-1})						
172.8	2.22	2.12	10.68	11.21	454.45	482.21
230.4	2.31	2.55	11.88	12.45	590.23	584.43
288.0	3.04	3.12	12.20	12.80	610.73	600.66
LSD at 0.5%	0.20	0.56	0.25	0.34	18.37	10.88
(B): *Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)						
Without SE or KS	3.07	3.19	10.30	11.02	438.97	481.17
1.20 SE	2.81	3.05	10.74	11.27	485.11	533.34
1.20 SE + 7.20 KS	2.72	2.85	11.69	12.19	561.63	546.81
2.40 SE	2.66	2.76	11.97	12.41	575.15	561.78
2.40 SE + 7.20 KS	2.43	2.60	12.03	12.53	584.18	573.67
3.60 SE	2.10	1.99	12.11	12.66	594.99	583.97
3.60 SE + 7.20 KS	1.87	1.74	12.30	12.97	622.57	609.64
LSD at 0.5%	0.14	0.20	0.15	0.11	11.60	10.09
A x B	NS	NS	**	**	**	**

Data in the same table show that root diameter and fresh weight/plant increased with the foliar application of *Spirulina* algae extract. However, they were thicker and heavier when combined with potassium silicate in both seasons. Otherwise, increasing the algae extract level from zero to 3.60 g L^{-1} resulted in a decrease in proline content in the leaf, which was more reduced with the fixed foliar dose of SE ha^{-1} compared to the other treatments in both seasons. The increase in root diameter and fresh weight/plant were (19.42%, 17.70%) and (41.83%, 26.70%), compared to the untreated plants in the 1st and 2nd seasons respectively. These results could be attributed to the role of *Spirulina* algae extract in promoting photosynthesis and shifting assimilated osmoregulation. Furthermore, it may be attributed to potassium silicate's role in improving plant physiological processes, reducing stress and maintaining plant water potential, stomatal conductance, and leaves under high levels of transpiration cannot be understated (Ibrahim *et al.*, 2017 and Galal *et al.*, 2022).

Interactions effect

Data in Table 6 show insignificant differences in the root diameter of plants fertilized with either 288.0 kg or 230.4 kg N ha^{-1} when they were sprayed with only 1.20 g L^{-1} SE. However, beets sprayed with (1.20 g L^{-1} SE+ 7.20 cm^3 KS), (2.40 g L^{-1} SE alone), (2.40 g L^{-1}SE+7.20 cm^3 KS), (3.60 g L^{-1} SE alone), (3.60 g L^{-1} SE+7.20 cm^3 KS) and those left without spraying and fertilized with 288.0 kg N ha^{-1} had wider root diameter compared to those enriched with 230.4 kg N ha^{-1}. In the second season, there were insignificant differences in root diameter of beets fertilized with 288.0 kg and/or 230.4 kg N ha^{-1} when they received only 2.40 g L^{-1} SE. However, fertilizing them with 288.0 kg N ha^{-1} resulted in greater values of root diameter than those fertilized with 230.4 kg N ha^{-1}. Overall, the thickest roots were obtained when the beet plants were fertilized with 288.0 kg N ha^{-1} and sprayed with 3.60 SE + 7.20 cm^3 KS ha^{-1}.

Table 6. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on root diameter in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	*Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 E+ 7.20 KS	3.60 SE	3.60SE+ 7.20 KS
172.8	9.00	10.05	10.72	11.11	11.17	11.25	11.45
230.4	10.78	11.00	12.00	12.22	12.27	12.35	12.56
288.0	11.10	11.17	12.35	12.56	12.65	12.72	12.84
LSD at 0.5%	0.27						
2nd season							
172.8	10.43	10.57	11.22	11.37	11.52	11.59	11.74
230.4	11.10	11.39	12.45	12.84	12.94	13.05	13.38
288.0	11.53	11.85	12.92	13.01	13.14	13.33	13.78
LSD at 0.5%	0.19						

The interaction between the studied factors significantly affected root fresh weight/plant in both seasons (Table 7). In the 1st season, insignificant variance was detected in root fresh weight/plant when beets were fertilized with 230.4 and/or 288.0 kg N ha^{-1} and sprayed with 1.20 g L^{-1} or left without SE and KS. However, supplying beets with 288.0 kg N ha^{-1}, combined with the other foliar treatments of SE and KS attained higher and appreciable values of root fresh weight compared to 230.4 kg N ha^{-1} with the same treatments. In the 2nd season, fertilizing beets with 288.0 kg N ha^{-1}, in combination with spraying them with (3.60 g L^{-1} SE and 3.60 g L^{-1} SE + 7.20 cm^3 KS) or left without SE or KS significantly led to getting heavier roots than those obtained by applying 230.4 kg N ha^{-1}, with the same combinations of SE and KS. Meanwhile, insignificant variance in root fresh weight/plant was observed as affected by applying 230.4 and/or 288.0 kg N ha^{-1}, combined with the other foliar treatments of SE and KS.

Table 7. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1}+ potassium silicate cm^3 L^{-1} on root fresh weight/plant in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	*Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm3 L^{-1} (KS)						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 SE+ 7.20 KS	3.60 SE	3.60 SE+ 7.20 KS
172.8	358.70	369.38	472.17	482.08	488.91	499.30	510.58
230.4	482.86	542.59	593.66	604.19	615.00	625.44	667.87
288.0	475.35	543.36	619.08	639.20	648.62	660.23	689.27
LSD at 0.5%	20.09						
2nd season							
172.8	363.56	472.33	482.63	492.44	506.80	518.55	539.18
230.4	526.15	559.90	575.00	589.81	598.62	606.37	635.16
288.0	553.80	567.80	582.79	603.10	615.59	627.00	654.57
LSD at 0.5%	17.47						

3. Sucrose% and root impurities

Root sucrose and impurities were significantly affected by the applied levels of N fertilizer in both seasons (Table 8). It was found that increasing nitrogen fertilization from 172.8 to 230.4 kg N ha^{-1} increased sucrose %. However, when the N level was raised to 288.0 kg N ha^{-1} a decrease in sucrose % was observed. These results indicate that adding 230.4 kg N ha^{-1} was the appropriate N-dose, while increasing it by 20% *i.e.,* 288.0 directed sugar beets to produce more foliage at the expense of sugar accumulation and storage in the tap roots.

On the other hand, it was observed that increasing nitrogen levels from 172.8 to 230.4 and 288.0 kg N ha^{-1} increased root impurities. These results may be due to that applying the moderate nitrogen dose (230.4 kg N ha^{-1}) in the form of ammonium nitrate and ammonium sulphate, as recommended in saline soil, led to a higher uptake of potassium than sodium, which may increase sucrose percentage due to potassium's role in the transfer of sucrose from leaves to roots as explained by (Enan, 2014), while excessive N application (288.0 kg N ha^{-1}) can enhance plant's ability to absorb more solutes from the soil solution. These findings are consistent with those reported by DeBruyn (2017) and Neamat Alla (2023).

Table 8. Sucrose% and root impurities (meq/100 g beet) as affected by nitrogen fertilizer levels, spraying a combination of algae extract and potassium silicate in the 2021/2022 and 2022/2023 seasons

Treatments	Sucrose %		Impurities (meq/100 g beet)					
			Potassium		Sodium		α-amino N	
	1st Season	2nd season	1st Season	2nd season	1st season	2nd season	1st season	2nd Season
(A): Nitrogen fertilization levels (kg ha^{-1})								
172.8	17.48	17.59	3.65	4.12	1.17	1.27	1.13	1.17
230.4	19.75	19.70	3.96	4.41	1.33	1.50	1.37	1.64
288.0	18.47	18.72	4.48	4.72	1.46	1.71	1.49	1.90
LSD at 0.5%	0.38	0.43	0.37	0.15	0.14	0.18	0.18	0.28
(B): *Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)								
Without SE or KS	18.11	18.30	5.34	6.17	1.65	1.90	1.04	1.18
1.20 SE	18.28	18.44	5.17	5.19	1.51	1.79	1.12	1.31
1.20 SE + 7.20 KS	18.38	18.53	4.90	4.81	1.37	1.65	1.24	1.52
2.40 SE	18.49	18.64	4.22	4.21	1.30	1.51	1.32	1.57
2.40 SE + 7.20 KS	18.73	18.76	3.72	3.96	1.24	1.37	1.42	1.67
3.60 SE	18.87	18.85	3.80	3.82	1.14	1.21	1.51	1.77
3.60 SE + 7.20 KS	19.10	19.16	2.05	2.76	1.05	1.03	1.66	1.95
LSD at 0.5%	NS	NS	0.21	0.20	0.10	0.15	0.10	0.17
A x B	**	**	**	**	NS	NS	NS	NS

In the same table, spraying the beet tops with *Spirulina* algae extract separately or in combination with potassium silicate resulted in a gradual decrease in potassium and sodium content in roots with a simultaneous increase in α-amino-N content in both seasons. Foliar application of the higher dose of the algal extract (3.60 g L^{-1}) decreased potassium and sodium content in roots, which was more pronounced in combination with potassium silicate than in the other combinations. The reduction of Na content in root sap may be due to the role of potassium and silicon in increasing enzyme activity and soluble solute concentration in the xylem, resulting in limited sodium adsorption by the plants (Liang, 1999). These results are consistent with those of Ahmad (2013), who found that exogenous application of potassium silicate significantly lowered Na content in wheat plants under salt stress. Contrariwise, spraying 3.60 g L^{-1} SE + 7.20 cm^3 KS significantly increased α-amino N compared to other combinations. However, the distinctions of foliar doses of algae extract alone or with potassium silicate failed to reach the significance level of their effect on root sucrose content in both seasons. These results may be due to the integration of algal extract with potassium silicate functions which contributed towards enhancing the water status of plants, boosting photosynthetic activity and reducing Na^+ uptake therefore, increasing K^+ uptake instead of sodium in saline soil as reported by by Tahir *et al.*, (2006).

Interactions effect

Data in Table 9 show that sucrose % was significantly affected by the interaction between nitrogen levels and the combination of SE and KS in both seasons. In the first season, there were insignificant differences in sucrose % in beets sprayed with (3.60 SE+7.20 cm^3 KS) and/or (2.40 SE+7.20 cm^3 KS), when they were given 288.0 kg N ha^{-1}. However, when plants were fertilized with 172.8 kg N ha^{-1} only, spraying beets with (3.60 g L^{-1} SE+7.20 cm^3 KS) markedly resulted in higher sucrose % than that recorded by applying (2.40 g L^{-1} SE+7.20 cm^3 KS). In the second season, the two spraying treatments of (1.20 g L^{-1} SE+7.20 cm^3 KS) and (without SE and KS) exhibited the same trend as interacted with the two N-doses of 172.8 and 288.0 kg N ha^{-1}, in their influence on sucrose %. These results showed the beneficial role of SE and KS combined with N-level on sucrose % in saline soil. Applying 230.4 kg N ha^{-1}, along with foliar application of 3.60 g L^{-1} SE and 7.20 cm^3 KS, directed beets towards sugar translocation at the expense of producing more foliage

Table 9. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on sucrose % in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	Spirulina algae extract g L^{-1} (SE) ha^{-1} + potassium silicate cm^3 L^{-1} (KS) ha^{-1}						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 SE+ 7.20 KS	3.60 SE	3.60 SE+ 7.20 KS
172.8	17.16	17.25	17.33	17.46	17.55	17.70	17.90
230.4	19.19	19.45	19.49	19.53	20.00	20.10	20.50
288.0	17.99	18.15	18.33	18.49	18.64	18.82	18.90
LSD at 0.5%	0.27						
2nd season							
172.8	17.21	17.35	17.43	17.52	17.62	17.76	18.24
230.4	19.24	19.47	19.58	19.68	19.97	19.92	20.22
288.0	18.45	18.51	18.58	18.72	18.87	18.86	19.02
LSD at 0.5%	0.14						

Data in Table 10 showed an insignificant difference in root potassium content between plants fertilized with 172.8 and 288.0 kg N ha^{-1} when they were left without spraying with SE and KS. However, fertilizing beets with 288.0 kg N ha^{-1}, significantly resulted in higher values of potassium in roots, compared with that fertilized with 172.8 kg ha^{-1}, under the other combinations of SE and KS, in the first season. In the second one, it was found that spraying beets with 2.40 SE and/or 3.60 SE caused insignificant differences in potassium content values in roots, of beets fertilized by 172.8 and 288.0 kg N ha^{-1}. However, the difference between these two N doses reached the level of significance under the other combinations of SE and KS.

Table 10. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on beet K content in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	*Spirulina* algae extract g L^{-1} (SE) ha^{-1} + potassium silicate cm^3 L^{-1} (KS) ha^{-1}						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 SE+ 7.20 KS	3.60 SE	3.60 SE+ 7.20 KS
172.8	5.15	4.91	4.72	3.83	2.98	2.51	1.45
230.4	5.56	5.06	4.72	4.30	3.86	2.65	1.55
288.0	5.30	5.53	5.27	4.54	4.32	3.24	3.17
LSD at 0.5%	0.36						
2nd season							
172.8	6.53	4.73	4.30	4.13	3.63	3.41	2.14
230.4	5.87	5.34	5.03	4.17	4.08	3.93	2.47
288.0	6.11	5.51	5.12	4.34	4.17	4.13	3.68
LSD at 0.5%	0.33						

4. Sugar lost to molasses, extracted sugar and quality index percentages

Sugar lost to molasses, extracted sugar and quality index percentages of sugar beet were significantly influenced by varying nitrogen levels and spraying algae extract in combination with potassium silicate in both seasons (Table 11). Increasing the N level from 172.8 kg to 288.0 kg ha^{-1} resulted in higher sugar lost to molasses % in both seasons. Nevertheless, both extracted sugar % and quality index values appreciably increased as N-dose was raised from 172.8 to 230.4 kg N ha^{-1}. Therefore, increasing the N-level to 288.0 kg N ha^{-1} reduced these two traits (Extracted sugar and quality index percentages). These results are probably referred to the same tendency of sucrose percentage (Table 8). Such effects were also noted by (Elwan and Helmy 2018).

Table 11. Some technological parameters as affected by nitrogen fertilizer levels, spraying a combination of algae extract and potassium silicate in the 2021/2022 and 2022/2023 seasons

Treatments	Sugar lost to molasses %		Extracted sugar %		Quality index %	
	1st Season	2nd season	1st Season	2nd Season	1st season	2nd season
(A): Nitrogen levels (kg ha^{-1})						
172.8	1.46	1.55	15.41	15.44	88.21	87.78
230.4	1.58	1.74	17.57	17.36	88.92	88.12
288.0	1.70	1.88	16.17	16.25	87.52	86.77
LSD at 0.5%	0.10	0.07	0.40	0.46	0.45	0.56
(B): Spirulina algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)						
Without SE or KS	1.74	1.93	15.77	15.77	87.07	86.16
1.20 SE	1.71	1.81	15.97	16.04	87.32	86.96
1.20 SE + 7.20 KS	1.69	1.79	16.10	16.14	87.53	87.13
2.40 SE	1.60	1.69	16.29	16.35	88.08	87.69
2.40 SE + 7.20 KS	1.55	1.67	16.58	16.49	88.52	87.93
3.60 SE	1.43	1.65	16.84	16.60	89.23	88.08
3.60 SE + 7.20 KS	1.35	1.52	17.15	17.05	89.76	88.94
LSD at 0.5%	NS	NS	0.17	0.11	0.22	0.31
A×B	NS	NS	NS	NS	**	**

Data in the same Table cleared those beets sprayed with a combination of 3.60 g L^{-1} SE + 7.20 cm^3 KS had the highest values of extracted sugar % and quality index %, where it exceeded those untreated by (8.75% and 8.11% in extracted sugar) and improved quality index % by (3.08% and 3.22%), in the 1st and 2nd season, respectively. These results may be due to reduced values of potassium and sodium contents recorded by applying 3.60 g L^{-1} SE + 7.20 cm^3 KS (Table 8). The impact of foliar doses of algae extract, whether administered alone or in combination with potassium silicate, failed to reach the significance level of their effect on the sugar lost to molasses content of the roots in both seasons.

Interaction effect

Data in Table 12 indicate that the quality index of sugar beet plants was significantly affected by the interaction between N levels and the combination of SE and KS in both seasons. In the case of fertilizing beets with 172.8 and/or 288.0 kg N ha^{-1}, an insignificant difference was found in the quality index % of beets left without SE and KS. Nevertheless, supplying beets with 172.8 kg N ha^{-1} resulted in higher quality index values than those recorded by applying 288.0 kg N ha^{-1} under the other combinations of SE and KS, in the 1st and 2nd seasons. These findings may explain the role of the studied treatments on trait of quality index. Fertilizing beet plants with 230.4 kg N ha^{-1}, along with foliar application of 3.60 g L^{-1} SE and 7.20 cm^3 KS, significantly improved the quality index compared to other treatments.

5. Root and sugar yields ha^{-1}

Data in Table 13 show that yields of root and sugar ha^{-1} were markedly influenced by the applied nitrogen levels in both seasons. Beets fertilized with 288.0 and/or 230.4 kg ha^{-1} (with insignificant variance between the two) produced the highest root and sugar yields ha^{-1}, compared to that applied with 172.4 kg N ha^{-1} in both seasons. The increase in root and sugar yields ha^{-1} could be due to the increase in the fresh weight of harvested individual roots (Tables 5) and sucrose % (Tables 8). These results are consistent with those found by (Elwan and helmy, 2018).

Table 12. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on quality index % for sugar beet in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	*Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 SE+ 7.20 KS	3.60 SE	3.60 SE+ 7.20 KS
172.8	86.88	87.08	87.42	88.22	88.70	89.14	90.03
230.4	87.64	88.20	88.36	88.54	89.06	89.88	90.79
288.0	86.68	86.70	86.83	87.48	87.80	88.67	88.47
LSD at 0.5%	0.38						
2nd season							
172.8	85.30	87.51	87.73	87.83	88.29	88.50	89.28
230.4	87.50	87.59	87.25	88.20	88.23	88.42	89.67
288.0	85.67	85.78	86.42	87.04	87.25	87.39	87.86
LSD at 0.5%	0.53						

Table 13. Root and sugar yields (megagram) ha^{-1} as affected by nitrogen fertilizer levels, spraying a combination of algae extract and potassium silicate in the 2021/2022 and 2022/2023 seasons

Treatments	Root yield ha^{-1} (megagram)		Sugar yield ha^{-1} (megagram)	
	1st season	2nd season	1st season	2nd season
(A): Nitrogen levels (kg ha^{-1})				
172.8	46.68	46.19	7.20	7.15
230.4	50.70	50.99	8.92	8.87
288.0	53.05	52.06	8.59	8.46
LSD at 0.5%	2.39	3.22	0.36	0.64
(B): *Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)				
Without SE or KS	46.02	44.13	7.27	6.99
1.20 SE	48.66	46.97	7.78	7.55
1.20 SE + 7.20 KS	49.15	48.55	7.92	7.85
2.40 SE	50.06	49.81	8.16	8.15
2.40 SE + 7.20 KS	50.91	51.57	8.45	8.51
3.60 SE	52.38	52.93	8.84	8.80
3.60 SE + 7.20 KS	53.82	54.26	9.25	9.26
LSD at 0.5%	1.15	1.50	0.22	0.26
A x B	**	**	**	**

As for the effect of *Spirulina* algae extract, data in the same table clear that root and sugar yields ha^{-1} were significantly and gradually increased by raising the sprayed SE level, either individually or mixed with KS. The highest root and sugar yields were produced by spraying beets with 3.60 SE + 7.20 cm^3 KS ha^{-1}, exceeding the untreated plants with SE and/or KS by (7.80 and 10.13 megagrams of roots ha^{-1}) and (1.98 and 2.27 megagrams of sugar), in the 1st and 2nd season, respectively. Meantime, an insignificant difference in root yield was detected between 1.20 g L^{-1} SE alone or 1.20 SE + 7.20 cm^3 KS ha^{-1}, in the 1st season, and (2.40 g L^{-1} SE alone) and (2.40 SE + 7.20 cm^3 KS ha^{-1}), in both seasons. Also, there was insignificant variance in sugar yield in the case of spraying beets with (1.20 g L^{-1} SE) or (1.20 SE + 7.20 cm^3 KS ha^{-1}) in the 1st season. The augmentative effect of algal extract and potassium silicate could be due to the increase in chlorophyll content in the leaves (Table 3), which promoted photosynthetic activity of the sprayed plants and led to a higher production of various metabolites, such as the accumulation of carbohydrates, dry matter in plant tissues and sucrose content (Table 8). Additionally, the stimulator effect of potassium silicate which contains silicon might be associated with silicon-decreased plant Na uptake increased potassium and consequently improved, yields (Muhammad *et al.*, 2014), which had a positive effect on the final production of root yield and consequently sugar yield ha^{-1}. These findings are in agreement with those reported by (Enan *et al.*, 2016, Aly *et al.*, 2014 and El-Fotoh *et al.*, 2020).

Interactions effect

The data in Table 14 show that the root yield ha^{-1} of the sugar beet plants in both seasons was significantly influenced by the interaction between the nitrogen levels and the combination of SE and KS. In the 1st season, there were insignificant differences between 230.4 and 288.0 kg N ha^{-1} in their effect on the harvested root yield ha^{-1}, when beets were sprayed with (2.40 SE alone) and (1.20 SE+ 7.20 cm^3 KS) ha^{-1} and between sprayed with (3.60 SE alone) or (3.60 SE+ 7.20 cm^3 KS) ha^{-1}. However, supplying beets with 288.0 kg N ha^{-1} markedly resulted in higher root yield in comparison with 230.4, in beets sprayed with the other mixtures of SE and KS. In the 2nd season, the foliar application of (1.20 g L^{-1} SE+ 7.20 cm^3 KS) ha^{-1} significantly produced higher root yield/ha than that recorded by spraying beets with (1.20 g L^{-1} SE) only along with the lowest N-dose (172.8 kg N ha^{-1}). Nevertheless, the variance in root yield as affected by supplying beets with (1.20 g L^{-1} SE alone) or (1.20 SE+ 7.20 cm^3 KS) ha^{-1} was insignificant under higher N fertilization levels (230.4 and 288.0 kg N ha^{-1}). Fertilizing the beet plants with 288.0 or 230.4 kg N ha^{-1} (with insignificant difference between them) and spraying with (3.60 g L^{-1} SE + 7.20 cm^3 KS) resulted in the highest values of root yield ha^{-1} in both seasons.

Table 14. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on root yield (Megagram ha^{-1}) of sugar beet in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	*Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 SE+ 7.20 KS	3.60 SE	3.60 SE+ 7.20 KS
172.8	43.57	46.24	46.52	46.93	47.34	47.80	48.39
230.4	46.18	49.02	49.85	50.20	50.58	53.46	55.59
288.0	48.31	50.70	51.07	53.06	54.81	55.89	57.48
LSD at 0.5%	1.99						
2nd season							
172.8	37.58	42.28	45.26	47.06	49.77	50.42	50.95
230.4	46.50	48.90	50.14	50.30	51.50	53.75	55.86
288.0	48.31	49.72	50.26	52.07	53.44	54.63	55.96
LSD at 0.5%	2.60						

Data in Table 15 manifest that sugar yield ha^{-1} was significantly influenced by the interaction between N fertilization levels and the combination of SE and KS, in both seasons. In the 1st one, fertilizing sugar beets with 230.4 kg N ha^{-1} substantially attained higher sugar yields ha^{-1} compared with those produced by applying 288.0 kg N ha^{-1}, when beets were sprayed with (1.20 SE) ha^{-1}, (1.20 SE+ 7.20 cm^3 KS) ha^{-1} and/or (3.60 SE+ 7.20 cm^3 KS) ha^{-1}, nevertheless the difference between 230.4 and 288.0 kg N ha^{-1} in their influence on sugar yield was insignificant under the other combinations of *Spirulina* algae extract and potassium silicate. The same results were obtained in the 2nd season. Fertilizing beet plants with 230.4 kg N ha^{-1} and spraying with (3.60 g L^{-1} SE + 7.20 cm^3 KS) achieved the highest sugar yield ha^{-1} in both seasons, compared to other treatments.

Table 15. Significant interaction between nitrogen levels (kg ha^{-1}) and *Spirulina* algae extract g L^{-1} + potassium silicate cm^3 L^{-1} on sugar yield (megagram ha^{-1}) of sugar beet in 2021/2022 and 2022/2023 seasons

Nitrogen fertilization levels (kg ha^{-1})	*Spirulina* algae extract g L^{-1} (SE) + potassium silicate cm^3 L^{-1} (KS)						
	1st season						
	Without SE and KS	1.20 SE	1.20 SE+ 7.20 KS	2.40 SE	2.40 SE+ 7.20 KS	3.60 SE	3.60 SE+ 7.20 KS
172.8	6.50	6.95	7.05	7.23	7.37	7.54	7.80
230.4	7.77	8.41	8.58	8.68	9.01	9.66	10.34
288.0	7.53	7.98	8.13	8.58	8.97	9.32	9.61
LSD at 0.5%	0.38						
2nd season							
172.8	5.53	6.42	6.92	7.24	7.74	7.92	8.30
230.4	7.83	8.34	8.57	8.73	8.99	9.47	10.13
288.0	7.64	7.89	8.07	8.48	8.80	9.03	9.35
LSD at 0.5%	0.44						

CONCLUSIONS

Under the conditions of the present work, fertilizing sugar beet plants at the rate of 230.4 kg N ha^{-1}, along with foliar spraying of beet tops with a mixture of (3.60 g L^{-1} ha^{-1} "Spirulina platensis" algae extract and 7.20 cm^3 of potassium silicate) led to a significant increase in sucrose %, quality index, root and sugar yields ha^{-1}, as well as low root contents of impurities (sodium and potassium).

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تخفيف الإجهاد الملحي علي بنجر السكر بإستخدام النيتروجين ومستخلص طحالب الإسبيرولينا وسليكات البوتاسيوم

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الملخص العربي

أقيمت تجربة حقلية بمنطقة جلبانة بسهل الطينة (خط طول ٣٢,٢٠ درجة شرقاً ، ودائرة عرض ٣٠,٥٧ درجة شمالاً) بمحافظة شمال سيناء، خلال موسمي ٢٠٢٢/٢٠٢١ و ٢٠٢٣/٢٠٢٢ لمعرفة المستوي الأمثل من السماد النيتروجيني والرش الورقي لبعض التوليفات من مستخلص طحالب "سبيرولينا بلاتنسيس" وسيليكات البوتاسيوم لأفضل نمو وأعلى حاصل وجودة من بنجر السكر. إشتمل هذا العمل على إحدي وعشرين معاملة تمثل التوافقات بين ثلاثة مستويات من السماد النيتروجيني (١٠٠% ، ٨٠% ، ٦٠% من متطلبات النيتروجين الموصي بها في منطقة الدراسة وهي ١٢٠ كجم نيتروجين للفدان) وهو ما يعادل (٢٨٨,٠ ، ٢٣٠,٤ ، ١٧٢,٨كجم ن/هكتار) ، وسبع توليفات رش ورقي من مستخلص سبيرولينا بلاتنسيس (SE) مع سيليكات البوتاسيوم (KS) ، على النحو التالي:

١. المقارنة (بدون رش مستخلص الطحالب ES أو سيليكات البوتاسيوم KS).
٢. ١,٢٠ جرام SE /لتر.
٣. ١,٢٠ جرام SE / لتر + ٧,٢٠ سم٣ KS / لتر.
٤. ٢,٤٠ جرام SE / لتر.
٥. ٢,٤٠ جرام / لتر + ٧,٢٠ سم٣ KS / لتر.
٦. ٣,٦٠ جرام SE / لتر.
٧. ٣,٦٠ جرام SE / لتر + ٧,٢٠ سم٣ KS / لتر.

تحت ظروف التربة الملحية تم إستخدام تصميم القطاعات الكاملة العشوائية بترتيب القطع المنشقة مرة واحدة في ثلاث مكررات.

أشارت النتائج إلي أن تسميد بنجر السكر بإضافة ٢٨٨,٠ كجم نيتروجين/هكتار أدت إلى أكبر محتوى البرولين وقطر الجذر والوزن الطازج للجذر، وشوائب الجذر والنسبة المئوية للسكر المفقود بالمولاس، وأكبر دليل لمساحة الأوراق ومحتوى الأوراق من الأصباغ الضوئية (كلوروفل أ ، كلوروفل ب ، الكاروتينات)، وأعلى حاصل جذور/هكتار - بينما أعطت إضافة ٢٣٠,٤ كجم ن/هكتار أعلى نسبة مئوية للسكروز والسكر المستخلص، ومؤشر الجودة فضلاً عن حاصل السكر/ هكتار في كلا الموسمين.

أدى رش أوراق نباتات بنجر السكر بمعدل (٣,٦٠ جم/لتر من مستخلص سبيرولينا مع ٧,٢٠ سم٣ سيليكات بوتاسيوم/لتر) إلى زيادة دليل مساحة الأوراق، وأصباغ البناء الضوئي، وقطر الجذر، والوزن الطازج للجذر، ومحتواه من الألفا-أمينو نيتروجين، وحاصلي الجذور والسكر/هكتار ، في حين انخفض محتوى البرولين بالأوراق، وكلاً من البوتاسيوم والصوديوم بالجذور مقارنة بالجرعات الفردية الأخرى من مستخلص الطحالب.

تحت ظروف هذا العمل، أدي تسميد نباتات بنجر السكر بمعدل ٢٣٠,٤ كجم نيتروجين/هكتار مع الرش الورقى بمزيج من (٣,٦٠ جم/لتر مستخلص طحالب "سبيرولينا بلاتنسيس" و ٧,٢٠ سم٣ سيليكات بوتاسيوم/لتر) إلى زيادة معنوية في نسبة السكروز وحاصلي الجذور والسكر/هكتار وإنخفاض محتويات الجذور من الشوائب (الصوديوم والبوتاسيوم).