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RESEARCH ARTICLE

Effect of algae extract foliar application and inter-row planting distances on the yield and quality of sugar beet

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Abstract Cultivation of sugar beet in the tropical and subtropical regions is rapidly growing as an important component of the sugar industry. The present study was carried out at the Agricultural Research Farm of the Delta Sugar Company, El-Hamoul, Kafr El-Sheikh, north of Egypt, in two growing seasons 2019/2020 and 2020/2021 to determine the effect of the foliar application of algae extract as a source of bio-stimulator and inter-row planting distances on the yield and quality of four sugar beet varieties. The results revealed that decreasing the inter-row planting distance (50 cm) accompanied with foliar application of algae extract has significantly promoted sucrose content, Na content, quality index%, root yield, recoverable sugar%, recoverable sugar yield and sugar loss yield, and reduced K%, α-amino-N% and sugar loss%. The multigerm variety Husam produced the highest values of sucrose content (20.17%), Na content (1.63%), quality index (82.50%), and recoverable sugar (17.86%) with sprayed of algae extracts compared to the control. Meanwhile, foliar application of algae extract to the monogerm variety Garrot produced the highest root yield (48.55 t feddan^{-1}; Feddan = 4200 m2), recoverable sugar yield (7.71 t fed^{-1}) and sugar loss yield (1.16 t fed^{-1}). In general, planting sugar beet at 50 cm inter-row distances with foliar application of algae extract resulted in the highest values of sucrose content, Na content, quality index %, root yield, recoverable sugar %, recoverable sugar yield, and sugar loss yield, and the lowest values of K %, α -amino-N %, and sugar loss %.

Keywords: *Beta vulgaris; Sustainable agricultural; Planting density; Bioinoculants; Root yield; Sugar yield*

Introduction

Sugar beet (*Beta vulgaris, L.*) is the only sucrose storing crop species that can be grown commercially in a wide variety of temperate climates (Abou-Elwafa 2011; Galal et al. 2022). However, cultivation of sugar beet in the tropical and subtropical regions is rapidly growing as an important component of the sugar industry (Balakrishnan and Selvakumar 2009; Abou-Elwafa et al. 2020). Sugar beet is considered a promising source for supplementing or replacing cane sugar production in such regions because of its ability to produce higher sugar yields in a short growing season in the newly reclaimed soils prevalent in such regions (Abo-Elwafa et al. 2013; Abo-Elwafa et al. 2006; Abou-Elwafa et al. 2020; Balakrishnan and Selvakumar 2009). Therefore, in the second half of the last century, great efforts have been made to introduce and adapt sugar beet cultivation to tropical and subtropical regions to replace or supplement cane sugar production which is dominating these regions (Abou-Elwafa 2011). It was introduced to

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the Egyptian agricultural system in the early 1980's and has acquired more importance and became the first source of refined sugar in Egypt. Planting densities are crucial for the conservation of water and the efficient use of fertilizers. It is, therefore, necessary to compare the traditional ridge planting approach with modern bed and flat planting techniques under different row geometrical distribution (Jafarnia et al. 2013). The production of the crop is expected to be highly affected by the planting method, plant density, and sowing depth. Moreover, better growth and higher yields can be obtained by two-row-bed planting technique and a plant density of 12 plants m-2 (Brar et al. 2015). Plant nutrients are the most pivotal components required for sustainable agricultural production. Producing healthy crops to fulfill the growing demands of the increasing world population is mainly depending on the kind of fertilizers applied to supply the plants with the major nutrients (Abofard et al. 2021; Gameh et al. 2020). However, in addition to it is becoming very expensive for many farmers to afford, the overuse of inorganic or mineral fertilizers has negative impacts on the environmental ecology and adversely influences human's health. Therefore, using specific preparations of living microorganisms (known as biofertilizers) as bioinoculants is believed to be the best eco-friendly substitute of inorganic or mineral fertilizers to enhance plant growth, maximize the yield potential of crop plants, manage tolerance to abiotic and biotic stresses, prevent phytopathogens attack and improve soil fertility (Fasusi et al. 2021; Kour et al. 2020). Living microorganisms are known to be potent tools for providing substantial benefits to crop plants for sustainable agricultural production. Furthermore, the beneficial microorganisms colonize the plant systems of crops (either epiphytic, endophytic or rhizospheric), and thus play a crucial role in nutrient uptake from surrounding ecosystems. The plant-associated microbes can enhance plant growth under either favorable or stressed conditions. The enhancement of plant growth occurs either via direct or indirect plant growth-promoting mechanisms such as biological nitrogen fixation, the production of different plant growth hormones, siderophores, different hydrolytic enzymes and solubilization of mineral nutrients (Yadav and Sarkar 2019; Mahanty et al. 2017; Kumari and Singh 2020).

Algae is considered as an important group of microorganisms capable of fixing atmospheric nitrogen, as well as it causes a significant increase in root growth, fresh and dry weights of roots, total biomass, yield component, photosynthetic pigments and growth-promoting hormones (Ghalab and Salem 2001). As a result of the functional activity, there is an increase in photosynthetic apparatus through raising the contents of total carbohydrates, starch, amino acids and protein (Raupp and Oltmanns 2006; Yassen et al., 2007). Algae extract, which is organic and bio-degradable in nature, is considered an important source of nutrition for sustainable agriculture, especially in the newly reclaimed soil. Chemical analysis of algae extracts has revealed the presence of a wide variety of plant growth regulators, such as auxins and cytokinins, in varying amounts (Zhang and Ervin 2004). Thus, algae extract stimulates root establishment, root elongation and promotes the vegetative growth of plants. Foliar application of algae extract has been reported to induce many positive effects, where spraying plants had led to improved crop yield and quality, increase nutrient uptake, resistance to abiotic stress conditions (Raupp and Oltmanns 2006). Extract of the Ascophyllum nodosum algae is a rich source of potassium and contains considerable amounts of Ca, Cu, Fe, Mg, Mn, P and Zn, hence it increases the 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 the contents of nitrogen, phosphorus, chlorophyll and protein in leaves most crop plants especially those grown under semi-arid and desert conditions (Abd El-Mawgoud et al. 2010; Marrez et al. 2014).

Therefore, the present study was carried out to study the effect of foliar application of algae extract as a source of bio-stimulator on the yield and quality of four sugar beet varieties under two inter-row planting distances.

Materials and methods

Plant material and field experiments

This study was carried out at the Agricultural Research Farm of the Delta Sugar Company, El-Hamoul, Kafr El-Sheikh, Egypt (31° 92′ N, 31° 14′ E, 14 m asl) across 2019/2020 and 2020/2021 growing seasons to study the effect of algae extract foliar application and inter-row planting distances on the yield and quality of four sugar beet varieties. The randomized complete block design (RCBD) in a split-split plot arrangement with three replicates was employed in this study. Two inter-row planting distances of 50 and 60 cm were allocated to the main plots. Two treatments of algae extract foliar application, i.e., the control treatment where no algae extract was applied to the plants and the application of 200 g of algae extract dissolved in an amount of 100 L of water per feddan were allocated to the sub-plots. The commercial Ascophyllum nodosum algae extract was used as a foliar application. Algae extract with 100% solubility and a pH of 8 contains 18-19% alginic acid, 45.0-55.0% organic matter, 1.0-3.0% nitrogen, 1.0-5.0% phosphorus (P_2O_5), 8-18% potassium (K_2O), and 2.0-8.0% amino acids.

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Algae extract foliar application was performed at three different time points through the growing season, i.e., at 55, 75, and 95 days after sowing. Four commercial sugar beet varieties, i.e., two monogerm seeds varieties designated as Nimaless and Garrot, and two multigerm varieties designated as Husam and Karam were Plants were grown on October 3rd, 2019 and 2020 and harvested on May 3rd, 2020 and 2021 in the first and second growing seasons, respectively. Seeds from either the monogerm and multigerm sugar beet varieties were sown by machine at the rate of one seed per hill. Recommended doses of N, P and K and all other cultural practices were performed according to locally recommended practices for sugar beet production. In brief, single super phosphate (15.5% P2O5) at a rate of 200 kg fed^{-1}. was applied during soil bed preparation. Nitrogen in the form of urea (46.5% N) at a rate of 120 kg fed^{-1}. was applied in two equal doses, i.e., the first one after 45 days from the sowing, and the second one was applied 30 days later. Potassium sulfate (50% K2O) at the rate of 100 kg fed^{-1}. was added with the first irrigation. Other agronomical practices were performed as locally recommended for sugar beet cultivation and production. The preceding crop was rice in both seasons.

allocated to the sub-sub plots in both growing seasons. The plot area in the case of 50 cm row width was (32.00 m2), including eight rows, each of 8 m long. Meanwhile, in the case of 60 cm row width, the plot area was (33.60 m2), including seven rows, each of 8 m long.

Soil analysis of the experimental sites

Composite represented soil (0-30 cm) samples were randomly collected from the experimental sites before sowing and after harvest and prepared for both physical and chemical analyses. Samples were air-dried, ground and finally were sieved using 2 mm sieves to determine the physical and chemical properties. Mechanical analysis was determined according to the international pipette method (Piper 1950). Soil pH was measured in (1: 2.5) soil: water suspension using HannapH-meter (Jackson 1967). Total soluble salts were determined by measuring the electrical conductivity (ECe) by electrical conductivity meter (EC meter model consort 410) in saturation extract of soil in dS/ m, United States Salinity Laboratory staff (Richards 1954). Total carbonates were determined using Collins calcimeter (Dexter et al. 1967). Organic matter was determined by walkley and Blacks method (Hesse and Hesse 1971). The basic physical and chemical properties of the experimental soils are presented in Table 1.

Table 1. Basic physical and chemical properties of the experimental soils in 2019/20 and 2020/21 growing seasons.

variable	2019/2020 growing season		2020/2021 growing season	
	Before planting	Post - harvest	Before planting	Post - harvest
Physical properties				
Sand %	24.50	26.29	25.23	26.44
Silt %	22.55	23.43	21.51	22.63
Clay %	52.56	50.33	51.79	49.80
Texture class	Clay	Clay	Clay	Clay
Chemical analysis				
Soil pH (1:2.5 susp.)	8.10	8.03	8.40	7.95
EC (dS m^{-1})	5.61	5.32	5.33	5.01
Organic matter %	1.32	1.24	1.41	1.19
Available N ppm	16.75	16.10	16.82	16.30
Available P ppm	10.40	10.23	10.51	10.21
Available K ppm	376	357	373	352
Soluble cations (meq L^{-1})				
Ca++	5.20	5.63	5.19	5.39
Mg++	6.47	7.02	6.25	7.00
Na+	45.10	41.51	45.03	40.93
K+	1.32	1.15	1.47	1.24
Soluble anions (meq L^{-1})				
HCO^{-}_{3}	3.74	3.54	3.65	34.70
Cl^{-}	32.12	29.89	31.67	29.50
SO^{-}_{4}	15.04	13.34	14.98	14.00
CO^{-}_{3}	0.00	0.00	0.00	0.00

Phenotypic evaluation

At harvest, the central area of each plot was employed to root yield. In the case of 50 cm intra-row spacing, the plot was considered as the 6 inner rows of 7 m in length to yield an area of 21 m^2. Meanwhile, in the case of 60 cm intra-row spacing, the plot was considered as the 5 inner rows of 7 m in length to yield the same plot area of 21 m^2. A representative root sample of about 20 kg of roots from each plot was used for juice quality analysis by measuring sucrose%, potassium (K)%, sodium (Na)% and α-amino-N% in the root juice. Root juice quality parameters were estimated using the venma, Automation BV AnalyzerIIG-16-12-99, 9716JP/ Groningen/Holland at Delta Sugar Company Limited Laboratories according to the procedure used by Le Docte (1927) and Brown and Lilland (1964). Quality index, sucrose losses%, and sugar loss yield were calculated using the following equations according to Reinefeld et al. (1974).

The following yield, yield related and quality traits were estimated:

1. Root and yield (t fed^{-1}): 210 days after sowing, plants from the inner rows of each subplot (21.0 m^2) were harvested, topped and cleaned to determine root yield as ton fed^{-1} on the fresh weight basis.
2. Sucrose content (Pol%).
3. Sodium content (Na%).
4. Potassium content (K%).
5. α-amino-N (%).
6. Quality index (Qz%), was calculated according to the following formula:
$$\text{Quality}\,\% = Pol\% - 0.29 + 0.343\,(K + Na) + 0.0939(\alpha - amino\ N)x100/Pol\%$$
7. Recoverable sugar (RS%), was calculated according to the following formula:
$$\text{Sugar recovery}\% = Pol - 0.29 - 0.343(K + Na) - 0.094(\alpha - amino\ N)$$
8. Sugar losses (SL%), was calculated according to the following formula:
$$\text{Sugar loss}\% = 0.343(K + Na) + 0.094(\alpha - amino\ N) + 0.29$$
9. Recoverable sugar yield (RSY; t fed^{-1}).
10. Sugar loss yield (SLY; t fed^{-1}).

Statistical analysis:

The Proc Mixed of SAS 130 package version 9.2 was used to perform analysis of variance (ANOVA) and Fisher's least significant difference (LSD) of significantly differed treatments.

Results and Discussion.

Effect of algae extract foliar application and inter-row planting distances on sugar beet juice quality parameters

Algae extracts are a rich wellspring of potassium and contain impressive amounts of Ca, Cu, Fe, Mg, Mn, P and Zn, consequently, it expands the intake and accumulation of these elements in plants. In most arable crops, optimal plant population supplemented with some agronomical practices such as foliar application of algae extracts has been found to improve potential yield and bio-fortification. The analysis of variance for the effects of inter-row, algae extract foliar applications, varieties and their interactions on sugar beet yields and quality parameters is shown in Table 2. Except for the effect of inter-row on sucrose content and Na% in both growing seasons, ANOVA exhibited significant effects of all the studied factors on all evaluated traits either in one or both growing seasons. These findings confirm the previous assumptions about the effects of inter-row planting distances, foliar application of algae extracts and the genetic background of the varieties used in this study.

Sucrose content, Na% and recoverable sugar% were significantly reduced in response to increasing the inter-row planting distance from 50 to 60 cm (Table 3). Meanwhile, K%, and α-amino-N% were significantly increased as the inter-row planting distance was increased from 50 to 60 cm (Table 3). Planting sugar beet at an inter-row distance of 50 cm resulted in the highest sucrose contents of 18.48 and 17.89% in the first and second growing seasons, respectively, which is significantly higher than the values resulted from planting sugar beet at an inter-row distance of 60 cm (18.38 and 17.70% in the first and second growing seasons, respectively). These results might be due to that optimal structure of plants canopy is associated with enhanced canopy photosynthetic capacity and thereby higher crop yield. The best crop canopy structure is mainly depending on the spatial arrangement of the crop plants which is associated with yield, besides morphological and functional combinations that influence light interception and distribution and increase light-energy absorption (Feng et al. 2016).

Table 2. Analysis of variance for inter-row planting distances, algae extract foliar application, varieties and their interactions on evaluated traits in 2019/2020 and 2020/2021 growing seasons

S.O.V.	d.f.	Sucrose%		Na%		K%		α-amino-N%		Qz%	
		2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Blocks	2	0.027ns	0.3181ns	0.011ns	0.001ns	0.022ns	0.238ns	0.001ns	0.002ns	0.057ns	3.503ns
Inter-row distance (R)	1	0.139ns	0.443ns	0.034ns	0.003ns	0.288*	1.628ns	0.0913**	0.022ns	0.288ns	24.47ns
Main plot error	2	0.039	0.072	0.005	0.001	0.008	0.031	1.333	0.001	0.013	0.368
Algae extract (A)	1	13.28**	27.62**	0.212**	0.482**	4.738**	12.98**	0.010ns	0.251**	105.67***	272.13***
RXA	1	0.001ns	0.067ns	0.001ns	0.017ns	0.411**	0.095ns	0.0133ns	0.019**	4.356**	2.59ns
Sub plot error	4	0.018	0.039	0.004	0.001	0.007	0.009	0.003	0.001	0.018	0.231
Varieties (V)	3	15.58**	1.336**	0.352**	0.094**	2.148**	0.743**	0.133**	0.012*	54.04***	14.02***
R×V	3	0.009ns	0.505ns	0.001ns	0.003ns	0.063ns	0.108ns	0.119**	0.030**	0.986	1.647ns
A×V	3	0.162**	0.058ns	0.008ns	0.001ns	0.224**	0.054ns	0.238**	0.002ns	3.960***	1.003ns
R×A×V	3	0.004ns	0.067ns	0.003ns	0.003ns	0.067ns	0.059ns	0.015**	0.011*	0.824*	0.63ns
Error	24	0.029	0.024	0.003	0.001	0.026	0.004	0.001	0.001	0.036	0.073

Table 2 cont.

S.O.V.	d.f.	RY		RS%		SL%		RSY		SLY	
		2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Blocks	2	0.01ns	3.626*	0.011ns	0.164ns	0.002ns	0.006ns	0.015*	0.144ns	0.001ns	0.002ns
Inter-row distance (R)	1	24.36**	39.79**	0.269*	0.778ns	0.023*	0.035ns	0.385**	0.843ns	0.044*	0.009ns
Main plot error	2	0.14	0.012	0.008	0.065	0.001	0.001	1.002	0.037	0.001	0.001
Algae extract (A)	1	283.4**	449.6**	20.24**	41.91**	0.542**	1.411***	20.49**	26.29**	0.010**	0.009**
R×A	1	0.301*	0.255ns	0.001ns	0.089ns	0.001ns	0.005ns	0.017ns	0.044ns	0.001ns	0.001ns
Sub plot error	4	0.03	0.056	0.008	0.059	0.001	0.001	0.004	0.024	0.001	0.001
Varieties (V)	3	374.9**	483.0**	18.05**	1.941**	0.225**	0.066***	2.982**	8.406**	0.291**	0.298**
R×V	3	3.85**	1.314ns	0.059**	0.532ns	0.009ns	0.002ns	0.175**	0.141ns	0.0013ns	0.002ns
A×V	3	1.194**	9.171**	0.311**	0.047ns	0.044**	0.002ns	0.099**	0.198ns	0.016**	0.005**
R×A×V	3	2.004**	0.111ns	0.008ns	0.099ns	0.008ns	0.003ns	0.065**	0.159ns	0.003**	0.001ns
Error	24	0.071	0.139	0.006	0.033	0.004	0.001	0.005	0.013	0.001	0.001

*, ** and ns denote significant, highly significant and non-significant effects, respectively.

Increasing inter-row planting distance from 50 to 60 cm significantly decreased quality index (Qz)% and recoverable sugar (RS)% in both growing seasons (78.91 and 78.83% and 15.92 and 15.37% under 50 cm, compared to (78.75 and 77.40% and 15.87 and 15.13% under 60 cm). The observed reduction in RS% and RSY in response to increasing the inter-row planting distance could be attributed to the higher effect of inter-row planting distances on sucrose content compared to its effect on root weight. These results are in accordance with Brar et al. (2015) and Bayat et al. (2019).

Table 3. Mean values of all studied traits of two inter-row planting distances in 2019/2020 and 2020/2021 growing seasons.

Trait	Growing season	Inter-row planting distance		$LSD_{0.05}$
		50 cm	60 cm	
Sucrose%	2019/2020	18.48	18.38	0.25
	2020/2021	17.89	17.70	0.33
Na%	2019/2020	1.43	1.38	0.09
	2020/2021	1.32	1.31	0.02
K%	2019/2020	4.84	5.00	0.11
	2020/2021	4.82	5.19	0.22
α-amino-N%	2019/2020	1.30	1.39	1.43
	2020/2021	1.38	1.42	0.02
Qz%	2019/2020	78.91	78.75	0.14
	2020/2021	78.83	77.40	0.75
RY (t fed^{-1})	2019/2020	41.40	39.98	0.467
	2020/2021	37.76	35.94	0.13
RS%	2019/2020	15.92	15.87	0.11
	2020/2021	15.38	15.13	0.32
SL%	2019/2020	2.53	2.57	0.03
	2020/2021	2.51	2.56	0.02
RSY (t fed^{-1})	2019/2020	6.52	6.34	1.24
	2020/2021	5.72	5.46	0.24
SLY (t fed^{-1})	2019/2020	1.00	1.06	0.04
	2020/2021	0.91	0.95	0.01

Foliar application of algae extract exhibited significant and highly significant effects on all studied traits (Table 4). Foliar application of algae extract has significantly promoted sucrose content, Na%, quality index%, recoverable sugar%, and reduced K%, α-amino-N%. The foliar application of algae extract resulted in 5.60 and 8.19% increase in sucrose content compared to the control treatment in the first and second growing seasons, respectively. However, Na content in the beet root juice was up to 8.84 and 14.18% enhanced in the first and second growing seasons, respectively. The control treatment was superior in K and α-amino-N contents in the beet root juice, where the lowest values of both traits of 4.61 and 4.49%, and 1.33 and 1.33% in the first and second growing seasons, respectively. This reduction in K and α-amino-N contents in response to the foliar application of algae extract led to 7.86 and 11.55% increase in the recoverable sugar%, 77.34 and 80.31% increase in quality index%, compared to the control treatment in the first and second growing seasons, respectively.

The observed promotive effects of algae extract could be attributed to its ability to increase cell layer penetrability and plant production by retaining nutrients such as nitrogen, which has a direct effect on leaf chlorophyll fixation. Green growth concentration may also play a role in delaying the maturation of leaves by reducing chlorophyll debasement. Similarly, algae extract acts as a bio-controller in plants, altering the balance of photosynthesis and respiration (Yassen et al. 2007; Enan et al. 2016).

Table 4. Mean values of all studied traits of foliar application of algae extract in 2019/2020 and 2020/2021 growing seasons

Trait	Growing season	Algae extract		$LSD_{0.05}$
		Control	Sprayed	
Sucrose%	2019/2020	17.90	18.96	0.11
	2020/2021	17.03	18.55	0.16
Na%	2019/2020	1.34	1.47	0.05
	2020/2021	1.21	1.41	0.02
K%	2019/2020	5.24	4.61	0.07
	2020/2021	5.53	4.49	0.08
α-amino-N%	2019/2020	1.36	1.33	0.04
	2020/2021	1.47	1.33	0.02
Qz%	2019/2020	77.34	80.31	0.11
	2020/2021	75.74	80.50	0.39
RY (t fed^{-1})	2019/2020	38.26	43.12	0.14
	2020/2021	33.79	39.91	0.19
RS%	2019/2020	15.25	16.55	0.07
	2020/2021	14.32	16.19	0.02
SL%	2019/2020	2.66	2.45	0.03
	2020/2021	2.71	2.37	0.01
RSY (t fed^{-1})	2019/2020	5.78	7.08	0.05
	2020/2021	4.85	6.33	0.12
SLY (t fed^{-1})	2019/2020	1.02	1.05	0.02
	2020/2021	0.92	0.95	0.02

The four evaluated varieties exhibited significant and highly significant variations in all studied traits in both growing seasons (Table 5). The multigerm variety Husam produced the highest values of sucrose content (19.80 and 18.23%), quality index (81.74 and 79.37%) and recoverable sugar % (17.44 and 15.75%), and the lowest K content (4.35 and 4.79%), in the first and second growing seasons, respectively. Meanwhile, the variety Nimaless produced the lowest values of sucrose content (17.28 and 17.46%), quality index (76.68 and 76.93%) and recoverable sugar% (14.64 and 14.84%), and the highest K content (5.31 and 5.21%) in the first and second growing seasons, respectively (Table 5).

Table 5. Mean values of all studied traits of four different varieties in 2019/2020 and 2020/2021 growing seasons.

Trait	Growing season	Variety				$LSD_{0.05}$
		Nimaless	Garrot	Husam	Karam	
Sucrose%	2019/2020	17.28	17.74	19.80	18.89	0.15
	2020/2021	17.46	17.85	18.23	17.63	0.22
Na%	2019/2020	1.24	1.27	1.58	1.53	0.07
	2020/2021	1.24	1.23	1.40	1.38	0.02
K%	2019/2020	5.31	4.86	4.35	5.17	0.10
	2020/2021	5.21	4.98	4.70	5.04	0.11
α-amino-N%	2019/2020	1.36	1.22	1.48	1.32	0.06
	2020/2021	1.41	1.41	1.45	1.47	0.03
Qz%	2019/2020	76.68	78.72	81.74	78.19	0.15
	2020/2021	76.93	78.60	79.37	77.57	0.54
RY (t fed^{-1})	2019/2020	44.85	46.16	35.66	36.08	0.20
	2020/2021	42.15	42.52	30.96	31.77	0.27
RS%	2019/2020	14.64	15.25	17.44	16.26	0.10
	2020/2021	14.84	15.39	15.75	15.03	0.28
SL%	2019/2020	2.64	2.71	2.38	2.58	0.04
	2020/2021	2.60	2.76	2.48	2.50	0.01
RSY (t fed^{-1})	2019/2020	6.57	7.04	6.23	5.88	0.07
	2020/2021	6.28	6.35	4.89	4.84	0.18
SLY (t fed^{-1})	2019/2020	1.16	1.17	0.84	0.96	0.02
	2020/2021	1.09	1.10	0.77	0.83	0.02

The superiority of the varieties Garrot and Husam in these yield and quality traits could be ascribed to the genetic makeup of the two varieties. These findings are in accordance with earlier results reported by Refay (2010).

Table 6 represents the effect of the interaction between inter-row planting distances and the foliar application of algae extract on the studied traits. Decreasing the inter-row planting distance accompanied with foliar application of algae extract produced the desirable values of most of the studied traits. Cultivated sugar beet plants at 50 cm inter-row planting distance sprayed with algae extract produced the lowest K (4.45 and 4.25%) and α-amino-N (1.27 and 1.33%) contents in the beet root juice and the highest values of quality index% (80.69 and 81.44%), in the first and second growing seasons, respectively. However, the highest values of sucrose content (19.10 and 18.62% in the first and second growing seasons, respectively) resulted from plants grown at 60 cm inter-row distances and sprayed with algae extract. Meanwhile, sugar beet plants cultivated at 60 cm inter-row distances without foliar application of algae extract exhibited the highest K (5.32 and 5.67%) and α-amino-N (1.39 and 1.51%) contents in the beet root juice, the lowest quality index% (76.17 and 75.25%), and recoverable sugar% (15.12 and 14.23%), in the first and second growing seasons, respectively. However, the highest values of sucrose content (19.10 and 18.62% in the first and second growing seasons, respectively) resulted from plants grown at 60 cm inter-row distances and sprayed with algae extract. Meanwhile, sugar beet plants cultivated at 60 cm inter-row distances without foliar application of algae extract exhibited the highest K (5.32 and 5.67%) and α-amino-N (1.39 and 1.51%) contents in the beet root juice, the lowest quality index% (76.17 and 75.25%), and recoverable sugar% (15.12 and 14.23%), in the first and second growing seasons, respectively. Narrower rows appear to provide higher root yields and recoverable sugar by compensating for poor plant establishment (Anonymous 1995). The obtained results are in agreement with those recorded by Enan et al. (2016) and Hossam et al. (2021).

The data presented in Table 7 showed that varieties responded differently to inter-row planting distances. The data revealed some fascinating insights: Firstly, the estimated values of some evaluated traits, i.e., sucrose content, Na% and recoverable sugar%, at narrower inter-row planting distances (50 cm) were higher than that evaluated under the wider inter-row planting distances (60 cm). The root weight of sugar beet plants appears to be lower under 50 cm inter-row planting distances compared to 60 cm inter-row planting distances, as the fibers appear to be low, and the sucrose content would directly increase. Meanwhile, the estimated values for the wider inter-row distances (60 cm) were higher than the narrower inter-row distances (50 cm) in three traits, i.e., K% and α-amino-N%. Second, under both inter-row planting distances, the multigerm variety Husam produced the highest values of sucrose content (19.83 and 18.58%), quality index% (81,77 and 80,30%) and recoverable sugar% (17.69 and 16.14%), and the lowest values of K content (4.27 and 4.55%) when cultivated at narrower inter-row distances of 50 cm in the first and second growing season, respectively.

Thirdly, the monogerm variety Garrot planted at 50 cm inter-row distance resulted in the lowest values of α-amino-N content in the beet root juice (1.11 and 1.31%) in both growing seasons. Meanwhile, the lowest values of Na content in the beet root juice (1.23 and 1.21%) were produced from the variety Nimaless under 60 cm inter-row planting distance, the same variety gave the lowest values of quality index (76.59 and 76.58%) under 60 cm inter-row planting distances.

Table 6. Mean values of all studied traits as affected by the interaction between inter-row planting distances and algae extract foliar application in the 2019/2020 and 2020/2021 growing seasons

Trait	Inter-row distance	50 cm		60 cm		$LSD_{0.05}$
	Algae extract	Control	Sprayed	Control	Sprayed	
Sucrose%	2019/2020	17.85	18.90	17.96	19.01	0.15
	2020/2021	17.09	18.48	17.18	18.62	0.22
Na%	2019/2020	1.36	1.50	1.37	1.54	0.07
	2020/2021	1.24	1.40	1.29	1.42	0.02
K%	2019/2020	5.25	4.44	5.32	4.78	0.10
	2020/2021	5.39	4.26	5.67	4.72	0.11
α-amino-N%	2019/2020	1.33	1.27	1.39	1.38	0.06
	2020/2021	1.43	1.33	1.51	1.33	0.03
Qz%	2019/2020	77.12	80.69	76.17	79.93	0.15
	2020/2021	76.22	81.44	75.25	79.55	0.54
RY (t fed^{-1})	2019/2020	38.89	43.91	37.63	42.33	0.20
	2020/2021	34.63	40.89	32.95	38.93	0.27
RS%	2019/2020	15.37	16.67	15.12	16.42	0.10
	2020/2021	14.40	16.36	14.23	16.02	0.28
SL%	2019/2020	2.68	2.42	2.53	2.47	0.04
	2020/2021	2.69	2.33	2.72	2.40	0.01
RSY (t fed^{-1})	2019/2020	5.85	7.19	5.71	6.98	0.07
	2020/2021	5.01	6.43	4.69	6.23	0.18
SLY (t fed^{-1})	2019/2020	1.05	1.08	0.99	1.01	0.02
	2020/2021	0.93	0.96	0.90	0.93	0.02

Table 7. Mean values of all studied traits as affected by the interaction between inter-row planting distances and sugar beet varieties in 2019/2020 and 2020/2021 growing seasons.

Trait	Inter-row distance	50 cm				60 cm				$LSD_{0.05}$
	Variety	Nimaless	Garrot	Husam	Karam	Nimaless	Garrot	Husam	Karam	
Sucrose%	2019/2020	17.36	17.86	19.83	18.95	17.21	17.62	19.78	18.83	0.20
	2020/2021	17.61	17.90	18.58	17.76	17.30	17.81	17.88	17.50	0.19
Na%	2019/2020	1.26	1.30	1.61	1.55	1.23	1.24	1.54	1.50	0.07
	2020/2021	1.27	1.24	1.49	1.38	1.21	1.23	1.31	1.38	0.03
K%	2019/2020	5.29	4.84	4.27	4.99	5.35	4.88	4.44	5.34	0.19
	2020/2021	5.12	4.67	4.55	4.95	5.50	5.29	4.85	5.12	0.07
α-amino-N%	2019/2020	1.35	1.12	1.34	1.29	1.36	1.33	1.62	1.24	0.04
	2020/2021	1.31	1.31	1.33	1.42	1.51	1.41	1.35	1.42	0.02
Qz%	2019/2020	76.66	78.53	81.77	78.67	76.59	78.90	81.70	77.71	0.23
	2020/2021	77.28	79.72	80.30	78.02	76.58	77.48	78.44	77.12	0.32
RY (t fed^{-1})	2019/2020	45.05	46.80	36.15	37.60	44.65	45.52	35.17	34.57	0.32
	2020/2021	43.22	43.72	31.40	32.70	41.08	41.32	30.52	30.83	0.45
RS%	2019/2020	14.61	15.13	17.69	16.26	14.68	15.37	17.59	16.25	0.10
	2020/2021	14.93	15.47	16.14	15.18	14.75	15.31	15.35	14.88	0.22
SL%	2019/2020	2.67	2.53	2.43	2.67	2.69	2.53	2.44	2.69	0.07
	2020/2021	2.59	2.43	2.44	2.58	2.63	2.49	2.53	2.62	0.03
RSY (t fed^{-1})	2019/2020	6.58	7.09	6.27	6.14	6.57	7.00	6.19	5.61	0.09
	2020/2021	6.39	6.38	5.09	5.07	6.17	6.36	4.69	4.61	0.14
SLY (t fed^{-1})	2019/2020	1.20	1.18	0.87	1.00	1.13	1.13	0.81	0.92	0.02
	2020/2021	1.11	1.05	0.76	0.86	1.08	1.02	0.77	0.80	0.04

The superiority of a specific sugar beet variety in particular traits may be attributed to its genetic made-up. These results are in agreement with earlier findings (Abu-Ellail et al. 2019; Mekdad 2012; Sahar and Salem 2016). These obtained results are more logical due to the availability of all the required factors for the growth and development of sugar beet plants.

The effects of the interaction between foliar application of algae extract and the four varieties on the evaluated traits are presented in Table 8. Except for K and α-amino-N contents in the beet root juice, the evaluated traits were significantly increased in response to the foliar application of algae extract in both growing seasons. These results could be attributed to that spraying sugar beet plants with algae extract resulted in higher values of photosynthetic pigments and root thickness as well as the fresh weight of leaves and roots compared to control. Moreover, the multigerm variety Husam sprayed with algae extract produced the highest values of sucrose content (20.17 and 19.06%), quality index (82.50 and 81.85 %) and recoverable sugar % (17.86% and 16.75%), and the lowest values of K (4.19 and 4.15%) and α-amino-N (1.21 and 1.30%) contents and sugar loss % (2.34 and 2.32%), while produced the highest undesirable value of Na content (1.63 and 1.50%) in the first and second growing seasons, respectively. The variety Nimaless under the control treatment produced the lowest values of all studied traits except for Na content that was produced from the variety Husam under foliar application of algae extract in both growing seasons (Table 8). The superiority of a sugar beet variety in specific traits seems to likely rely on its genetic constitution. These findings are consistent with earlier findings (Abu-Ellail et al. 2019).

Table 9 shows the effects of the interaction between the four evaluated verities, inter-row planting distances and the foliar application of algae extract on five sugar beet quality parameters (sucrose content, Na%, K%, α-amino-N% and quality index %). The highest sucrose contents (20.30 and 19.52%), the highest quality index values (82.48 and 82.88%) and the lowest K contents (4.09 and 4.00%), in the first and second growing seasons respectively, were produced from the variety Husam cultivated at 50 cm inter-row planting distances under foliar application of algae extract. Meanwhile, the lowest values of Na contents (1.14 and 1.11%) resulted from the variety Garrot planted at 60 cm inter-row distances under the control treatment in both growing seasons, whereas planting the same variety at 50 cm inter-row distances under foliar application of algae extract resulted in the lowest and α-amino-N contents (0.99 and 1.19%) in both growing seasons.

Effect of algae extract foliar application and inter-row planting distances on root and recoverable sugar yields.

In most arable crops, optimal plant population supplemented with some agronomical practices such as, foliar application of algae extracts, has been found to improve potential yield and biofortification. The analysis of variance (ANOVA) for the effects of inter-row, algae extract foliar applications, varieties and their interactions on sugar beet yield and recoverable sugar yield traits is shown in Table 2. The analysis of variance exhibited significant effects of all the studied factors on root (RY) and recoverable sugar (RSY) yields either in one or both growing seasons.

Root and recoverable sugar yields were significantly reduced in response to increasing the inter-row planting distance from 50 to 60 cm (Table 3). The highest values of RY (41.40 and 37.76 t fed^{-1} in the first and second growing seasons, respectively) were produced from cultivating sugar beet at 50 cm inter-row planting distance compared to planting at 60 cm inter-row distance (39.98 and 35.94 t fed^{-1} in the first and second growing seasons, respectively (Table 3). These results could be a consequence of varying proportions of nutrients, water and other growth elements being used. The findings are consistent with those of Hilal (2010) and Ferweez et al. (2010). These results might be due to that the optimal structure of plants canopy is associated with enhanced canopy photosynthetic capacity and thereby higher crop yield. The best crop canopy structure is mainly depending on the spatial arrangement of the crop plants which is associated with yield, besides morphological and functional combinations that influence light interception and distribution and increase light-energy absorption (Feng et al. 2016). Likewise, recoverable sugar yield was reduced from 6.52 and 5.72 to 6.34 and 5.46 t fed^{-1} by increasing the inter-row planting distance from 50 to 60 cm in the first and second growing seasons, respectively (Table 3). The observed reduction in RSY in response to increasing the inter-row planting distance could be attributed to the higher effect of inter-row planting distances on sucrose content compared to its effect on root weight. These results are in accordance with Brar et al. (2015) and Bayat et al. (2019).

Foliar application of algae extract exhibited significant and highly significant effects on RY and RSY (Table 4). The higher RY produced from the foliar application of algae extract (43.12 and 39.91 t fed^{-1} in the first and second growing seasons, respectively) in combination with the high recoverable sugar% resulted in higher recoverable sugar yield (7.08 and 6.33 t fed^{-1} in the first and second growing seasons, respectively). The potential of algal extract to boost cell layer penetrability and plant output by retaining nutrients such as nitrogen, which has a direct effect on leaf chlorophyll fixation, could explain its evident favorable benefits. Green growth concentration could potentially help to delay leaf maturation by lowering chlorophyll debasement. Similarly, algae extract functions as a bio-controller in plants, affecting photosynthesis and respiration balance (Yassen et al. 2007; Enan et al. 2016).

The four evaluated varieties exhibited significant and highly significant variations in all studied traits in both growing seasons (Table 5). The variety Garrot produced the highest RY of 46.16 and 42.52 t fed^{-1} with the lowest Na and α-amino-N which led to the production of the highest recoverable sugar yields of 7.04 and 6.35 t fed^{-1} in the first and second growing seasons, respectively. On the other hand, the lowest RY values accompanied with the highest Na and α-amino-N contents which led to the lowest RSY in both growing seasons (Table 5). The superiority of the variety Garrot in the yield traits could be ascribed to the genetic makeup of the two varieties. These findings are in accordance with earlier results reported by Refay (2010).

The influence of the interaction between inter-row planting distances and the foliar application of algal extract on RY and RSY is shown in Table 6. Decreasing the inter-row planting distance accompanied with foliar application of algae extract produced the desirable values of RY and RSY. Cultivated sugar beet plants at 50 cm inter-row planting distance sprayed with algae extract produced the highest values of RY (43.91 and 40.89 t fed^{-1}) and RSY (7.19 and 6.43 t fed^{-1}) in the first and second growing seasons, respectively. Meanwhile, sugar beet plants cultivated at 60 cm inter-row distances without foliar application of algae extract produced the lowest values of RY (37.63 and 32.95 t fed^{-1}) and RSY (5.71 and 4.69 t fed^{-1}) in the first and second growing seasons, respectively. By compensating for poor plant establishment, narrower rows tend to give higher root and recoverable sugar yields (Anonymous 1995). Moreover, Rice (1999) found that root and sugar yields were decreased in response to planting at wider rows. The findings are consistent with those of Enan et al. (2016) and Hossam et al. (2021).

The data presented in Table 7 showed that varieties responded differently to inter-row planting distances. The data showed that the measured values of RY and RSY at narrower inter-row planting distances (50 cm) were higher than that estimated under the wider inter-row planting distances (60 cm). Moreover, the monogerm variety Garrot planted at 50 cm inter-row distance resulted in the highest values of RY (46.80 and 43.72 t fed^{-1}) and RSY (7.09 and 6.38 t fed^{-1}) in both growing seasons. These obtained results are more logical due to the availability of all the required factors for the growth and development of sugar beet plants.

Table 8. Mean values of all studied traits as affected by the interaction between algae extract foliar application and sugar beet varieties in 2019/2020 and 2020/2021 growing seasons

Trait	Algae extract	Control				Sprayed				$LSD_{0.05}$
	Variety	Nimaless	Garrot	Husam	Karam	Nimaless	Garrot	Husam	Karam	
Sucrose%	2019/2020	16.66	17.21	19.44	18.31	17.91	18.26	20.17	19.48	0.20
	2020/2021	16.79	17.10	17.40	16.85	18.12	18.61	19.06	18.41	0.195
Na%	2019/2020	1.18	1.17	1.52	1.48	1.30	1.38	1.63	1.57	0.07
	2020/2021	1.14	1.13	1.30	1.29	1.34	1.34	1.50	1.48	0.03
K%	2019/2020	5.73	5.30	4.52	5.40	4.89	4.42	4.19	4.94	0.19
	2020/2021	5.78	5.44	5.26	5.63	4.84	4.52	4.15	4.44	0.07
α-amino-N%	2019/2020	1.55	1.29	1.34	1.46	1.17	1.16	1.21	1.38	0.04
	2020/2021	1.58	1.48	1.41	1.51	1.34	1.33	1.30	1.34	0.02
Qz%	2019/2020	74.61	76.92	80.98	76.87	78.75	80.51	82.50	79.50	0.23
	2020/2021	74.74	76.49	76.89	74.83	79.12	80.71	81.85	80.32	0.32
RY (t fed^{-1})	2019/2020	42.58	43.77	33.48	33.20	47.12	48.55	37.83	38.97	0.32
	2020/2021	38.43	38.92	29.15	28.65	45.87	46.12	32.77	34.88	0.45
RS%	2019/2020	13.85	14.58	17.02	15.54	15.44	15.92	17.86	16.97	0.10
	2020/2021	13.99	14.45	14.75	14.08	15.69	16.34	16.75	15.98	0.22
SL%	2019/2020	2.82	2.64	2.41	2.76	2.46	2.39	2.34	2.59	0.07
	2020/2021	2.77	2.66	2.65	2.77	2.44	2.27	2.32	2.44	0.03
RSY (t fed^{-1})	2019/2020	5.88	6.38	5.71	5.15	7.27	7.71	6.75	6.60	0.09
	2020/2021	5.37	5.62	4.30	4.11	7.19	7.28	5.49	5.57	0.14
SLY (t fed^{-1})	2019/2020	1.20	1.15	0.81	0.92	1.13	1.16	0.88	1.01	0.02
	2020/2021	1.17	1.03	0.77	0.79	1.11	1.04	0.76	0.87	0.04

The effects of the interaction between foliar application of algae extract and the four varieties on the evaluated traits are presented in Table 8. RY and RSY were significantly increased in response to the foliar application of algae extract in both growing seasons. These results could be attributed to that spraying sugar beet plants with algae extract resulted in higher values of photosynthetic pigments and root thickness as well as the fresh weight of leaves and roots compared to control. Moreover, foliar application of algae extract to the variety Garrot resulted in the highest RY (48.55 and 46.11 t fed^{-1}) and RSY (7.71 and 7.28 t fed^{-1}) in the first and second growing seasons, respectively. The lowest values were produced from the variety Karam under the control treatment and with foliar application of algae extract for both root and recoverable sugar yields. In general, the superiority of a sugar beet variety in specific traits seems to likely rely on its genetic constitution. These findings are consistent with earlier findings (Abu-Ellail et al. 2019). Furthermore, the three-order interaction between inter-row planting distances, algae extract foliar application and varieties exhibited significant effects RY and RSY (Table 10). The variety Garrot planted at 50 cm inter-row distances under foliar application of algae extract produced the highest RY (49.17 and 47.27 t fed^{-1}) and RSY (7.77 and 6.87 t fed^{-1}) in the first and second growing seasons, respectively. Meanwhile, the lowest RY (32.37 and 27.90 t fed^{-1}) and RSY (5.00 and 3.90 t fed^{-1}), in the first and second growing seasons, respectively, resulted from the variety Karam planted at 60 cm inter-row distances under the control treatment.

Effect of algae extract foliar application and inter-row planting distances on sugar loss

The ANOVA results revealed significant effects of all the studied factors on sugar loss (SL)% and sugar loss yield (SLY)in both growing seasons (Table 2). Sugar loss% and sugar loss yield were significantly increased as the inter-row planting distance was increased from 50 to 60 cm (Table 3). The lowest SL% and SLY values of 2.53 and 2.51%, and 1.00 and 0.91 t fed^{-1} in the first and second growing seasons, respectively, were produced from planting sugar beet at 50 cm inter-row distance. Meanwhile, cultivating sugar beet at 60 cm enhanced SL% and SLY by 1.50 and 1.00%, and 3.40 and 5.60% in the first and second growing seasons, respectively (Table 3). The observed increase in SL% and SLY in response to increasing the inter-row planting distance could be attributed to the higher effect of inter-row planting distances on sucrose content compared to its effect on root weight. These results are in accordance with Brar et al. (2015) and Bayat et al. (2019). Foliar application of algae extract has significantly promoted SL%, where reduced SLY in both growing seasons (Table 4). The lowest SLY values (1.02 and 0.92 t fed^{-1} in the first and second growing seasons, respectively) were produced from the control treatment with an estimated increase of about 2.86 and 3.16% under the foliar application of algae extract. In both growing seasons, the four tested varieties showed significant and highly significant variations SL% and SLY (Table 5). The multigerm variety Husam produced the lowest SL% (2.38 and 2.48%) and SLY (0.84 and 0.78 t fed^{-1}) in the first and second growing seasons, respectively. Meanwhile, the variety Nimaless produced the highest SLY (1.16 and 1.09 t fed^{-1}) in the first and second growing seasons, respectively (Table 5). The superiority of the variety Husam in the sugar loss traits could be ascribed to the genetic makeup of the two varieties. These findings are in accordance with earlier results reported by Refay (2010).

Table 9. Mean values of sucrose%, Na%, K%, Qz% and α-amino-N% as affected by the interaction among inter-row planting distances, algae extract foliar application and sugar beet varieties in 2019/2020 and 2020/2021 growing seasons

Inter-row distance	Algae Extract	Variety	Sucrose%		Na%		K%		α-amino-N%		Qz%	
			2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
50 cm	Control	Nimaless	16.66	16.72	1.18	1.18	5.88	5.63	1.55	1.37	74.03	74.97
		Garrot	17.14	17.09	1.2	1.14	5.4	5.27	1.24	1.43	76.32	77.03
		Husam	19.36	17.65	1.54	1.31	4.44	5.11	1.22	1.43	81.06	77.72
		Karam	18.25	16.92	1.52	1.33	5.28	5.54	1.31	1.49	77.07	75.15
	Sprayed	Nimaless	17.87	17.91	1.33	1.36	4.69	4.6	1.17	1.25	79.29	79.59
		Garrot	18.17	18.72	1.41	1.34	4.27	4.07	0.99	1.19	80.74	82.41
		Husam	20.3	19.52	1.68	1.57	4.09	4	1.45	1.29	82.48	82.88
		Karam	19.46	18.59	1.58	1.44	4.7	4.37	1.47	1.37	80.27	80.90
60 cm	Control	Nimaless	16.55	16.66	1.18	1.1	5.58	5.92	1.54	1.58	75.18	74.51
		Garrot	17.28	17.11	1.14	1.11	5.19	5.61	1.33	1.54	77.53	75.94
		Husam	19.52	17.15	1.5	1.29	4.61	5.41	1.46	1.59	80.89	76.06
		Karam	18.36	16.78	1.44	1.24	5.51	5.73	1.21	1.53	76.67	74.51
	Sprayed	Nimaless	17.96	18.34	1.27	1.32	5.08	5.08	1.17	1.43	78.20	78.64
		Garrot	18.35	18.5	1.34	1.33	4.57	5	1.33	1.27	80.28	79.01
		Husam	20.24	18.61	1.58	1.53	4.28	4.29	1.77	1.6	82.52	80.82
		Karam	19.5	18.23	1.56	1.51	5.18	4.52	1.28	1.31	78.74	79.74
LSD0.05			0.29	0.26	0.09	0.04	0.27	0.1	0.06	0.03	0.32	0.46

Increasing the inter-row planting distance accompanied with foliar application of algae extract produced the desirable values of SL% and SLY. Table 6 shows the effect of the interaction between inter-rower planting distances and the foliar-applied algae extract on SL5 and SLY. Cultivated sugar beet plants at 50 cm inter-row planting distance sprayed with algae extract produced the lowest SL% (2.42 and 2.32%), in the first and second growing seasons, respectively. On the other hand, the highest SLY values in both growing seasons of 1.08 and 0.96 t fed^{-1} were produced from the plants cultivated at 50 cm inter-row distances and sprayed with algae extract. Table 7 shows that different varieties responded differently to inter-row planting distances. SLY at narrower inter-row planting distances (50 cm) were higher compared to the wider inter-row planting distances (60 cm). Meanwhile, the estimated SL% values for the wider inter-row distances (60 cm) were higher compared to the narrower inter-row distances (50 cm). The multigerm variety Husam produced the lowest values of SL% (2.43 and 2.44%) and SLY (0.87 and 0.76 t fed^{-1}) under the cultivation at narrower inter-row distances of 50 cm in the first and second growing season, respectively. The superiority of a specific sugar beet variety in particular traits may be attributed to its genetic make-up. These results are in agreement with earlier findings (Abu-Ellail et al. 2019; Mekdad 2012; Sahar and Salem 2016).

The effects of the interaction between foliar application of algae extract and the four varieties on the evaluated traits are presented in Table 8. The lowest values of SLY were produced from the variety Husam either under the control treatment (0.81 and 0.77 t fed^{-1}) or the foliar application of algae extract (0.88 and 0.76 t fed^{-1}) in both growing seasons, suggesting that this trait is more dependent on the genetic constitution of the varieties. Furthermore, the three-order interaction between inter-row planting distances, algae extract foliar application and varieties exhibited significant effects on SL% and SLY (Table 10). The variety Husam sprayed with algae extract at 60 cm inter-row distances revealed the lowest SL% (2.27 and 2.18%) in the first and second growing seasons, respectively. The variety Husam was superior in producing the lowest SLY values (0.77 and 0.77 t fed^{-1}) when planted at 60 cm inter-row distances without foliar application of algae extract, whereas the highest SLY values (1.18 and 1.05, and 1.17 and 1.06 t fed^{-1}) resulted from either planting the variety Garrot at 50 cm inter-row distances and the variety Nimaless at 60 cm inter-row distances without foliar application of algae extract in the first and second growing seasons, respectively.

Table 10. Mean values of recoverable sugar%, sugar loss%, root, recoverable sugar and sugar loss yields as affected by the interaction among inter-row planting distances, foliar application of algae extract and sugar beet varieties in 2019/2020 and 2020/2021 growing seasons.

Inter-row distance	Algae Extract	Variety	RY (t fed^{-1})		RS%		SL%		RSY (t fed^{-1})		SLY (t fed^{-1})	
			2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
50 cm	Control	Nimaless	42.97	39.43	13.84	13.96	2.85	2.75	5.91	5.50	1.22	1.180
		Garrot	44.43	40.17	14.45	14.47	2.69	2.62	6.41	5.81	1.19	1.047
		Husam	34.13	29.50	16.89	15.02	2.46	2.63	5.78	4.43	0.84	0.74
		Karam	34.03	29.40	15.51	14.15	2.73	2.77	5.29	4.32	0.93	0.82
	Sprayed	Nimaless	47.13	47.00	15.38	15.49	2.49	2.42	7.24	7.28	1.17	1.13
		Garrot	49.17	47.27	15.81	16.47	2.36	2.25	7.77	6.87	1.16	1.06
		Husam	38.17	33.30	17.70	17.27	2.40	2.25	6.76	5.75	0.91	0.75
		Karam	41.17	36.00	17.00	16.20	2.60	2.39	7.00	5.83	1.07	0.90
60 cm	Control	Nimaless	42.20	37.43	13.86	14.02	2.79	2.77	5.85	5.24	1.17	1.06
		Garrot	43.10	37.67	14.70	14.42	2.59	2.69	6.34	5.44	1.11	1.01
		Husam	32.83	28.80	17.16	14.48	2.36	2.67	5.63	4.17	0.77	0.77
		Karam	32.37	27.90	15.57	14.01	2.79	2.76	5.00	3.90	0.90	0.77
	Sprayed	Nimaless	47.10	44.73	15.49	15.89	2.43	2.45	7.29	7.10	1.09	1.09
		Garrot	47.93	44.97	16.03	16.20	2.42	2.29	7.65	7.28	1.15	1.03
		Husam	37.50	32.23	18.03	16.52	2.28	2.18	7.77	7.29	0.85	0.77
		Karam	36.77	33.77	16.93	15.75	2.58	2.48	6.21	5.31	0.95	0.84
$LSD_{0.05}$			0.45	0.63	0.13	0.30	0.10	0.04	0.12	0.19	0.03	0.05

Conclusion

In conclusion, it is recommended that decreasing the inter-row planting distance (50 cm) accompanied with foliar application of algae extract has significantly promoted sucrose content, Na%, quality index%, root yield, recoverable sugar%, recoverable sugar yield and sugar loss yield, and reduced K%, α-amino-N% and sugar loss%. The multigerm variety Husam produced the highest values of sucrose content, Na content, α-amino-N, quality index, and recoverable sugar with sprayed of algae extracts compared to the control. Meanwhile, foliar application of algae extract to the monogerm variety Garrot produced the highest root yield, recoverable sugar yield and sugar loss yield.

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الملخص العربي

تأثير الرش الورقي لمستخلص الطحالب ومسافات الزراعة بين الخطوط على محصول وجودة بنجر السكر

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أجريت هذه الدراسة فى المزرعة البحثية بشركة الدلتا للسكر ، الحامول ، محافظة كفرالشيخ ، شمال مصر فى موسمى زراعة 2020/2019 و 2021/2020 وذلك لدراسة تأثير تطبيق الرش الورقى لمستخلصات الطحالب كمصدر للمحفزات الحيوية ومسافات الزراعة بين الخطوط على المحصول وصفات الجودة لاربعة اصناف من بنجر السكر. تم استخدام تصميم القطاعات كاملة العشوائية للقطع تحت المنشقة فى ثلاث مكررات. أوضحت النتائج أن تقليل مسافة الزراعة بين الخطوط (50 سم) والمصحوبة بنطبيق الرش الورقى لمستخلص الطحالب قد عزز بشكل كبير كلا من محتوى السكر ، نسبة محتوى الصوديوم ، دليل الجودة ، محصول الجذور ، نسبة السكرالقابل للاستخلاص ، محتوى السكرالقابل للاستخلاص ، ومحصول السكر القابل للاستخلاص و محصول الفاقد من السكر بينما ادت الى انخفاض فى محتوى كلا من البوتاسيوم والفا امين نيتروجين بالاضافة الى النسبة المئوية لفقد السكر. ولقد اعطى الصنف حسام متعدد الأجنة اعلى قيم للنسبة المئوية لمحتوى السكر (20.17%) ونسبة محتوى الصوديوم (1.63%) ودليل الجودة (82.50%) ونسبة السكر القابل للاستخلاص (17.86%) وذلك بتطبيق الرش الورقى لمستخلصات الطحالب مقارنة بالكنترول (عدم استخدام الرش الورقى) . من ناحية اخرى اعطى الصنف جاروت احادى الأجنة اعلى محصول للجذور (48.55 طن/فدان) ومحصول السكر القابل للاستخلاص (7.71 طن /فدان) وفقد محصول السكر (1.16 طن /فدان) بتطبيق الرش الورقى لمستخلصات الطحالب. بشكل عام ادت زراعة بنجر السكر على مسافات ضيقة بين الخطوط (50سم) مع تطبيق الرش الورقى لمستخلصات الطحالب للحصول على اعلى قيم لمحتوى السكر، محتوى الصوديوم ، دليل الجودة ، محصول الجذور ، نسبة السكر القابل للاستخلاص ، محصول السكر القابل للاستخلاص ، فقد محصول السكر وفى نفس الوقت اعطت اقل القيم لمحتوى البوتاسيوم والالفا امين النيتروجينى ، نسبة فقد السكر.

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