OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2022.XX.XX

Research Article
Impact of Compost Tea and *Spirulina platensis* Algae on Sugar Beet Grown under Different Levels of Inorganic Nitrogen Fertilizer

[1]Basem Sobhy Ibrahim Makhlouf and [2]Samar Abd El-Aty Mohamed Helmy

[1]Department of Agronomy Research, Sugar Crops Research Institute, Agricultural Research Center, Giza 12619, Egypt
[2]Department of Physiology and Biochemistry Research, Sugar Crops Research Institute, Agricultural Research Center, Giza 12619, Egypt

Abstract
Background and Objective: Nitrogen is an essential macronutrient for plant growth, improving the absorption and utilization of some other nutrients and controlling total plant development. Compost tea (CT) is an aqueous extract of compost that contains high organic matter levels necessary for plants and aerobic soil microorganisms. *Spirulina platensis* is a multi-cellular blue-green micro-alga that contains green pigments, high levels of nutrients and plant growth regulators. This work was designed to study the possibility of using CT and *S. platensis* algae culture filtrate (ACF) in improving plant growth, yield and quality of sugar beet grown under different nitrogen fertilizer levels. **Materials and Methods:** Two field experiments were conducted at Ismailia Research Station, Ismailia Province, Egypt, during the 2019/2020 and 2020/2021 seasons. The study involved two N levels (90 and 120 kg/fed), three CT rates (without, 30 and 60 l/fed) and three ACF levels (without, 1 and 2 l/fed) three times. A split-plot design was used. **Results:** Adding 120 kg N/fed increased crop growth rate (CGR), root yield/fed (RY) and sugar yield/fed (SY), while, sucrose (%) and quality index (QI) decreased. Soil drench with 60 l CT/fed incremented leaf area index (LAI), CGR, sucrose (%), RY and SY. Increasing ACF level up to 2 l/fed increased LAI, sucrose (%), QI, RY and SY. Root yield was positively correlated with SY and negatively with QI. **Conclusion:** Applying 90 kg N/fed combined with a soil drench of 60 l CT/fed and foliar spraying with 2 l ACF/fed thrice can be recommended to attain economical root and sugar yields.

Key words: Compost tea, correlation, nitrogen, quality, *Spirulina platensis*, sugar beet, yield

Citation: Makhlouf, B.S.I. and Samar A.M. Helmy, 2022. Impact of compost tea and *Spirulina platensis* algae on sugar beet grown under different levels of inorganic nitrogen fertilizer. Pak. J. Biol. Sci., 25: XX-XX.

Corresponding Author: Basem Sobhy Ibrahim Makhlouf, Department of Agronomy Research, Sugar Crops Research Institute, Agricultural Research Center, Giza 12619, Egypt

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Egypt suffers from a negative gap in sugar between production and consumption, which can be minimized by expanding the sugar beet area in the newly reclaimed soils. Egyptian growers got used to applying excessive amounts of inorganic nitrogen to maximize their crop yields. Meanwhile, their awareness of environmental pollution is low, in addition to raising costs of fertilization processes, due to the leaching of nutrients beyond the root zone. Therefore, the possibility of using organic and biosources such as compost tea and algae, besides an inorganic N aims to reduce both pollution and costs of growing sugar beet as well.

Nitrogen is a necessary element for sugar beet growth and yield and controlling total plant development, in addition to improving the absorption and utilization of some other nutrients. Even though excessive addition of nitrogen enhances the vegetative growth of sugar beet, it impedes the transfer of dry matter from plant foliage to the storage root and hence reduces sugar content. According to Makhlouf and Abd El-All[1], elevating N levels from 80-120 kg N/fed (fed = 0.42 ha^{-1}) led to a significant increase in leaf area index (LAI), photosynthetic pigments, impurities, root and sugar yields, whereas adding 100 kg N/fed gave the highest sucrose and extracted sugar percentages. Mizran *et al.*[2] revealed that the highest foliage weight/plant (TFW), sucrose, purity and extractable sugar percentages were obtained from sugar beet plants enriched with 310 kg N ha^{-1}. Wang *et al.*[3] showed that sugar beet fertilized with 120 kg ha^{-1} resulted in the highest chlorophyll content, dry matter accumulation and final yield.

Compost tea is an organic product resulting from the aqueous extraction of composted materials prepared by the biological role of beneficial microorganisms, which can protect and stimulate plant growth[4]. Compost tea is effective in treating soil fertility and acute nutritional deficiency, particularly in desert environments. The more sandy the soil, the more tea will move beneath it and the organisms in it will move[5]. Compost tea contains a significant amount of soluble mineral nutrients that are easily absorbed by plants, which promotes crop growth and productivity. In this regard, Abd El-Rahman *et al.*[6] and Osman *et al.*[7] cleared that spraying beet canopies with compost tea significantly increased root fresh weight/plant, sucrose (%), purity% and root and sugar yields, meanwhile impurities content reduced. Pibars *et al.*[8] stated that soil drenching with 80 l compost tea/fed led to gradual increases in beetroot and sugar yields. Abdel-Mola *et al.*[9] revealed that the best leaves fresh and dry weights/plant, photosynthetic pigments, total carbohydrates and NPK percentages of henna plants were obtained due to the use of 60 mL compost tea/l.

Spirulina platensis is a photosynthetic and multi-cellular blue-green micro-alga. Micro-algae extracts are mostly made up of natural bioactive materials rich in mineral elements, gibberellins, auxins, cytokinins, abscisic acid, proteins, carbohydrates and vitamins[10]. Foliar spray of algae-based bio-stimulants in crop production is a hopeful and advanced agricultural technique owing to its eco-friendly, with obtaining better crop production[11]. Enan *et al.*[12] and Ghazy *et al.*[13] indicated that foliar application of *S. platensis* algae extract on beet canopies sharply increased photosynthetic pigments, fresh and dry weights/plant, extractable sugar (%), quality index, N and K contents in leaves and root and sugar yields, while α-amino N and Na reduced. Abd El-Aleem *et al.*[14] revealed that plant height and fennel yield increased with the spraying of 2 l *S. platensis* algae extract/fed. Abdallah *et al.*[15] cleared that foliar application of *S. platensis* at 7.5 mL L^{-1} four times+75% of recommended N dose improved the fresh and dry weight/plant of sweet basil. Abu El-Fotoh *et al.*[16] showed that spraying sugar beet foliage with blue-green algae extract at 3 l/fed significantly increased photosynthetic pigments content, sucrose and purity percentages and yields of root and sugar/fed.

This study was conducted to find out the appropriate levels of compost tea and *Spirulina platensis* algae culture filtrate in combination with ammonium nitrate as an inorganic traditional nitrogen source to get the highest yield and quality of sugar beet, as well as to decrease both costs and keep the soil in the high gene.

MATERIALS AND METHODS

Location and treatments: Two field experiments were conducted at Ismailia Agricultural Research Station (Lat. 30°35'30"N, Long. 32°14'50"E and 10 m above sea level), Ismailia Province, Egypt, in 2019/2020 and 2020/2021 seasons to study the possibility of using compost tea and algae (*Spirulina platensis*) in improving plant growth and physiological characteristics, yield and quality of sugar beet crop grown under different levels of inorganic nitrogen fertilizer in a loamy sand soil with a sprinkler irrigation system. A randomized complete block design in a split-plot arrangement was employed with three replicates to layout 18 treatments, which represented two nitrogen fertilizer levels (90 and 120 kg N/fed), which occupied the main plots, whereas nine combinations among three compost tea (CT) levels (without, 30 and 60 l/fed) and three algal culture filtrate (ACF) levels (without, 1 and 2 l/fed), which were distributed randomly in the subplots. The experimental unit area was 17.5 m^2 including 5 ridges of 0.5 m apart and 7 m long, with 0.2 m between hills. Nitrogen fertilizer was added as

Table 1: Soil physical and chemical properties of the experimental sites (at 50 cm depth)

2019/2020 season								
Particle size distribution						Available nutrients ($mg\ kg^{-1}$)		
Sand (%)	Silt (%)	Clay (%)	Soil texture	EC ($dS\ m^{-1}$)	pH	N	P	K
87.92	2.23	9.85	Loamy sand	0.83	8.06	27.48	5.89	115.50
Soluble cations and anions ($mEq\ L^{-1}$)								
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-}		OM (%)
3.09	1.33	3.51	0.41	1.06	2.59	4.69		0.14
2020/2021 season								
Particle size distribution						Available nutrients ($mg\ kg^{-1}$)		
Sand (%)	Silt (%)	Clay (%)	Soil texture	EC ($dS\ m^{-1}$)	pH	N	P	K
86.77	2.15	11.08	Loamy sand	0.87	8.11	31.11	6.03	121.21
Soluble cations and anions ($mEq\ L^{-1}$)								
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-}		OM (%)
3.21	1.19	3.59	0.66	1.11	2.62	4.92		0.17

ammonium nitrate "33.5% N" in five equal batches, after thinning process (at 4-6 true leaves) and every two-week interval later on. Each level of compost tea was applied in three equal split doses, the 1st dose was sprayed on the soil surface around sugar beets after thinning and the other two were applied at 20-day intervals later on. Algal culture filtrate was sprayed on beet canopies three times, after thinning and the other two times were applied every 25-day interval. The volume of each solution was 300 L of water/fed, using the back-portable sprayer. Soil samples were collected from the experimental sites before sowing, to determine physical and chemical properties according to ICARDA[17], as shown in Table 1.

Compost tea preparation: Aerated compost tea was prepared from a matured compost made from rice straw, farmyard manure, bentonite, rock phosphate, feldspar, elemental sulfur and urea with action of *Trichoderma viride* and *Trichoderma harzianum* inoculum, which had been composted in the thermophilic and aerobic heap for three months[18]. To prepare the compost tea, ten kg of mature compost (in a 150 L plastic barrel) was blended with 100 L of tap water (previously-stored to avoid the harmful effect of Cl_2 on microbial load of compost) and some chemical additives, namely 1 kg molasses, 0.5 kg $(NH_4)_2\ SO_4$, 50 g $MgSO_4.\ 7H_2O$ and 10 g NaCl. This mixture had been kept in a shaded place for 7 days with daily stirring by an air compressor using a PVC pipe dipped in the barrel. Aeration was done at the rate of 4 hrs/day in intermittent periods[5]. Then, the liquid mixture was filtered on a 100-mesh screen to become ready to use. Compost tea was obtained from Microbiology Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt. Some physicochemical characteristics of compost tea are shown in Table 2.

Table 2: Some physicochemical characteristics of compost tea during the two growing seasons 2019/2020 and 2020/2021

Property	2019/2020	2020/2021
pH	6.81	6.59
EC ($dS\ m^{-1}$ at 25°C)	2.67	2.81
Total soluble N (ppm)	115.5	121.3
Available P (ppm)	40.9	42.2
Available K (ppm)	137.7	141.0
Total count of bacteria ($CFU\ mL^{-1}$)	1.2×10^7	1.2×10^7
Germination test of cress seeds (%)	91.0	89.0

CFU: Colony-forming unit

Preparation of *Spirulina platensis* algae culture: *Spirulina platensis* algae were grown on Zarrouks medium[19]. The culture was incubated in a growth chamber under continuous shaking at 150 rpm, illumination (2000 lux) and a temperature of 35±2°C. After 30 days of incubation, the culture was homogenized and filtered till it was used. *Spirulina platensis* culture contained 8.7% N, 1.6% P and 1.1% K, with an EC of 19.4 $dS\ m^{-1}$ and pH of 9.69. *Spirulina platensis* algae culture filtrate was obtained from Microbiology Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt.

Crop husbandry: Single calcium super-phosphate fertilizer (15% P_2O_5) was added at 200 kg/fed during land preparation. Potassium sulfate fertilizer (48% K_2O) was added at 100 kg/fed in a 3-equal dose, the 1st one was applied with the 3rd N-dose and the other two ones were given with N doses. The preceding summer crop was peanuts. The multi-germ sugar beet variety "Faten" was sown manually during the 2nd week of October on one side of ridges, while harvesting was done at age of 210 days, in both seasons. Other agricultural practices were followed as recommended by Sugar Crops Research Institute, Agricultural Research Center, Egypt.

Measurements

Plant growth traits, physiological characteristics and root yield: After 105 days from sowing, the leaf area index (LAI) was measured using Eq. 1[20]. Photosynthetic pigments (chlorophyll a, b and carotenoids) were determined according to Eq. 2, 3 and 4[21]. Crop growth rate (CGR, g/week) and relative growth rate (RGR, g/g/week) were calculated according to Eq. 5 and 6[20], respectively. At harvest, root yield/fed was determined based on the experimental unit (kg) and converted to ton/fed. Root and top fresh weights/plant (g) were assessed. Top to root ratio was calculated on a fresh weight basis.

$$\text{LAI} = \frac{\text{Leaf area per plant } \left(\text{cm}^2\right)}{\text{Plant ground area } \left(\text{cm}^2\right)} \quad (1)$$

where, plant leaf area was determined using the “disk method” in 50 leaf disks of 1.0 cm diameter.

$$\text{Chlorophyll a (mg g}^{-1}\text{ fresh leaf)} = 9.784 \text{ (A 662)} - 0.99 \text{ (A 644)} \quad (2)$$

$$\text{Chlorophyll b (mg g}^{-1}\text{ fresh leaf)} = 21.426 \text{ (A 644)} - 4.65 \text{ (A 662)} \quad (3)$$

$$\text{Carotenoids (mg g}^{-1}\text{ fresh leaf)} = 4.695 \text{ (A 440)} - 0.268 \text{ (chl. "a"+chl. "b")} \quad (4)$$

Where:
A = Optical density at the wave length indicate.

$$\text{CGR} = \frac{W_2 - W_1}{T_2 - T_1} \quad (5)$$

$$\text{RGR} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \quad (6)$$

where, W_1, A_1 and W_2, A_2, respectively refer to the dry weight and leaf area of the plant at sampling times T_1 and T_2 (105 and 135 days from sowing, respectively).

Quality parameters and sugar yield (at harvest): Ten fresh sugar beetroots were randomly collected from the middle ridges of each experimental unit to determine sucrose (%) using "Saccharometer" and impurities content (K, Na and α-amino N, mEq/100 g beet) in roots according to the method described by AOAC[22]. Sugar lost to molasses (%) (SLM) was calculated using Eq. 7[23]. Extracted sugar (%) (ES) was computed by Eq. 8[23]. The quality index (QI) was calculated by Eq. 9. After that, sugar yield/fed (ton) was calculated by multiplying root yield/fed (ton) by extracted sugar (%).

$$\text{SLM} = 0.14 \text{ (Na+K)} + 0.25 \text{ (}\alpha\text{-amino N)} + 0.5 \quad (7)$$

$$\text{ES} = \text{Sucrose (\%)} - \text{SLM} - 0.6 \quad (8)$$

$$\text{QI} = \frac{\text{Extracted sugar (\%)} \times 100}{\text{Sucrose (\%)}} \quad (9)$$

Correlation coefficient: Simple correlation coefficient was computed among some of the studied traits[24].

Economic evaluation: Economic evaluation of root yield/fed (average of the two seasons) with sucrose incentive, was calculated according to equations 10 and 11 as follows:

$$\text{Total revenue/fed (L.E.)} = \text{Root yield/fed (ton)} \times \text{Ton's initial price} \quad (10)$$

Where:

Ton’s initial price of roots at 16% sucrose	=	L.E. 550
Sucrose incentive above 16%	=	L.E. 25/unit of sucrose/ton of roots

$$\text{Net return/fed (L.E.)} = \text{Total revenue/fed (L.E.)} - \text{Total costs/fed (L.E.)} \quad (11)$$

where, L.E. One = 0.064 USD, according to the exchange rate of the Egyptian currency against the US dollar, May, 2021.

The costs included prices of seeds, fertilizers, the studied treatments, other recommended agricultural practices and casual labor.

Statistical analysis: The collected data were statistically analyzed according to Casella[25], using the "MSTAT-C" computer software package. The least significant of difference (LSD) method was used to test differences between means at a 5% level of probability.

RESULTS

Main effects

Plant growth traits, physiological characteristics and root yield: Sugar beet plants fertilized with the maximum level of N, i.e., 120 kg/fed, gave statistical increases in crop growth rate

(CGR), top fresh weight/plant (TFW) and top to root ratio (T/R), in the 1st season and chlorophyll b, carotenoids and relative growth rate (RGR), in the 2nd one, in addition to leaf area index (LAI), chlorophyll a, root fresh weight/plant (RFW) and root yield/fed, in both seasons in Table 3, as compared to plants fertilized with 90 kg N/fed. The highest and most significant values were obtained with the addition of 120 kg N/fed fertilized to beet plants, recording 3.26 and 3.54 in LAI, 3.51, 1011 and 1128 g/plant in RFW and 26.32 and 28.45 t in root yield/fed, in the 1st and 2nd season, respectively, corresponding to 378 g in TFW, 0.374 for T/R and 12.48 g/week in CGR, in the 1st one.

Soil drench with the maximum level of compost tea (CT), i.e., 60 l/fed, appreciably affected LAI, chlorophyll b and carotenoids content in leaves, CGR, RGR, RFW, TFW, T/R and root yield/fed of sugar beet, in both seasons, as well as chlorophyll a, in the 2nd one, as compared to that left without drench. The continuous increase in CT levels added to the soil up to 60 l/fed was accompanied by a gradual and considerable increase in LAI in the 2nd season and RFW, TFW, chlorophyll "b", carotenoids, CGR and root yield/fed, in both seasons. Soil drench with 60 l CT/fed gave the greatest values in all the studied traits in this regard, scoring 1064 and 1169 g in RFW and 13.61 and 14.99 g/week for CGR, corresponding to 27.58 and 29.16 t in root yield/fed, in the 1st and 2nd season, successively, followed by 30 l/fed level and untreated control. Leaf area index and top/root ratio in the 1st season and chlorophyll "b" in the 2nd one, were significantly increased in case of increasing CT level to 30 l/fed, whereas increasing compost tea level from 30 to 60 l/fed had a minimal effect on these traits. Vice versa, RGR in both seasons and top to root ratio in the 2nd one statistically increased as a result of raising CT level from 30 to 60 l/fed. The highest values of all the previously mentioned traits were found with the addition of CT at 60 l/fed, followed by 30 l/fed, while the check treatment recorded the lowest one.

In the same Table, spraying beet canopies with 1 l/fed of algal culture filtrate (ACF) led to a significant increment in LAI and chlorophyll in the 1st season, in addition to chlorophyll b and RGR in the 2nd one, as relative to untreated beets. However, the distinctions failed to reach the level of significance with increasing the ACF level from 1 to 2 l/fed. Contrariwise, there was a significant increase in the aforementioned traits with the gradual increase of ACF level up to 2 l/fed, in the corresponding seasons. Crop growth rate and RGR sharply increased as a result of raising ACF spray level from 1 to 2 l/fed, whilst there was a marginal effect between 1 l/fed and that untreated control in the 1st season. It was observed that spraying foliage beets with ACF at 2 l/fed produced the highest values of LAI (3.17 and 3.58), heavier RFW/plant (995 and 1121 g) and CGR (12.47 and 14.86 g/week), corresponding to root yield/fed (26.20 and 28.19 t), in the 1st and 2nd season, successively, followed by 1 l/fed level of ACF and that left without spraying.

Quality parameters and sugar yield: Application of N fertilizer to the soil appreciably influenced K and α-amino N content in roots, sucrose (%), sugar lost to molasses (SLM) and extracted sugar (%), in both seasons and sugar yield/fed and quality index in the 1st and 2nd season, respectively, whereas sodium content was not affected in Table 4. Feeding beet plants with 120 kg N/fed was accompanied by a fundamental increase in K and α-amino N contents and SLM, as well as sugar yield/fed, while sucrose (%), extracted sugar (%) and quality index declined, as relative to that plants were fed with 90 kg N/fed. When sugar beet was fed with 120 kg N/fed, the significant and maximum values of sugar yield/fed were achieved, as it reached 4.31 t in the 1st season. While the same N level gave the lowest sucrose (%) (18.36 and 16.62%) and extracted sugar (%) (16.38 and 14.45%), in the 1st and 2nd season, respectively, followed by the other nitrogen level, i.e., 90 kg/fed. In this regard, it could be noticed that the real increase in root yield/fed (Table 3) compensated for the decrease in sucrose (%), which in turn gave a noticeable increment in sugar yield/fed.

Application of 30 l CT/fed to the soil was more distinctive, where it resulted in a significant increase in sucrose (%) and extracted sugar (%) in both seasons, compared to that left without application, while raising compost tea level from 30 to 60 l/fed did not give any significant distinctions in these traits. Here too, K and α-amino N contents in both seasons and SLM in the 2nd one were significantly incremented by the gradual increase in CT levels, meanwhile Na content declined. It could be observed that the quality index was slightly improved as a result of elevating the CT level to 30 l/fed and then decreased with the tendency towards adding 60 l/fed by 0.45. Raising CT level from zero to 60 l/fed led to a marked increment in sucrose (%), extracted sugar (%) and sugar yield, in both seasons. The highest sugar yield/fed was achieved with 60 l CT/fed, as it reached 4.62 and 4.34 t, followed by 30 l/fed (4.29 and 4.01 t), while the untreated control gave the lowest yield (3.76 and 3.64 t), in the 1st and 2nd season, successively.

In terms of algae effect, foliar application of *Spirulina platensis* algae culture filtrate (ACF) on beet canopies appreciably influenced impurities content, sucrose (%), SLM, extracted sugar (%), quality index and sugar yield, in both seasons in Table 4. In the 2nd season, feeding beet plants with

Table 3: The main effect of nitrogen, compost tea and algal culture filtrate levels on growth traits, physiological characteristics and root yield

	LAI		Chl. a		Chl. b		Carot.		CGR		RGR		RFW		TFW		T/R		RY/fed (ton)	
Treatments	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Nitrogen level																				
90 kg/fed	2.68	3.16	3.29	3.19	2.04	1.79	0.98	0.67	11.00	10.74	0.075	0.068	896	1060	263	320	0.290	0.301	24.11	25.97
120 kg/fed	3.26	3.54	3.51	3.42	2.18	2.14	1.15	0.97	12.48	14.00	0.084	0.091	1011	1128	378	396	0.374	0.350	26.32	28.45
LSD 0.05	*	*	*	*	NS	*	NS	*	*	NS	NS	*	*	*	*	NS	*	NS	*	*
Compost tea level (CT)																				
Without	2.60	3.02	3.33	3.18	1.84	1.79	0.81	0.69	10.42	10.31	0.075	0.062	869	1034	247	310	0.280	0.299	22.79	25.25
30 l/fed	3.01	3.38	3.40	3.34	2.09	1.95	1.11	0.81	11.19	11.82	0.075	0.069	928	1080	327	341	0.351	0.315	25.27	27.22
60 l/fed	3.32	3.63	3.47	3.39	2.39	2.16	1.28	0.96	13.61	14.99	0.089	0.109	1064	1169	387	423	0.366	0.361	27.58	29.16
LSD 0.05	0.35	0.09	NS	0.11	0.23	0.15	0.11	0.08	0.70	1.37	0.004	0.010	19	11	28	23	0.032	0.020	0.37	0.56
Algal culture filtrate level (ACF)																				
Without	2.66	3.10	3.27	3.16	2.02	1.82	0.88	0.76	11.14	9.55	0.077	0.066	901	1067	312	353	0.340	0.328	23.86	26.46
1 l/fed	3.09	3.36	3.44	3.29	2.09	1.97	1.07	0.82	11.61	12.70	0.079	0.084	966	1095	318	361	0.327	0.327	25.59	26.99
2 l/fed	3.17	3.58	3.49	3.46	2.22	2.11	1.25	0.88	12.47	14.86	0.083	0.089	995	1121	332	361	0.330	0.320	26.20	28.19
LSD 0.05	0.35	0.09	0.07	0.11	NS	0.15	0.11	0.08	0.70	1.37	0.004	0.010	19	11	NS	NS	NS	NS	0.37	0.56

LAI: Leaf area index, Chl.: Chlorophyll (mg g^{-1} leaf fresh weight, lfw), Carot.: Carotenoids (mg $^{-1}$g lfw), CGR: Crop growth rate (g/week), RGR: Relative growth rate (g/g/week), RFW: Root fresh weight/plant (g), TFW: Top fresh weight/plant (g), T/R: Top to root ratio, RY: Root yield, 1st: First season (2019/2020), 2nd: Second season (2020/2021) and *, NS: Significant and insignificant differences, respectively

Table 4: The main effect of nitrogen, compost tea and algae culture filtrate levels on quality parameters and sugar yield

			Impurities content (mEq/100 g beet)													
	Sucrose (%)		K		Na		α-amino N		Sugar lost to molasses (%)		Extracted sugar (%)		Quality index		Sugar yield/ fed (ton)	
Treatments	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Nitrogen level																
90 kg/fed	19.04	16.94	2.99	3.00	1.21	2.14	0.89	0.91	1.31	1.45	17.13	14.90	89.95	87.89	4.14	3.88
120 kg/fed	18.36	16.62	3.28	3.39	1.15	1.96	1.04	1.26	1.38	1.56	16.38	14.45	89.18	86.95	4.31	4.12
LSD 0.05	*	*	*	*	NS	NS	*	*	*	*	*	*	*	*	*	NS
Compost tea level (CT)																
Without	18.38	16.45	2.88	3.04	1.40	2.27	0.83	0.89	1.31	1.47	16.48	14.38	89.59	87.38	3.76	3.64
30 l/fed	18.89	16.81	3.07	3.19	1.28	2.07	0.88	1.04	1.33	1.50	16.97	14.72	89.77	87.53	4.29	4.01
60 l/fed	18.83	17.07	3.45	3.36	0.86	1.80	1.19	1.33	1.39	1.55	16.82	14.92	89.32	87.37	4.64	4.34
LSD 0.05	0.24	0.28	0.11	0.14	0.09	NS	0.11	0.09	0.04	0.03	0.24	0.27	0.26	NS	0.08	0.11
Algal culture filtrate level (ACF)																
Without	18.19	16.24	3.31	3.31	1.25	2.09	1.02	1.20	1.39	1.56	16.20	14.13	89.02	86.68	3.86	3.74
1 l/fed	18.53	16.95	3.20	3.25	1.10	2.11	1.01	1.05	1.36	1.51	16.58	14.83	89.42	87.53	4.24	3.99
2 l/fed	19.38	17.14	2.89	3.02	1.18	1.94	0.87	1.00	1.29	1.44	17.49	15.10	90.25	88.07	4.58	4.25
LSD 0.05	0.24	0.28	0.11	0.14	0.09	0.13	0.11	0.09	0.04	0.03	0.24	0.27	0.26	0.21	0.08	0.11

1st: First season (2019/2020), 2nd: Second season (2020/2021) and *, NS: Significant and insignificant differences, respectively

1 l/fed of ACF markedly increased sucrose (%), extracted sugar (%) and quality index, compared to untreated ones, while the increases in these traits were negligible by increasing spray level from 1 to 2 l/fed, except for α-amino N. On the other hand, the persistent increase in ACF level sprayed on the plants up to 2 l/fed produced the highest and most significant values of sucrose and extracted sugar percentages, in the 1st one, in addition to sugar yield/fed in both seasons, compared to the check treatment.

Spraying beet canopies with algal culture filtrate (ACF) at 2 l/fed resulted in achieving the highest values of sugar, which were 19.38 and 17.14 % in sucrose (%), 17.49 and 90.25 and 88.07 % in the quality index, corresponding to 4.58 and 4.25 t in sugar yield/fed, in the 1st and 2nd season, respectively, followed by 1 l/fed and that left without spraying. Impurities content and SLM were reduced by raising the ACF level to 2 l/fed, except for Na content which had no clear cut trend.

Significant interaction effects

First-order interactions

Interaction between nitrogen and compost tea levels: Under the two N levels, significant variances were observed with the upward increase in compost tea (CT) levels up to 60 l/fed in their effect on sugar yield/fed (in the 1st season), LAI and root yield/fed, in the 2nd one and RFW, in both seasons in Table 5. A similar tendency was detected in CGR and TFW with the same gradual increase in CT level combined with 90 kg N/fed, in the 1st season. The differences among chlorophyll "a" averages were insignificant by increasing CT up to 60 l/fed along with 120 kg N/fed, while a significant variance was found with raising CT levels to 30 l/fed+90 kg N/fed, in the 2nd season. Extracted sugar (%) and quality index in the 1st and 2nd season, respectively and sucrose in both seasons sharply incremented with raising CT level from 30 to 60 l/fed combined with 90 kg N/fed, meanwhile these traits severely reduced with the same increase of CT along with 120 kg N/fed. Under the different N levels, marginal differences were noticed in α-amino N and SLM by increasing CT to 30 l/fed, but significant variances appeared when the CT level was raised from 30 to 60 l/fed.

Application of 90 kg N/fed combined with 60 l CT/fed was more distinct than the other ones, as it recorded the highest and most significant values, which reached 19.08 and 17.51% in sucrose (%), in the 1st and 2nd season, respectively, as well as 17.51 % for extracted sugar (%) and 4.66 t for sugar yield/fed, in the 1st one. Meanwhile, the addition of 120 N/fed along with 60 l CT/fed resulted in the heaviest RFW (1103 and 1195 g/plant) in the two growing seasons, respectively, as well

Table 5: Significant interaction effect between nitrogen and compost tea levels

N-level	Compost tea level (CT)	LAI	Chl.a	CGR	RFW/plant (g)		TFW/ plant (g)	RY/fed (t)	Sucrose (%)		α-amino N	SLM (%)	ES (%)	QI	SY/fed (ton)
		2nd	2nd	1st	1st	2nd	1st	2nd	1st	2nd	1st	1st	1st	2nd	1st
90 kg/fed	Without	2.76	2.99	9.55	812	991	177	24.41	18.58	16.49	0.81	1.28	16.70	87.70	3.64
	30 l/fed	3.21	3.31	10.94	851	1046	261	25.91	19.08	16.82	0.83	1.31	17.17	87.82	4.12
	60 l/fed	3.50	3.28	12.50	1025	1143	350	27.61	19.44	17.51	1.03	1.33	17.51	88.18	4.66
120 kg/fed	Without	3.28	3.37	11.28	927	1076	316	26.10	18.18	16.41	0.85	1.33	16.25	87.06	3.87
	30 l/fed	3.56	3.38	11.45	1004	1114	394	28.54	18.71	16.80	0.92	1.34	16.76	87.24	4.46
	60 l/fed	3.77	3.50	14.72	1103	1195	424	30.72	18.21	16.63	1.36	1.47	16.14	86.57	4.61
LSD 0.05		0.13	0.16	0.99	27	16	40	0.80	0.33	0.39	0.16	0.05	0.35	0.29	0.11

α-amino N (mEq/100 g beet), SLM: Sugar lost to molasses, ES: Extracted sugar, QI: Quality index and SY: Sugar yield, LAI: Leaf area index, Chl.: Chlorophyll (mg g^{-1} leaf fresh weight, lfw), CGR: Crop growth rate (g/week), RFW: Root fresh weight/plant (g), TFW: Top fresh weight/plant (g), RY: Root yield, 1st: First season (2019/2020), 2nd: Second season (2020/2021) as the most significant value of root yield/fed (30.72 t) in the 2nd one, which in turn was reflected in an increase in impurities content and a reduction in the quality index to 86.57%.

Interaction between nitrogen and algae culture filtrate levels: In Table 6, substantial variances were detected in carotenoids and K contents in the 1st season and LAI in the 2nd one, as a result of gradual increases in algal culture filtrate (ACF) levels up to 2 l/fed, when beet plants were fertilized with 90 kg N/fed, while the differences between 1 and 2 l ACF/fed combined with 120 kg N/fed were insignificant in their effect on these traits in the 2nd season. The variances between the different levels of ACF were insignificant in their effect on carotenoid content in the 2nd season, when beets were fed with 90 kg N/fed. Meanwhile, significant differences were observed in the case of beet fertilized with 120 kg N/fed, except for the distinction between levels of 1 and 2 l ACF/fed.

Except for the slight differences in sucrose (%), extracted sugar (%) and quality index obtained by increasing ACF levels from control to 1 l/fed along with 120 kg N/fed, these traits in the 1st season, as well as RFW in the 2nd one significantly differed from the upward increase in ACF levels up to 2 l/fed combined with the different nitrogen levels. There was a significant variance in the means of chlorophyll "a" with increasing ACF level from zero to 2 l/fed combined with the two N levels, corresponding to a marginal distinction between 1 and 2 l/fed along with 90 kg N/fed, in both seasons, as well as with 120 kg N/fed, in the 1st one. In the 2nd season, raising ACF level from 1 to 2 l/fed combined with 90 kg N/fed increased root yield/fed from 25.10 to 26.99 t, versus 27.82 to 29.40 t under 120 kg N/fed. However, the quality index significantly increased by decreasing N-level.

Interaction between compost tea and algae culture filtrate levels: Table 7 showed that the differences between control and 2 l/fed of algal culture filtrate (ACF) combined with 30 l compost tea (CT)/fed were significant in their effect on LAI and carotenoids content, while insignificant variances were observed with 60 l CT/fed. A significant increment was detected in chlorophyll "a" and RGR with increasing ACF levels from control to 2 l/fed along with 60 l CT/fed, while there was an insignificant increase with 30 l CT/fed. Under the different levels of CT with the continuous increase in ACF level up to 2 l/fed, significant increments were achieved in root yield/fed, quality index and sugar yield, except for registered differences in root yield with raising ACF level from 1 to 2 l/fed under the check treatment of CT, as well as quality index and sugar yield with increasing ACF level to 1 l/fed along with the different CT levels. Top fresh weight/plant had been affected but without

Table 6: Significant interaction effect between nitrogen and algae culture filtrate levels

		LAI	Chl. a (mg g^{-1} lfw)		Carot. (mg g^{-1} lfw)		RFW/plant (g)	RY/fed (ton)	Sucrose (%)	K	α-amino N	ES (%)	QI
N-level	ACF level	2nd	1st	2nd	1st	2nd	2nd	2nd	1st	1st	2nd	1st	1st
90 kg/fed	Without	2.83	3.15	3.01	0.72	0.67	1027	25.10	18.48	3.25	0.97	16.51	89.35
	1 l/fed	3.16	3.32	3.21	0.97	0.66	1059	25.84	19.04	3.01	0.90	17.13	89.97
	2 l/fed	3.48	3.41	3.36	1.24	0.69	1094	26.99	19.60	2.69	0.84	17.74	90.53
120 kg/fed	Without	3.37	3.39	3.32	1.03	0.85	1106	27.82	17.91	3.37	1.43	15.89	88.69
	1 l/fed	3.56	3.56	3.38	1.18	0.98	1131	28.13	17.99	3.39	1.19	16.02	88.86
	2 l/fed	3.67	3.58	3.56	1.26	1.07	1148	29.40	19.16	3.08	1.16	17.24	89.97
LSD 0.05		0.13	0.10	0.16	0.16	0.11	16	0.80	0.33	0.16	0.14	0.35	0.37

ACF: Algal culture filtrate, K: Potassium (mEq/100 g beet), α-amino N (mEq/100 g beet), ES: Extracted sugar, QI: Quality index, , 1st: first season (2019/2020) and 2nd: second season (2020/2021):

Table 7: Significant interaction effect between compost tea and algae culture filtrate levels

Compost tea level (CT)	ACF level	LAI	Chl. a	Carot.	RGR	RFW/ plant (g)	TFW/ plant (g)	RY/fed (ton)	Sucrose (%)		ES (%)	QI	SY/fed (ton)	
		2nd	2nd	1st	1st	1st	2nd	1st	1st	2nd	2nd	2nd	1st	2nd
Without	Without	2.73	2.94	0.57	0.070	839	306	21.79	17.79	15.09	12.99	86.08	3.45	3.20
	1 l/fed	2.93	3.20	0.75	0.072	878	289	23.16	18.08	17.00	14.92	87.78	3.74	3.74
	2 l/fed	3.41	3.40	1.11	0.082	891	336	23.42	19.28	17.26	15.24	88.27	4.08	3.99
30 l/fed	Without	3.05	3.33	0.86	0.075	872	330	23.73	18.52	16.74	14.62	87.32	3.92	3.88
	1 l/fed	3.48	3.24	1.16	0.078	938	369	25.68	18.59	16.71	14.60	87.35	4.27	3.91
	2 l/fed	3.62	3.46	1.31	0.073	973	324	26.40	19.57	16.99	14.94	87.92	4.67	4.24
60 l/fed	Without	3.52	3.22	1.20	0.086	991	422	26.07	18.26	16.89	14.64	86.64	4.23	4.13
	1 l/fed	3.67	3.44	1.31	0.087	1082	425	27.92	18.93	17.14	14.99	87.45	4.71	4.36
	2 l/fed	3.71	3.51	1.33	0.095	1120	423	28.77	19.28	17.18	15.13	88.02	4.98	4.54
LSD 0.05		0.16	0.19	0.19	0.008	33	40	0.64	0.41	0.48	0.46	0.36	0.13	0.19

ACF: Algal culture filtrate, LAI: Leaf area index, Chl.: Chlorophyll (mg g^{-1} lfw), Carot.: Carotenoids (mg g^{-1} lfw), RGR: Relative growth rate (g/g/week), RFW: Root fresh weight, TFW: Top fresh weight, RY: Root yield, ES: Extracted sugar (%), QI: Quality index, SY: Sugar yield, 1st: First season (2019/2020) and 2nd: Second season (2020/2021) a clear-cut trend. Raising ACF level from zero to 2 l/fed in combination with 60 l CT/fed resulted in the heaviest RFW, which increased from 991 to 1120 g/plant, as well as root yield/fed increased from 27.92 to 28.77 t. In addition to achieving the highest values of LAI, chlorophyll "a" and carotenoids (mg/g lfw), RGR (g/g/week) and TFW (g/plant), they recorded 3.71, 3.51, 1.33, 0.095 and 423, respectively.

There were significant variances toward the increase in sucrose (%) (in the 1st season) and quality index and sugar yield (in the 2nd one), when ACF level was raised from 1 to 2 l/fed along with 30 l CT/fed. A similar trend was observed in these traits as well as extracted sugar (%) in the 2nd season, with raising ACF level from zero to 2 l/fed+60 l CT/fed. Application of 60 l CT/fed combined with 2 l ACF/fed was more distinct, as it attained the significant and maximum values of sucrose (%) (19.28 and 17.18 %) and sugar yield/fed (4.98 and 4.54 t), in the 1st and 2nd season, respectively.

Second-order interaction

Interaction among levels of nitrogen x compost tea x algae culture filtrate: Table 8 revealed that a substantial increase in LAI was found as a result of raising algae culture filtrate (ACF) level from zero to 2 l/fed combined with 90 and/or 120 kg N/fed+30 l/fed of compost tea (CT), in the 2nd season. In the 1st season, chlorophyll "a" and RGR appreciably differed when ACF level was raised from 1 to 2 l/fed along with 30 l CT/fed and 90 kg N/fed, simultaneously the variances were insignificant with 120 kg N/fed. Under the different levels of N and CT, significant variances were detected in CGR, when ACF levels were increased from zero up to 2 l/fed, in the 2nd season. Meanwhile, there was a negligible impact with increasing ACF levels from 1 to 2 l/fed. Raising ACF level from zero to 2 l/fed along with 60 l CT/fed considerably affected chlorophyll "a", when beets were fertilized with 120 kg N/fed, in both seasons, whilst the effect was insignificant on chlorophyll "a" under 90 kg N/fed, in the 2nd season.

The aforementioned 2nd order interaction significantly influenced K content, sucrose (%) and extracted sugar (%) in the 1st season, root yield in the 2nd one and sugar yield in both seasons. Under the different N levels, elevating ACF from 1 to 2 l/fed combined with 30 l CT/fed, sucrose and extracted sugar percentages markedly varied. Potassium content was statistically influenced when the ACF level was raised from zero to 2 l/fed along with the different levels of nitrogen and CT. There was a significant difference between 1 and 2 l/fed of ACF levels in their impact on root and sugar yields/fed, when beets were fertilized with 90 kg N/fed+60 l CT/fed as a soil drench. However, the variances were insignificant under the same conditions above combined with 120 kg N/fed. The interaction among 60 l CT/fed, 2 l ACF/fed and 90 kg N/fed produced the highest sucrose (%) (20.04%) and extracted sugar (%) (18.16%), in the 1st season, as well as the greatest sugar yield/fed (5.09 and 4.55 t) in the two growing seasons, respectively. On the other hand, adding 120 kg N/fed in combination with 60 l CT/fed and 2 l ACF/fed resulted in the highest values of chlorophyll "a" (3.68 mg/g lfw), LAI (3.82), CGR (19.30 g/week), in the 2nd season.

Table 8: Significant interaction effect among nitrogen, compost tea and algae culture filtrate levels

			LAI	Chl. a (mg/g lfw)		CGR	RGR	RY/fed (ton)	S (%)	K	ES (%)	SY/fed (ton)	
N-level	Compost tea level (CT)	ACF level	2nd	1st	2nd	2nd	1st	2nd	1st	1st	1st	1st	2nd
90 kg/fed	Without	Without	2.39	2.91	2.52	6.38	0.068	23.58	18.04	3.09	16.08	3.27	3.06
		1 l/fed	2.56	3.36	3.13	8.63	0.071	24.20	18.57	2.76	16.70	3.73	3.66
		2 l/fed	3.34	3.38	3.33	10.78	0.070	25.44	19.14	2.29	17.33	3.92	3.91
	30 l/fed	Without	2.75	3.26	3.32	8.17	0.072	25.58	18.79	3.23	16.82	3.81	3.72
		1 l/fed	3.35	3.29	3.19	9.41	0.078	25.79	18.85	2.82	16.95	4.04	3.81
		2 l/fed	3.52	3.33	3.41	12.17	0.071	26.36	19.61	2.80	17.73	4.50	3.96
	60 l/fed	Without	3.34	3.28	3.18	10.62	0.081	26.13	18.60	3.44	16.63	4.19	3.99
		1 l/fed	3.56	3.30	3.31	14.56	0.075	27.54	19.70	3.44	17.75	4.71	4.25
		2 l/fed	3.59	3.51	3.34	15.94	0.090	29.15	20.04	3.00	18.16	5.09	4.55
120 kg/fed	Without	Without	3.08	3.36	3.35	8.91	0.072	25.48	17.54	3.16	15.57	3.62	3.34
		1 l/fed	3.30	3.49	3.27	12.37	0.073	25.92	17.58	3.26	15.61	3.74	3.81
		2 l/fed	3.48	3.47	3.48	14.77	0.094	26.89	19.42	2.71	17.57	4.25	4.06
	30 l/fed	Without	3.35	3.40	3.33	10.81	0.077	27.44	18.25	3.33	16.25	4.03	4.04
		1 l/fed	3.61	3.54	3.28	14.16	0.078	27.78	18.33	3.33	16.38	4.51	4.01
		2 l/fed	3.72	3.60	3.51	16.19	0.075	30.39	19.54	2.93	17.65	4.84	4.51
	60 l/fed	Without	3.70	3.40	3.26	12.44	0.090	30.53	17.93	3.62	15.83	4.26	4.28
		1 l/fed	3.79	3.65	3.57	17.06	0.099	30.69	18.17	3.60	16.07	4.71	4.47
		2 l/fed	3.82	3.67	3.68	19.30	0.099	30.92	18.52	3.62	16.50	4.87	4.53
LSD 0.05			0.23	0.18	0.27	3.36	0.011	1.38	0.58	0.27	0.60	0.19	0.27

ACF: Algae culture filtrate, LAI: Leaf area index, Chl.: Chlorophyll, CGR: Crop growth rate (g/week), RGR: Relative growth rate (g/g/week), RY: Root yield, S: Sucrose, K: Potassium ((mEq/100 g beet), ES: Extracted sugar, SY: Sugar yield, 1st: First season (2019/2020) and 2nd: Second season (2020/2021)

Correlation coefficient analysis: Table 9 cleared that root yield exhibited positive and highly significant correlations ($p \leq 0.01$) with root fresh weight/plant (RFW), crop growth rate (CGR), relative growth rate (RGR) and sugar yield. Furthermore, root yield was positively correlated with sucrose (%), extracted sugar (%) and sugar lost to molasses (SLM) and negatively with quality index, but without significance. A weak correlation was found between RFW and each sucrose (%) ($r = 0.268$) and extracted sugar (%) ($r = 0.198$). Negative and insignificant correlation coefficients ($p<0.01$) were found between the quality index and each of RFW, RGR and root yields, while it was positive and highly significant with sucrose (%) and extracted sugar (%). Sugar lost to molasses (%) was negatively and significantly correlated with sucrose at a 5% probability level and extracted sugar (%) and quality index ($p<0.01$), while it was positively with RFW, CGR and RGR. Sugar yield had a positive and high significant correlation with all parameters in this respect, except for quality index and sugar lost to molasses, which did not reach the level of significance. Simultaneously, the correlation between sugar yield and each of sugar lost to molasses and quality index was positive but without significant.

Economic evaluation: Table 10 shows the values of root yield/fed and sucrose (%) (average of the two seasons). It can be observed that the combination (N_2+CT_2+ACF_2) attained the greatest root yield/fed (30.01 t), while sucrose (%) decreased to 17.65%. On the other hand, the highest sucrose (%) (18.82%) was obtained from the combination (N_1+CT_2+ACF_2), versus a decrease in root yield/fed to 28.58 t.

As shown in Fig. 1, the total costs differed according to the used quantities of inorganic nitrogen as well as levels of CT and ACF; consequently, the total revenue varied. Based on the net return data, it can be noted that the application of nitrogen fertilizer, CT and ACF mostly tended to increase the total revenue as a result of the continuous increase in root yield, which corresponded to the increase in application rates. The combination (N_2 + CT_2 + ACF_2) achieved the highest total revenue, as it reached L.E. 17867, followed by the combination (N_1 + CT_2 + ACF_2), which recorded L.E. 17730. However, the combination (N_1 + CT_2 + ACF_2) resulted in the highest values of net return, as it scored L.E. 8166, followed by the combination (N_2 + CT_2 + ACF_2), which attained L.E. 7857.

DISCUSSION

The positive impact of nitrogen on plant growth and physiological traits (Table 3) could be due to its role in cell division and expansion, where it is an essential component of amino acids, which are the building blocks of plant proteins and are necessary for growth and development of vital plant tissues and cells such as cell membranes and chlorophyll[26]. Also, supplying plants with N to a certain extent leads to increases in protein formation and this encourages the formation of large-surfaced leaves that metabolize carbohydrates with high efficiency, but increasing N above the

Table 9: Simple correlation coefficient analysis between some of the studied traits (average of the two seasons)

Traits	1	2	3	4	5	6	7	8
1. Root fresh weight/plant (g)								
2. Crop growth rate (g/week)	0.946**							
3. Relative growth rate (g/g/week)	0.914**	0.913**						
4. Root yield/fed (ton)	0.963**	0.937**	0.900**					
5. Sucrose (%)	0.268	0.401	0.194	0.283				
6. Sugar lost to molasses (%)	0.460	0.281	0.439	0.460	-0.542*			
7. Extracted sugar (%)	0.198	0.342	0.130	0.211	0.995**	-0.619**		
8. Quality index	-0.112	0.066	-0.144	-0.107	0.880**	-0.873**	0.921**	
9. Sugar yield/fed (ton)	0.881**	0.916**	0.802**	0.915**	0.643**	0.116	0.587**	0.295

*and **Denote significance at 0.05 and 0.01 levels of probability, respectively

Table 10: Root yield/fed (ton) and sucrose% (average of the two seasons)

		Root yield/fed (ton)			Sucrose (%)		
		Algal culture filtrate level (ACF)					
N-level	Compost tea level (CT)	ACF_0	ACF_1	ACF_2	ACF_0	ACF_1	ACF_2
N_1	CT_0	21.98	23.26	23.99	16.50	17.87	18.25
	CT_1	24.11	24.83	25.87	17.70	17.85	18.32
	CT_2	25.67	27.05	28.58	18.01	18.60	18.82
N_2	CT_0	24.35	24.96	25.56	16.39	17.21	18.29
	CT_1	26.13	27.64	28.90	17.57	17.46	18.25
	CT_2	28.73	30.01	30.23	17.15	17.47	17.65

N_1 and N_2: 90 and 120 kg N/fed, respectively, CT_0, CT_1 and CT_2: Without, 30 and 60 l/fed of compost tea, respectively and ACF_0, ACF_1 and ACF_2: Without, 1 and 2 l/fed three times of algal culture filtrate, respectively

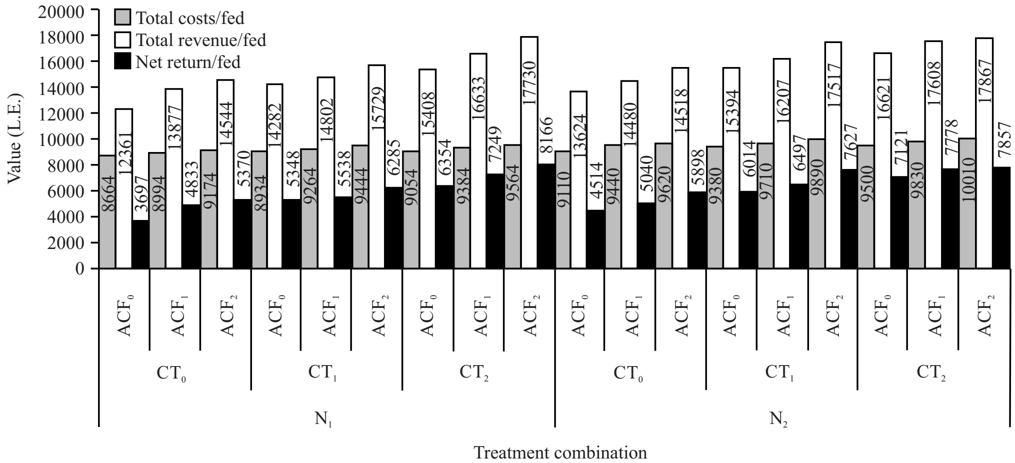

Fig. 1: Economic evaluations of root yield/fed (average of 2019/2020 and 2020/2021 seasons) with sucrose incentive
N_1 and N_2: 90 and 120 kg N/fed (L.E. 205/50 kg ammonium nitrate "33.5% N", average price for both seasons); CT_0, CT_1 and CT_2: Without, 30 and 60 l/fed of compost tea (L.E. 4/L) and ACF_0, ACF_1 and ACF_2: Without, 1 and 2 l/fed thrice of algae culture filtrate (L.E. 60/L), respectively

appropriate limit may lead to a lack of absorption of some other elements, especially phosphorous and this negatively affects plant growth. The content of chlorophyll in sugar beet leaves is strongly related to nitrogen fertilization and determines the final yield of crops[3]. Moreover, the low value of N in the experimental site (Table 1) may be one of the reasons for the clear effect of nitrogen. Such findings are similar to those stated by Makhlouf and Abd El-All[1] and Wang *et al.*[3]. On the other hand, the reduction in sucrose (%), extractable sugar (%) and quality index (Table 4) with lifting N level may be attributed to the role of N in increasing RFW (Table 3), water retention in roots and consequently increasing non-sucrose substances, such as proteins and amino compounds, caused by the extreme of N uptake[27]. The significant increase in the quality index as a consequence of fertilization with a lower level of nitrogen, i.e., 90 kg/fed, maybe due to an increment in sucrose and extracted sugar percentages, which corresponds to lower contents of impurities such as potassium and α-amino nitrogen. These results are in line with those obtained previously by Pogłodziński *et al.*[28] who observed that raising N levels added to the soil up to 200 kg ha^{-1} decreased sucrose (%) and increased α-amino nitrogen content, while K and Na contents and sugar yield ha^{-1} of sugar beet were not affected. The obtained increase in sugar yield by adding 120 kg N/fed (Table 4) may be referred to as the increase in root yield/fed (Table 3), which compensated for the decrease in sucrose percentage. In line with these results, Varga *et al.*[29] proved that application of 99 kg N/ha produced maximum root and sugar yields ha^{-1}, versus a reduction in sucrose content. This trend supports the collected results in Table 3 and 4.

The augmentative impact of compost tea (CT) on plant growth, chlorophylls and carotenoids content (Table 3) may be attributed to its beneficial effects, where it contains many macronutrients (Table 2), natural hormones like cytokinins, gibberellins and indole acetic acid, vitamins and antioxidants in available forms for plants, which positively reflected on their growth with a favourable allocation to roots relative to shoots and its composition[30]. Also, compost tea contains rhizobacteria in an active state via their existence in a suitable niche that stimulates root growth and provides it with a larger surface area[31]. The highest CGR was obtained under application with compost tea[32]. Similar results were obtained with Abd El-Rahman *et al.*[6], who found that application of 20 l compost tea/fed significantly increased RFW and root yield/fed of sugar beet, as compared to untreated plants and/or treated with 15 l/fed, in sandy soil. In the same trend, the best values were obtained for leaves fresh and dry weights/plant and photosynthetic pigments of henna plants, due to the use of 60 ml compost tea/l[9]. Regarding the fertile content of compost tea from NPK (Table 2), the application of compost tea improved NPK absorption in plants[9] and reestablished the ionic balance by alleviating excessive absorption levels of Na in sugar beet plants[7]. This tendency supports the obtained results in Table 4. The obvious increment in potassium and α-amino N content of juice may be attributed to that nutrient analysis revealed that nitrogen and potassium were well presented in compost tea added under this study (Table 2), making teas an interesting source of fertilizer for crop application[33], but this increase was negatively reflected on juice quality. It is noteworthy that the efficiency of the sugar extraction process is adversely affected by increasing the concentration of solute substances other than sucrose and the inter-relationships between the accumulation of sucrose and these so-called impurities, which plays a principal role in the values of the quality index. The increment in sugar yield may be back to the fact that adding compost tea to the soil improved root yield/fed (Table 3), along with the accumulation of dry matter, in turn, enhanced sucrose content in beetroots (Table 4), as well as improved total carbohydrates[9]. The results are consistent with those obtained by Pibars *et al.*[8] and Osman *et al.*[7].

Feeding sugar beet plants with different levels of algal culture filtrate (ACF) increased all morphological and physiological parameters (Table 3). The beneficial impact of algal culture filtrates maybe because it contains auxins, cytokinins and polysaccharides that have an effective role in cell division and enlargement and stimulate physiological activities, which positively reflected on plant growth characteristics and roots productivity. In addition, spraying algae extract improves the photosynthetic pigment contents[34]. It may play a role through its containment of cytokinins in delaying the leaves' ageing by reducing the chlorophyll degradation[16] and its influence stimulated the nutrients held by plants[35]. In the same trend, foliar application with algae extract increased chlorophyll content and fresh and dry weights/plant in sugar beet[12]. Also, El-Sharnoby *et al.*[36] demonstrated that foliar utilization of *S. platensis* algae with 2 g/l+120 kg N/fed fundamentally improved photosynthetic pigment contents, RFW, TFW and root and sugar yields. The increases in sucrose (%), extracted sugar and quality index with the highest level of ACF treated beet canopies, i.e., 2 l/fed (Table 4) could be attributed to raising chlorophyll content in leaves (Table 3), which encouraged the photosynthetic activity of the treated plants, leading to more different metabolic substances production, such as accumulation of carbohydrates and dry matter in plant tissues, which positively contributed to the final output, i.e., sugar yield. These findings are in line with those reported by El-Fotoh *et al.*[16] and Ghazy *et al.*[13]. In addition, Morsy[37] found that the application of algae extracts to the soil or foliage increased carbohydrate content.

The significant variances in growth and yield characteristics (Table 5) resulting from the upward increase in CT levels under the different N levels may be referred to as the role of microorganisms present in compost tea that stimulate nutrient uptake and improve plant growth by producing hormone-like and/or volatile molecules with biostimulant effects[38]. The combination of 90 kg N/fed added to the soil+soil drenching with 60 l CT/fed was more distinct in sucrose (%) and extracted sugar (%) increases than that gained by 120 kg N/fed with the same level of compost tea mentioned above (Table 5). This result indicates that the use of compost tea is effective in treating soil fertility and nutrient deficiencies[5], which has a positive effect on sugar storage in roots and improves juice quality. The positive influence of applying a combination of organic and natural sources on some morphological, physiological and quality traits (Table 7) may be due to the integration of roles between soil supplement of compost tea (60 l/fed) and *S. platensis* algae culture filtrate (2 l/fed) sprayed on beet canopies, as compost tea can improve soil microbial populations and stability[39], which is accompanied by better nutrient uptake by tea-treated plants, ultimately promoting overall root development[40]. Furthermore, algae culture increased photosynthetic efficiency and carbohydrate accumulation, which had a positive impact on root sugar storage. Under conditions of low nitrogen fertilizer level, i.e., 90 kg N/fed, the favourable combination of 60 l compost tea/fed as a soil drench and 2 l/fed of algal culture filtrate as a foliar spray on beet canopies (Table 8) may be attributed to the better environmental conditions provided by compost tea in the plant rhizosphere besides as well as its role in increasing the presence of beneficial microorganisms and the level of supply in available form of nutritional elements required by the plant[31]. Furthermore, algae extract is considered a source of the high content of plant regulators that directly enhance the metabolism process, as well as containing some nutrients essential for plant growth and development[16].

Regarding correlation coefficient analysis (Table 9), the weak correlation that was found between RFW and each sucrose (%) and extracted sugar (%) may indicate that RFW was not increased to the size that negatively affects sugar content. The observed adverse correlation between the RFW and quality index may be due to the increase in impurity contents represented in potassium and α-amino N with a decrease in sucrose and extracted sugar percentages. On the other hand, the strong correlation between sugar and root yields is probably attributed to the high positive correlation between growth parameters and root weights, which was positively reflected in the final sugar yield. Some investigators studied the association between root and/or sugar yield with each of the yield components and juice quality, El-Sarag and Moselhy[41] found that sugar yield was positively correlated with root yield but negatively correlated with quality index. Also, Makhlouf *et al.*[42] stated that root and sugar yields were significantly and/or positively correlated with sucrose (%), while root yield was negatively correlated with quality index.

The economic evaluation (Fig. 1) showed that sugar beets fertilized with the low N level, i.e., 90 kg/fed+60 l CT/fed+2 l/fed of ACF, resulted in higher net return values than that gained under the maximum N level, i.e., 120 kg/fed combined with the same levels of CT and ACF. The positive result may be due to an increase in the total sugar incentive payable over the total tons of roots. These observations indicate that the efficiency of sugar beet plants in using nitrogen was higher under the low N level, along with compost tea and algal culture filtrate treatments than under the maximum N level fertilization. The previous results indicate that it is necessary to conduct focused studies on the use of environmentally friendly non-traditional sources to improve the yield and quality of the sugar beet crop.

CONCLUSION

Under conditions of the current study, supplying beet plants with a combination of (90 kg N/fed+60 l/fed of compost tea as a soil drench+foliar spraying with 2 l/fed three times of *Spirulina platensis* algae culture filtrate) can be recommended to get economical root and sugar yields of sugar beet grown in a loamy sand soil at Ismailia Province, Egypt.

SIGNIFICANCE STATEMENT

This study assured the possibility of using compost tea and *Spirulina platensis* algae culture filtrate to improve plant growth traits and physiological properties, as well as root and sugar yields of sugar beet grown under a moderate level of inorganic nitrogen fertilizer. The results will provide valuable information for future studies. Therefore, there should be additional future studies focusing on the importance of non-traditional sources in plant nutrition and improving soil properties, especially in reclaimed soils, for sustainable agriculture.

ACKNOWLEDGMENT

The authors acknowledge the technical support provided by Sugar Crops Research Institute (SCRI), Agricultural Research Center (ARC), Giza, Egypt.

REFERENCES

1. Makhlouf, B.S.I. and A.E.A. Abd El-All, 2017. Effect of deficit irrigation, nitrogen and potassium fertilization on sugar beet productivity in sandy soils. Menoufia J. Plant Prod., 2: 325-346.
2. Mizran, B.T.H., K.A. Bohlika and I.S. Abuzaid, 2021. Response of productivity and quality of sugar beet crop to different nitrogen and potassium fertilizer levels in sandy soils. Alexandria Sci. Exch. J., 42: 1635-1645.
3. Wang, N., F. Fu, H. Wang, P. Wang and S. He *et al*., 2021. Effects of irrigation and nitrogen on chlorophyll content, dry matter and nitrogen accumulation in sugar beet (*Beta vulgaris* L.). Sci. Rep., Vol. 11. 10.1038/s41598-021-95792-z.
4. Saad, S.A., B.M. Elameen, T. AbdElkareem AbdElhameed, W.M.A. Yassien and A.M. El-Tayeb, 2021. The effect of compost tea application on some soil characteristics. Int. J. Res. Appl. Sci. Eng. Technol., 9: 511-514.
5. Ingham, E.R., 2005. The Compost Tea Brewing Manual. 5th Edn., Soil Food Web Inc., Corvallis, United States, Pages: 79.
6. El-Rahman, M.M.A., A.A.A. El-Ftooh and M.A. Ghonema, 2017. Response of some sugar beet varieties to foliar spraying with compost tea and its relationship with two sugar beet insects, beet fly, (*Pegomya mixta* Vill.) and tortoise beetle (*Cassida vittata* Vill.) under newly reclaimed sandy soil. Menoufia J. Plant Prod., 2: 53-63.
7. Osman, H.S., A.M.S. Rady, A. Awadalla, A.E.D. Omara and E.M. Hafez, 2021. Improving the antioxidants system, growth, and sugar beet quality subjected to long-term osmotic stress by phosphate solubilizing bacteria and compost tea. Int. J. Plant Prod., 16: 119-135.
8. Pibars, S.K., H.A. Mansour and M.S. Gaballah, 2018. Effect of water regime and compost tea on growth characters of sugar beet under different irrigation system. World Wide J. Multidisciplin. Res. Dev., 4: 321-325.
9. Abdel-Mola, M., M. Aboel-Ainin and A. Ayyat, 2021. Enhancement of vegetative growth criteria and accumulation of secondary metabolites by using compost tea and paclobutrazol on henna (*Lawsonia inermis* L.) plants. Egypt. J. Hortic., 48: 207-219.
10. Bello, A.S., I. Saadaoui and R. Ben-Hamadou, 2021. "Beyond the source of bioenergy": Microalgae in modern agriculture as a biostimulant, biofertilizer, and anti-abiotic stress. Agronomy, Vol. 11. 10.3390/agronomy11081610.
11. Bella, E.L., A. Baglieri, E.I. Rovetto, P. Stevanato and I. Puglisi, 2021. Foliar spray application of *Chlorella vulgaris* extract: Effect on the growth of lettuce seedlings. Agronomy, Vol. 11. 10.3390/agronomy1102030.
12. Enan, S.A.A.M., A.M. El-Saady and A.B. El-Sayed, 2016. Impact of foliar feeding with alga extract and boron on yield and quality of sugar beet grown in sandy soil. Egypt. J. Agron., 38: 319-336.
13. Ghazy, N.A., O.A.A. El-Hafez, A.M. El-Bakery, D.I.H. El-Geddawy, 2021. Impact of silver nanoparticles and two biological treatments to control soft rot disease in sugar beet (*Beta vulgaris* L). Egypt. J. Biol. Pest. Control., Vol. 31. 10.1186/s41938-020-00347-5.
14. Abd El-Aleem, W., S.F. Hendawy, E.S. Hamed and W.I.M. Toaima, 2017. Effect of planting dates, organic fertilization and foliar spray of algae extract on productivity of dutch fennel plants under sinai conditions. J. Med. Plants Stud., 5: 327-334.

15. Abdallah, M.A., S.M.M. Salem and D.M.G. Hendi, 2019. Effect of nitrogen fertilizer rates and microalgae application on the vegetative growth and biochemical constituents of sweet basil plants. J. Hortic. Sci. Ornamental Plants, 11: 244-251.
16. El-Fotoh, H.M.A., L.A.A. El-Rahman and S.M.S. El-Kalawy, 2020. Effect of sulphur application and some foliar feeding on productivity and roots quality of sugar beet. J. Soil Sci. Agric. Eng., 11: 631-639.
17. Estefan, G., R. Sommer and J. Ryan, 2013. Methods of Soil, Plant, and Water Analysis: A Manual for the West Asia and North Africa Region. 3rd Edn., ICARDA, Lebanon, Pages: 243.
18. Abdel-Wahab, A.F.M., 2008. Evaluation of enriched compost and its role in synergy with rhizobacteria and N-fertilization for improving maize productivity in sandy soil. Arab Univ. J. Agric. Sci., 16: 319-334.
19. Yan, S.G., L.P. Zhu, H.N. Su, X.Y. Zhang, X.L. Chen, B.C. Zhou and Y.Z. Zhang, 2010. Single-step chromatography for simultaneous purification of C-phycocyanin and allophycocyanin with high purity and recovery from *Spirulina* (*Arthrospira*) *platensis*. J. Appl. Phycol., 23: 1-6.
20. Gharib, H.S. and A.S. El-Henawy, 2015. Response of Sugar Beet to Three Irrigation Regimes. In: Applications of Furrow and Micro Irrigation in Arid and Semi-Arid Regions, Goyal, M.R. (Ed.), Chapter 13, Apple Academic Press., Canada, ISBN: 9780429161919, Pages: 28.
21. Vijayalakshmi, M.R. and S. Rjarathnam, 2011. Analytical Methods in Fruit and Vegetable Processing. In: Advances in Preservation and Processing Technologies of Fruits and Vegetables. Rjarathnam, S. and R.S. Ramteke (Eds.), New India Publishing Agency, New Delhi, India, ISBN: 978-93-80235-52-3 pp: 575-604.
22. AOAC., 2019. Official methods of analysis of the Association of Analytical Chemists. 21st Edn., Official Methods of Analysis™ Washington, DC, USA.
23. Harvey, C.W. and J.V. Dutton, 1993. Root Quality and Processing. In: The Sugar Beet Crop. Cook, D.A. and R.K. Scott (Eds.), Springer, Dordrecht, ISBN: 978-94-010-6654-9, pp: 571-617.
24. Cohen, J., P. Cohen, S.G. West and L.S. Aiken, 2002. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. 3rd Edn., Routledge, New York, ISBN: 9780203774441, Pages: 536.
25. Casella, G., 2008. Statistical Design. 1st Edn., Springer, New York, ISBN: 978-0-387-75965-4, Pages: 307.
26. Tsialtasa, J.T. and N. Maslaris, 2008. Sugar beet response to N fertilization as assessed by late season chlorophyll and leaf area index measurements in a semi-arid environment. Inter. J. Plant Prod., 2: 57-70.
27. Abdelaal, K.A.A. and F.T. Sahar, 2015. Response of sugar beet plant (*Beta vulgaris* L.) to mineral nitrogen fertilization and bio-fertilizers. Int. J. Curr. Microbiol. Appl. Sci., 4: 677-688.
28. Pogłodziński, R., P. Barłóg and W. Grzbisz, 2021. Effect of nitrogen and magnesium sulfate application on sugar beet yield and quality. Plant Soil Environ., 67: 507-513.
29. Varga, I., Z. Lončarić, S. Kristek, A.M. Kulundžić, A. Rebekić and M. Antunović, 2021. Sugar beet root yield and quality with leaf seasonal dynamics in relation to planting densities and nitrogen fertilization. Agriculture, Vol. 11. 10.3390/agriculture11050407.
30. Smith, R.F., S.I. Cameron, J. Letourneau, T. Livingstone, K. Livingstone, K. Sanderson, 2006. Assessing the Effects of Mulch, Compost Tea, and Chemical Fertilizer on Soil Microorganisms, Early Growth, Biomass Partitioning, and Taxane Levels in Field-grown Rooted Cuttings of Canada Yew (*Taxus canadensis*). Proceeding of 33rd Plant Growth Regulator Society of America Annual Conference, July 9-13, 2006, Canadian Forest Service Publications, 27-33.
31. Badawi, F.S.F., A.H. Desoky and T. Selim, 2014. Response of two lentil varieties to bio-enriched compost tea. Nat. Sci., 12: 119-130.
32. Safaee, M., A. Rahimi, B. Torabi and A. Khoram, 2016. Effect of vermi-compost fertilizer application and foliar spraying of compost tea and acid humic on growth indices of safflower (*Carthamus tinctorius* L.). J. Agroecol., 9: 805-820.
33. González-Hernández, A.I., M.B. Suárez-Fernández, R. Pérez-Sánchez, M. Ángeles Gómez-Sánchez and M.R. Morales-Corts, 2021. Compost tea Induces growth and resistance against *Rhizoctonia solani* and *Phytophthora capsici* in pepper. Agronomy, Vol. 11. 10.3390/agronomy11040781.
34. Kim, S.K. and K. Chojnacka, 2015. Marine Algae Extracts: Processes, Products, and Applications. Wiley-VCH Verlag GmbH and Co. KGaA, Weinheim, Germany, ISBN: 9783527337088, Pages: 784.
35. Abdel-Mawgoud, A.M.R., A.S. Tantaway, M.M. Hafez and H.A.M. Habib, 2010. Seaweed extract improves growth, yield and quality of different watermelon hybrids. Res. J. Agric. Biol. Sci., 6: 161-168.
36. EL-Sharnoby, H.M., E.A. Badr and F.F.A. Elenen, 2021. Influence of foliar application of algae extract and nitrogen fertilization on yield and quality of sugar beet grown in reclaimed sandy soil. SVU-Inter. J. Agric. Sci., 3: 1-15.
37. Morsy, N., 2019. Productivity and quality of kohlrabi grown in a newly reclaimed sandy soil using organic and mineral-N fertilizer regimes with or without spraying of *Spirulina platensis* extract. Egypt. J. Hortic., 46: 169-178.
38. Luziatelli, F., A.G. Ficca, G. Colla, E.B. Švecová and M. Ruzzi, 2019. Foliar application of vegetal-derived bioactive compounds stimulates the growth of beneficial bacteria and enhances microbiome biodiversity in lettuce. Front. Plant Sci., Vol. 10. 10.3389/fpls.2019.00060.
39. Naidu, Y., S. Meon, J. Kadir and Y. Siddiqui, 2010. Microbial starter for the enhancement of biological activity of compost tea. Int. J. Agric. Biol., 12: 51-56.

40. Mahmoud, E., E. El-Gizawy and L. Geries, 2015. Effect of compost extract, N_2-fixing bacteria and nitrogen levels applications on soil properties and onion crop. Arch. Agron. Soil Sci., 61: 185-201.
41. El-Sarag, E.I. and S.H. Moselhy, 2013. Response of sugar beet quantity and quality to nitrogen and potasium fertilization under sandy soils conditions. Asian J. Crop Sci., 5: 295-303.
42. Makhlouf, B.S.I., E.H.S. El-Laboudy and F.F.B. Abu-Ellail, 2021. Effect of N-fixing bacteria on nitrogen fertilizer requirements for some sugar beet varieties. J. Plant Prod., 12: 87-96.