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RESEARCH ARTICLE

The impact of nitrogen fertilization, bio-fertilizers and molasses on the growth and morphological characteristics of sugar beet plants (Beta vulgaris L.)

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Abstract

Two field experiments were carried out at the research farm of Nubaryia Sugar and Refining Company (NSRC), located at (30°63' 88.93" N latitude; 30°22′ 46.21″ E longitude), El-Behaira Governorate during the two successive fall seasons of 2019/2020 and 2020/2021. The main objectives of this study were to determine the impact of four nitrogen fertilizer levels (without, 60, 80 and 100 kg fed^{-1}), three bio-fertilizers treatments (without, Cerealine® and T.S®), four Molasses levels (without, 20, 40 and 60 kg.fed^{-1}) and their interactions on growth and morphological characteristics of sugar beet plants. A split-split plot design with three replications was used, where the nitrogen fertilizer levels were allocated in the main plots and bio-fertilizer treatments were distributed in the sub-plots, as well as molasses treatments occupied the sub-sub plots. The results indicated that increasing nitrogen fertilizer rates significantly improved growth, and morphological characteristics as well as the biomass of sugar beet plants. The high rates of nitrogen (100 and 80 kg N fed^{-1}), bio-fertilizers treatments (T.S®) and molasses (60 and 40 kg N fed^{-1}) alone produced the highest morphological characteristics (leaf area index, root length, root diameter), growth character (root fresh weight, leaves fresh weight and total fresh weight) throughout the 1st and 2nd seasons, respectively, without significant differences. The interaction between nitrogen rates, molasses and bio-fertilizers (80 kg N fed^{-1}+ 40 kg Molasses fed^{-1}+ T.S) gave the highest values for most all studied characteristics. So, bio-fertilizer treatments proved a major role in crop production optimization and are expected to reduce the pollution of the agricultural environment.

Key words: Sugar beet; Growth characteristics; Mineral fertilizers; Molasses; Biofertilizer.

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Introduction

Sugar beet ranked the second sugar crop after sugarcane in the world as it provides about 40% of the world's sugar production. The importance of this crop is not only to produce sugar but also to use its top in feeding animals due to the high nutritive value of the sugar beet canopy.

Egypt faces many difficulties that affect the productivity of crops in general and sugar crops in particular, including sugar beet, which evolves significantly at the moment. Solower, it became the first source for the production of sugar in Egypt, where the production of sugar from beets account for about 61.2% (1708400 tons) of sugar production in Egypt while sugarcane production was 29.9% (835215 tons; Sugar Crops Council 2022). One of the main problems is the water after the construction of El-Nahda Dam and the high prices of fertilizer, particularly nitrogen.

One of the most important limiting factors in sugar beet cultivation is nitrogen fertigation. The use of N-fixing bacteria is of economic importance to modern agriculture as they can partially lower the cost of mineral N fertilizers. Dropping production costs and reducing environmental pollution ensuring high yields. Bio-fertilizer has emerged as a promising component of integrating nutrient supply systems in intensive agriculture. Therefore, attempts have been made to use bio-fertilizer as being the cheapest and safe for agricultural application (Ahmed et al. 2023a&b; Galal et al. 2022).

Bio-fertilizers technologies are based on enhancing and improving the naturally existing nutrient transformation activities in the soil profiles when the inoculants should be able to be adapted to the environmental conditions prevailing in the site of application. Whereas inoculation seeds of various C3 and C4 plants with associative nitrogen-fixing bacteria led to improved plant growth and yield (Eid, 1982). Sugar beet molasses was used in this study, so that; use of sugar beet molasses in agriculture stimulates nutrient elements uptake efficiency and soil biological activity (Samavat and Samavat, 2014).

Molasses has been used in the past as fertilizer and soil improver, particularly on sandy soil and soil of poor structure (Al-Dhumri et al. 2023; Alharbi et al. 2023). As well as provides other favorable effects on plant growth (Schenck, 2001). Filter mud cake, FYM and molasses increased NPK uptake and yields (Aljabri et al. 2021; Alotaibi et al. 2021; Abo-Baker 2017). Therefore, the aims of the present study were focused on the effect of four nitrogen fertilizer levels (without, 60, 80 and 100 kg fed^{-1}), three bio-fertilizers treatments (without, Cerealine® and T.S®), four Molasses levels (without, 20, 40 and 60 kg fed^{-1}) and their interactions on growth characteristics of sugar beet plants during 2019/2020 and 2020/2021 seasons under the environmental conditions of Nubaria district.

Materials and methods

Two field experiments were carried out at the research farm of Nubaryia Sugar and Refining Company (NSRC), located at (30°63' 88.93" N latitude; 30°22′ 46.21″ E longitude), El-Behaira Governorate during the two successive fall seasons of 2019/2020 and 2020/2021. The main objectives of this study were to determine the impact of four nitrogen fertilizer levels, three bio-fertilizers treatments, (without, Cerealine® and T.S®), four Molasses levels and their interactions on growth and morphological characteristics of sugar beet plants (Beta vulgaris L.).

Bio-fertilizers

The studied bio-fertilizers included the following: without Bio-fertilizers (Untreated), Cerealine® and T.S®. The seeds of sugar beet were inoculated with Cerealine ® before sowing and away from direct sunlight, while T.S® was added after sowing of sugar beet seeds with the first irrigation after thinning. Cerealine ® contains bacteria that fixed atmospheric nitrogen but T.S® contains molasses as the organic material carrier of microorganisms, and a set of mixed cultures of *Bacillus circulans* 0.5×10^9 (cfu), *B. poylmyxa* 2×10^7 (cfu), *B. megatherium* 1.5×10^9 (cfu), *Candida* spp. 1.5×10^7 (cfu), and *Trichoderma* spp. 0.5×10^6 (cfu) m L^{-1} that facilitated phosphorus absorption, with the rate of 5 L fed^{-1}. These bio-fertilizers contain living microorganisms that, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. The seeds of sugar beet were inoculated with Cerealine® before sowing away from direct sunlight, while T.S® was added after sowing of sugar beet plants with the first irrigation after thinning.

Molasses rates

The studied Molasses levels included: without Molasses fertilizer (without), 20 kg Molasses fed^{-1}, 40 kg Molasses fed^{-1}, and 60 kg Molasses fed^{-1} applied as a side-dressing in two equal doses, the first was applied after thinning and the other was applied four weeks later. The chemical composition of molasses produced from beet sugar processing is shown in Table 1.

Table 1. Chemical compositions of molasses produced from beet sugar processing.

Molasses Parameters	Value	Molasses Parameters	Value
PH	8.3	K (%)	5.70
Brix (%)	78.5	Ca (%)	0.330
Total sugar (%)	49.0	Mg (%)	0.229
Ash (%)	12.9	Na (%)	0.171
N (%)	1.73	Density (g/cm2)	1.61
P (%)	0.013		

Nitrogen rates

The studied nitrogen levels included: without nitrogen fertilizer (without), 60 kg N fed^{-1}, 80 kg N fed^{-1}, and 100 kg N fed^{-1} applied as a side-dressing in two equal doses, the first was applied after thinning and the other was applied four weeks later in Form of ammonium nitrate 33.5% N. The experimental plots were cultivated with the multigerm sugar beet variety (PTS 970 cv.) on September 20 in both growing seasons. However, harvest was performed on April 1 and 10 in the two studied growing seasons, respectively.

Experiment design

A split-split plot design with three replications was used, where the nitrogen fertilizer levels were allocated in the main plots and bio-fertilizer treatments were distributed in the sub-plots. The sub-plot area was 21 m2 (1/200 fed.), with 6 m in length and 3.5 m width, i.e., six ridges, as well as molasses treatments, occupied the sub-sub plots. Sugar beet seeds were hand-sown (3-5 seeds/hill) using the dry sowing method on one side of the ridge in hills 15 cm apart and irrigated immediately after sowing. Plants were thinned at the age of 35 days from sowing to obtain one plant/hill. All other agricultural practices were applied at the recommendations of the Egyptian Ministry of Agriculture. Soil samples were randomly taken pre-sowing from the experimental site at a depth of 0 to 30 cm from the soil surface and prepared for both physical and chemical analysis according to Ankerman and Large (1974) as shown in Table 2.

Table 2. Physical and chemical properties of the experimental soil in 2019/2020 and 2020/2021 growing seasons.

Soil properties	Season		Soil properties	Season	
	2019/2020	2020/2021		2019/2020	2020/2021
A- Mechanical analysis			2- Soluble anions (1:2) (Cmo1/kg soil)		
Sand %	91	93	CO^-_3+ HCO^-	5.1	5.2
Clay %	5.83	3.87	CL^-	7.29	7.19
Silt %	3.17	3.13	SO^-_4	1.01	0.94
Soil texture	Sandy	Sandy	Calcium carbonate	6.23	6.13
B- Chemical properties			Total nitrogen (mg/kg)	2.4	2.5
pH 1:1	8.14	8.33	Available phosphorus (mg/kg)	0.2	0.2
E.C. (ds/m)	1.45	1.34			
1- Soluble cautions (1:2) (Cmo1/kg soil)			Organic matter %	0.38	0.37
K^+	0.87	0.98			
Ca^{++}	2.84	2.78			
Mg^{++}	1.82	1.96			
Na^{++}	8.97	7.68			

Data Recorded

Five guarded plants were randomly sampled from each plot at harvest to determine the following growth characteristics:

- Leaf area index (LAI):
- Root length (cm).
- Root diameter (cm).
- Root fresh weight (g/ plant).
- Leaves fresh weight (g/ plant).
- Total fresh weight (g/ plant).

Statistical analysis

All collected data were subjected to statistical analysis following the procedure described by Gomez and Gomez (1984). The least significant difference test (LSD) at 0.05 probability was used to compare between means of the different treatments.

Results

Leaf area index

Data in Table 3 showed that the leaf area index gradually increased with increasing nitrogen fertilizer levels and the highest value 5.67 was obtained by 100 kg N fed^{-1} with significant variations between other nitrogen fertilizer levels at $P \leq 0.05$, but the lowest value 4.57 was obtained by 60 kg N fed^{-1} when compared to the untreated check which gave 4.20 without significant variations at $P \leq 0.05$ during the two studied seasons of 2019/2020 and 2020/202.

Bio-fertilizer of Cerealine and T.S gave leaf area index 5.14 and 4.95 without significant differences, respectively compared to the untreated check that gave 4.51 at $P \leq 0.05$ during the two studied seasons of 2019/2020 and 2020/202.

Table 3. Effect of bio and chemical nitrogen fertilizer with molasses and their interaction on leaf area index (LAI) of sugar beet plants by the combined analysis of the 2019/ 2020 and 2020/ 2021 growing seasons.

Nitrogen (N)	Biofertilizer (Bio)	Molasses (Mo)				
		Control	20 Kg fed^{-1}	40 Kg fed^{-1}	60 Kg fed^{-1}	Mean
Control	Control	5.40	4.96	4.50	3.75	4.65
	Cerealine	3.45	4.21	6.03	3.00	4.17
	T.S	3.62	4.52	3.72	3.25	3.78
Mean		4.16	4.56	4.75	3.33	4.20 c
60 Kg fed^{-1}	Control	4.03	3.83	2.86	3.86	3.64
	Cerealine	6.30	5.23	6.16	5.29	5.74
	T.S	3.34	4.43	4.67	4.84	4.32
Mean		4.56	4.50	4.56	4.66	4.57 c
80 Kg fed^{-1}	Control	3.27	4.33	5.70	5.43	4.68
	Cerealine	5.75	3.29	5.45	4.55	4.76
	T.S	2.54	6.33	6.20	7.48	5.64
Mean		3.85	4.65	5.78	5.82	5.03 b
100 Kg fed^{-1}	Control	3.29	6.84	4.83	5.36	5.08
	Cerealine	4.98	5.24	5.45	7.80	5.87
	T.S	5.74	5.76	5.65	7.13	6.07
Mean		4.67	5.95	5.31	6.76	5.67 a
Bio × Mo	Control	4.00	4.99	4.47	4.60	4.51 b
	Cerealine	5.12	4.49	5.77	5.16	5.14 a
	T.S	3.81	5.26	5.06	5.67	4.95 a
Mean		4.31 b	4.92 a	5.10 a	5.14 a	4.87

$LSD_{0.05}$			
Nitrogen (N):	0.38	N × Bio:	0.55
Biofertilizer (Bio):	0.28	N × Mo:	0.44
Molasses (Mo):	0.22	Bio × Mo:	0.38
		N × Bio × Mo:	0.75

Applying 60 kg molasses fed^{-1} gave the highest value of leaf area index of 5.14 compared to the control treatment which gave 4.31 with significant differences at P≤0.05 during the two studied seasons of 2019/2020 and 2020/202. Outcomes obtained from the combined analysis showed that the interaction between nitrogen and bio-fertilizer (100 kg N fed^{-1}+T.S) gave the highest value of 6.07, but the lowest leaf area value of 4.43 was achieved from the application of 20 kg N fed^{-1} and T.S. moreover, the combined analysis showed that the interaction between nitrogen and molasses (100 kg N fed-1 and 60 kg molasses fed^{-1}) gave the highest value of LAI of 6.76, however, the lowest LAI value of 4.66 resulted from the application of 60 kg N fed^{-1} and 60 kg molasses fed^{-1}. The interaction between bio-fertilizer and molasses had significantly affected LAI with the highest value (5.77) obtained from the application of Cerealine and 40 kg molasses fed^{-1}. with value and the lowest LAI of 4.49 resulted from the application of T.S + 20 kg fed-1 molasses.

Data in Table 3 demonstrated that the combined analysis of the nitrogen fertilizer and bio-fertilizer with molasses and their interaction exhibited significant effects (P≤0.05) on LAI in the 2019/2020 and 2020/2021 growing seasons. The highest LAI values (7.80 and 7.48) were obtained from the application of 100 kg N fed^{-1} in combination with Cerealine and 60 kg molasses fed^{-1}, and 80 kg Nfed^{-1} in combination with T.S and 60 kg molasses fed^{-1}, without significant differences between them in both seasons. On the other hand, the lowest LAI value (3.29) was recorded for the application of 80 kg N fertilizer in combination with T.S and 20 kg molasses fed^{-1}.

Root length (cm)

Data in Table 4 shows that root length was gradually increased with increasing the applied nitrogen fertilizer levels up to 100 kg N fed^{-1} which gave the maximum root length of 33.19 cm followed by 80 kg N fed^{-1} which gave 32.94 cm without significant variations at P≤0.05, however, the control treatment produced the significantly (P≤0.05) lowest value of 31.44 cm. Compared to the control treatment, the application of Cerealine and T.S gave the significantly (P≤0.05) highest root length values of 32.95 and 32.34 cm, respectively. The application of 60 kg molasses fed^{-1} gave the significantly (P≤0.05) highest value of root length (33.46 cm) compared to the control treatment which gave 31.82 cm.

The combined analysis showed that the interaction effect resulted from the application of nitrogen and bio-fertilizer (100 kg N fed^{-1} + Cerealine) gave the highest value of 34.08 cm, followed by (80 kg N fed^{-1}+ Cerealine) which achieved a root length of 33.46 cm without significant difference between them at P≤0.05. Moreover, the interaction between nitrogen and molasses at levels of 100 kg N fed^{-1} and 60 kg molasses fed-1 gave the highest root length value of 35.83 cm, however, the lowest root length value (31.06 cm) resulted from the application of 60 kg N fed^{-1} and 20 kg molasses fed^{-1}. The combined analysis also showed that the interaction between bio-fertilizer and molasses had a significant effect on root length and the highest value (34.83 cm) was obtained from the application of Cerealine and 60 kg molasses fed^{-1}, whereas the lowest root length value of 31.54 cm was obtained from the application of Cerealine and 40 kg molasses fed^{-1}.

Table 4. Effect of bio and chemical nitrogen fertilizer with molasses and their interaction on root length (cm) of sugar beet plant by the combined analysis of the 2019/ 2020 and 2020/ 2021 growing seasons.

Nitrogen (N)	Biofertilizer (Bio)	Molasses (Mo) Control	20 Kg fed^{-1}	40 Kg fed^{-1}	60 Kg fed^{-1}	Mean
	Control	34.17	29.50	31.17	31.00	31.46
Control	Cerealine	25.83	33.83	28.50	36.83	31.25
	T.S	37.50	28.83	29.00	31.17	31.63
Mean		32.500	30.72	29.56	33.00	31.44 c
	Control	31.00	30.17	30.83	30.00	30.50
60 Kg fed^{-1}	Cerealine	32.83	32.17	33.50	33.50	33.00
	T.S	31.67	30.83	34.00	34.00	32.63
Mean		31.83	31.06	32.78	32.50	32.04 b
	Control	36.33	31.00	37.33	31.67	34.08
80 Kg fed^{-1}	Cerealine	33.17	36.00	29.83	34.83	33.46
	T.S	30.50	31.50	32.17	31.00	31.29
Mean		33.33	32.83	33.11	32.500	32.94 a
	Control	30.50	33.33	31.17	31.67	31.67
100 Kg fed^{-1}	Cerealine	32.67	35.17	34.33	34.17	34.08
	T.S	25.67	32.67	35.33	41.67	33.83
Mean		29.61	33.72	33.61	35.83	33.19 a
	Control	33.00	31.00	32.63	31.08	31.93 b
Bio × Mo	Cerealine	31.13	34.29	31.54	34.83	32.95 a
	T.S	31.33	30.96	32.63	34.46	32.34 b
Mean		31.82 b	32.08 b	32.26 b	33.46 a	32.41

$LSD_{0.05}$		N × Bio:	0.87
Nitrogen (N):	0.53	N × Mo:	1.30
Biofertilizer (Bio):	0.43	Bio × Mo:	1.13
Molasses (Mo):	0.65	N × Bio × Mo:	2.25

Data in Table 4 demonstrated that the findings of combined analysis among the nitrogen fertilizer and bio-fertilizer with molasses and their interaction had a significant effect on root length during the 2019/2020 and 2020/2021 seasons. The highest root length (41.67 cm) was obtained from the application of 100 kg N fed-1 in combination with T.S and 60 kg molassesfed$^{-1.}$ On the other hand, the lowest root length value (29.83 cm) was obtained from the application of 80 kg Nfed^{-1} · in combination with Cerealine and 40 kg fed-1 of molasses.

Root diameter (cm)

Data in Table 5 showed that the application of 100 kg N fed^{-1} produced the highest root diameter of 33.11 cm, whereas the application of 60 kg N fed^{-1} yielded the lowest value of 31.99 cm and the control treatment which produced 31.49 cm with no significant differences. The application of the Bio-fertilizers, i.e., Cerealine and T.S, gave a root diameter of 32.95 and 32.29 cm which differed significantly (P≤0.05) from the control treatment which gave a root diameter of 31.88 cm. The application of 60 kg molasses fed^{-1} gave the highest value of root diameter of 33.49 cm, while the control treatment gave the significantly (P≤0.05) lowest value of 31.35 cm.

The combined analysis exhibited that the interaction effect between nitrogen and bio-fertilizer (80 kg N fed^{-1} + Cerealine) gave the significantly highest root diameter of 34.46 cm, whereas the lowest root diameter of 31.17 cm was realized from the application of 60 kg N fed^{-1} with Cerealine. Whereas the effect of the interaction between nitrogen and T.S recorded the highest root diameter value (33.13 cm) at 80 kg N fed^{-1} with T.S. The application of either 100 kg N fed^{-1} with 60 kg molasses fed^{-1} or 80 kg N fed^{-1} with 40 kg molasses/fed. gave the highest root diameter of 35.00 or 34.89 cm, respectively, without a significant difference at P≤0.05. However, the lowest root diameter of 31.33 cm was realized from the application of 80 kg N fed^{-1} with 20 kg molasses fed^{-1}.

Table 5. Effect of bio and chemical nitrogen fertilizer with molasses and their interaction on root diameter (cm) of sugar beet plants by the combined analysis of the 2019/ 2020 and 2020/ 2021 growing seasons.

Nitrogen (N)	Biofertilizer (Bio)	Molasses (Mo)				
		Control	20 Kg fed^{-1}	40 Kg fed^{-1}	60 Kg fed^{-1}	Mean
Control	Control	29.50	32.50	31.83	31.17	31.25
	Cerealine	31.50	34.00	31.00	35.17	32.92
	T.S	27.83	30.33	32.00	31.00	30.29
Mean		29.61	32.28	31.61	32.44	31.49 b
60 Kg fed^{-1}	Control	33.17	31.00	31.33	32.17	31.92
	Cerealine	30.17	31.50	29.83	33.17	31.17
	T.S	31.33	32.00	32.83	35.33	32.88
Mean		31.56	31.50	31.33	33.56	31.99 b
80 Kg fed^{-1}	Control	30.33	30.67	32.17	31.33	31.13
	Cerealine	32.33	31.83	40.50	33.17	34.46
	T.S	34.67	31.50	32.00	34.33	33.13
Mean		32.44	31.33	34.89	32.94	32.90 a
100 Kg fed^{-1}	Control	30.50	33.67	31.67	37.00	33.21
	Cerealine	33.50	31.67	35.17	32.67	33.25
	T.S	31.33	32.00	32.83	35.33	32.88
Mean		31.78	32.44	33.22	35.00	33.11 a
Bio × Mo	Control	30.88	31.96	31.75	32.92	31.88 b
	Cerealine	31.88	32.25	34.13	33.54	32.95 a
	T.S	31.29	31.46	32.42	34.00	32.29 b
Mean		31.35 d	31.89 c	32.76 b	33.49 a	32.37

$LSD_{0.05}$		N × Bio:	1.20
Nitrogen (N):	0.62	N × Mo:	1.00
Biofertilizer (Bio):	0.60	Bio × Mo:	0.87
Molasses (Mo):	0.50	N × Bio × Mo:	1.74

The combined analysis showed that the interaction between bio-fertilizer and molasses had a significant effect on root diameter and the highest value (34.13 or 33.54 cm) was obtained from the application of either Cerealine combined with 40 kg molasses fed^{-1} or Cerealine combined with 60 kg molasses fed^{-1}, however, the lowest root diameter of 32.25 cm was realized from the application of 20 kg molasses fed^{-1} without bio-fertilizer.

Data in Table 5 demonstrated that the combined analysis of the 2019/2020 and 2020/2021 seasons for nitrogen fertilizer and bio-fertilizer with molasses interaction had a significant effect on root diameter. The highest root diameter of 40.50 cm was obtained from the application of 80 kg N fed^{-1}. in combination with T.S and 40 kg molasses fed^{-1}, whereas the significantly lowest value (35.33 or 34.33 cm) resulted from the application of either 60 kg N fed^{-1} in combination with T.S and 60 kg molasses fed^{-1} or 80 kg N fed^{-1} in combination with T.S and 60 kg molasses fed^{-1}.

Root fresh weight/plant (g)

Data in Table 6 verified by combined analysis for the two studied growing seasons that the root fresh weight increasingly improved with rising nitrogen fertilizer levels with the application of 100 kg N fed^{-1} produced the highest root fresh weight of 1247.26 g/plant compared to the control treatment which produced the significantly (P≤0.05) lowest value of 844.46 g/plant. The application of the Cerealine bio-fertilizer resulted in the significantly (P≤0.05) highest root fresh weight of 1207.12, compared to the control treatment that gave the lowest root fresh weight of 1002.87 g/plant.

The application of 60 kg molasses fed^{-1} gave the significantly (P≤0.05) highest root fresh weight of 1148.51 g/plant compared to the control treatment that gave the lowest value of 1009.39 g/plant. The combined analysis showed that the application of the nitrogen level of 100 kg N fed^{-1} and the T.S bio-fertilizer gave the significantly (P≤0.05) highest root fresh weight of 1399.92 g/plant, however, the lowest root fresh weight value of 695.00 g/plant was produced from the application of 60 kg N fed^{-1} combined with Cerealine. The application of 100 kg N fed^{-1} combined with 40 kg molasses fed^{-1} gave the significantly (P≤0.05) highest root fresh weight of 1400.56 g/plant, while the lowest value of 1052.22 g/plant was obtained from the application of 60 kg N fed^{-1} combined with 20 kg molasses fed^{-1}. The interaction between bio-fertilizer and molasses had a significant effect (P≤0.05) on root fresh weight and the highest value (1441.79 g/plant) was obtained from the application of Cerealine combined with 40 kg molasses fed^{-1}, whereas the lowest value (1090.58 g/plant) resulted from the application of Cerealine with 20 kg fed^{-1} of molasses. Data in Table 6 demonstrated that the combined analysis of nitrogen fertilization, bio-fertilizers and molasses and their interaction had significant effects on root fresh weight in the 2019/2020 and 2020/2021 growing seasons. The highest root fresh weight of 1775.00 g/plant was obtained from the application of 60 kg N fed^{-1} combined Cerealine and 60 kg molasses fed^{-1}, while the value (712.50 g/plant) resulted from the application of 60 kg N fed^{-1} in combination with Cerealine and 20 kg fed^{-1} of molasses.

Table 6. Effect of bio and chemical nitrogen fertilizer with molasses and their interaction on fresh weight of root (g/ plant) of sugar beet plant by the combined analysis of the 2019/ 2020 and 2020/ 2021 growing seasons.

Nitrogen (N)	Biofertilizer (Bio)	Molasses (Mo) Control	20 Kg fed^{-1}	40 Kg fed^{-1}	60 Kg fed^{-1}	Mean
	Control	774.67	749.67	678.33	728.17	732.71
Control	Cerealine	715.67	1379.83	1298.00	852.00	1061.38
	T.S	884.00	671.67	648.67	752.83	739.29
Mean		791.44	933.72	875.00	777.67	844.46 c
	Without	1175.33	1108.33	786.33	1128.33	1049.58
60 Kg fed^{-1}	Cerealine	695.00	712.50	1666.67	1775.00	1212.29
	T.S	1090.00	1335.83	1061.17	850.83	1084.46
Mean		986.78	1052.22	1171.39	1251.39	1115.44 b
	Control	998.33	1403.33	935.00	1231.67	1142.08
80 Kg fed^{-1}	Cerealine	1373.33	1256.67	1231.67	1338.33	1300.00
	T.S	1103.33	1006.67	1040.67	1371.67	1130.58
Mean		1158.33	1222.22	1069.11	1313.89	1190.89 a
	Control	981.67	1276.67	1096.67	993.33	1087.08
100 Kg fed^{-1}	Cerealine	1016.67	1013.33	1570.83	1418.33	1254.79
	T.S	1304.67	1419.17	1534.17	1341.67	1399.92
Mean		1101.00	1236.39	1400.56	1251.11	1247.26 a
	Control	982.50	1134.50	874.08	1020.38	1002.87 c
Bio × Mo	Cerealine	950.17	1090.58	1441.79	1345.92	1207.12 a
	T.S	1095.50	1108.33	1071.17	1079.25	1088.56 b
Mean		1009.39 b	1111.14 a	1129.01 a	1148.51 a	1099.51

$LSD_{0.05}$			
		N × Bio:	79.71
Nitrogen (N):	71.68	N × Mo:	92.52
Biofertilizer (Bio):	39.88	Bio × Mo:	80.12
Molasses (Mo):	46.33	N × Bio × Mo:	160.24

Leaves fresh weight/plant (g)

Data in Table 7 showed that the leaves fresh weight was progressively increased with increasing nitrogen fertilizer levels with the highest leaves fresh weight of 858.79 g/plant was produced from the application of 100 kg N fed^{-1}. Meanwhile, the control treatment (without nitrogen fertilization) produced the lowest value of 421.25 g/plant. The application of the Cerealine and T.S bio-fertilizers produced the highest fresh weight values of the leaves of 722.07 and 692.66 g/plant, which differ significantly from the lowest value (621.35 g/plant) produced from the control treatment. The application of 60 kg molasses fed^{-1} gave the significantly (P≤0.05) highest value of leaves fresh weight of 719.57 g/plant compared to the control treatment that gave the lowest value of 605.88 g/plant.

The combined analysis showed that the application of the nitrogen level of 80 kg N fed^{-1} and the Cerealine bio-fertilizer gave the significantly (P≤0.05) highest leaves fresh weight of 937.92 g/plant, whereas the lowest value of 480.83 g/plant was produced from the application of 60 kg N fed-1 combined with Cerealine. The application of 100 kg N fed^{-1} combined with 40 kg molasses/fed. gave the significantly (P≤0.05) highest leaves fresh weight of 975.06 g/plant, while the lowest value of 537.61 g/plant was obtained from the application of 60 kg N fed^{-1} combined with 40 kg molasses fed^{-1}. The interaction between bio-fertilizer and molasses had a significant effect (P≤0.05) on leaves fresh weight and the highest value (856.88 g/plant) was obtained from the application of Cerealine combined with 60 kg molasses fed^{-1}, whereas the lowest value (690.63 g/plant) resulted from the application of T.S with 40 kg fed^{-1} of molasses.

Data in Table 7 showed that the combined analysis of nitrogen fertilization, bio-fertilizers and molasses and their interaction had significant effects on leaves fresh weight in the 2019/2020 and 2020/2021 growing seasons. The highest leaves fresh weight of 1031.33 g/plant was obtained from the application of 80 kg N fed^{-1} combined Cerealine and 60 kg molasses fed^{-1}, while the value (480.83 g/plant) resulted from the application of 60 kg N fed^{-1} in combination with Cerealine and 40 kg fed-1 of molasses.

Table 7. Effect of bio and chemical nitrogen fertilizer with molasses and their interaction on fresh weight of leaves (g/ plant) of sugar beet plant by the combined analysis of the 2019/ 2020 and 2020/ 2021 growing seasons.

Nitrogen (N)	Biofertilizer (Bio)	Molasses (Mo) Control	20 Kg fed^{-1}	40 Kg fed^{-1}	60 Kg fed^{-1}	Mean
	Control	428.67	316.33	399.17	423.33	391.88
Control	Cerealine	478.17	419.83	462.50	412.83	443.33
	T. S	371.67	455.00	385.83	501.67	428.54
Mean		426.17	397.06	415.83	445.94	421.25 c
	Control	538.33	590.67	388.67	411.67	482.33
60 Kg fed^{-1}	Cerealine	434.17	632.17	480.83	1085.00	658.04
	T. S	410.00	846.67	743.33	564.17	641.04
Mean		460.83	689.83	537.61	686.94	593.81 b
	Control	672.33	776.00	649.17	763.50	715.25
80 Kg fed^{-1}	Cerealine	902.00	884.67	933.67	1031.33	937.92
	T. S	968.33	744.17	1028.33	737.67	869.63
Mean		847.56	801.61	870.39	844.17	840.93 a
	Control	783.33	827.67	1146.33	826.50	895.96
100 Kg fed^{-1}	Cerealine	660.00	952.17	885.50	898.33	849.00
	T. S	623.50	830.00	893.33	978.83	831.42
Mean		688.94	869.94	975.06	901.22	858.79 a
	Control	605.67	627.67	645.83	606.25	621.35 b
Bio × Mo	Cerealine	618.58	722.21	690.63	856.88	722.07 a
	T. S	593.38	718.96	762.71	695.58	692.66 a
Mean		605.88 b	689.61 a	699.72 a	719.57 a	678.69

$LSD_{0.05}$			
		N × Bio:	62.29
Nitrogen (N):	94.39	N × Mo:	70.96
Biofertilizer (Bio):	31.16	Bio × Mo:	61.45
Molasses (Mo):	35.54	N × Bio × Mo:	122.90

Total fresh weight/plant (g)

Data in Table 8 showed that the total fresh weight was increased with increasing nitrogen fertilizer levels with the highest total fresh weight of 2106.06 g/plant was produced from the application of 100 kg N fed^{-1}. Meanwhile, the control treatment (without nitrogen fertilization) produced the lowest value of 1265.71 g/plant. The application of either the Cerealine or T.S bio-fertilizers produced the highest total fresh weight values of 1929.19 and 1781.22 g/plant, which differ significantly from the lowest value (1624.22 g/plant) produced from the control treatment. The application of 60 kg molasses fed^{-1} gave the significantly ($P \leq 0.05$) highest value of the total fresh weight of 1868.08 g/plant compared to the control treatment that gave the lowest value of 1615.26 g/plant.

The combined analysis showed that the application of the nitrogen level of 80 kg N fed^{-1} and the Cerealine bio-fertilizer gave the significantly ($P \leq 0.05$) highest total fresh weight of 2237.92 g/plant, whereas the lowest value of 1725.50 g/plant was produced from the application of 60 kg N fed^{-1} combined with T.S bio-fertilizer. The application of 100 kg N fed^{-1} combined with 40 kg molasses fed^{-1} gave the significantly ($P \leq 0.05$) highest total fresh weight of 2375.61 g/plant, while the lowest value of 1709.00 g/plant was produced from the application of 60 kg N fed^{-1} combined with 40 kg molasses fed^{-1}. The interaction between bio-fertilizer and molasses had a significant effect ($P \leq 0.05$) on leaves fresh weight and the highest value (2202.42 g/plant) was obtained from the application of Cerealine combined with 60 kg molasses fed^{-1}, whereas the lowest value (1774.83 g/plant) resulted from the application of T.S with 60 kg fed^{-1} of molasses.

Table 8. Effect of bio and chemical nitrogen fertilizer with molasses and their interaction on total fresh weight of plant (g/ plant) of sugar beet plant by the combined analysis of the 2019/ 2020 and 2020/ 2021 growing seasons.

Nitrogen (N)	Biofertilizer (Bio)	Molasses (Mo) Control	20 Kg fed^{-1}	40 Kg fed^{-1}	60 Kg fed^{-1}	Mean
	Control	1203.33	1066.00	1077.50	1151.50	1124.58
Control	Cerealine	1193.83	1799.67	1760.50	1264.83	1504.71
	T.S	1255.67	1126.67	1034.50	1254.50	1167.83
Mean		1217.61	1330.78	1290.83	1223.61	1265.71 c
	Control	1713.67	1699.00	1175.00	1540.00	1531.92
60 Kg fed^{-1}	Cerealine	1129.17	1344.67	2147.50	2860.00	1870.33
	T.S	1500.00	2182.50	1804.50	1415.00	1725.50
Mean		1447.61	1742.06	1709.00	1938.33	1709.25 b
	Control	1670.67	2179.33	1584.17	1995.17	1857.33
80 Kg fed^{-1}	Cerealine	2275.33	2141.33	2165.33	2369.67	2237.92
	T.S	2071.67	1750.83	2069.00	2109.33	2000.21
Mean		2005.89	2023.83	1939.50	2158.06	2031.82 a
	Control	1765.00	2104.33	2243.00	1819.83	1983.04
100 Kg fed^{-1}	Cerealine	1676.67	1965.50	2456.33	2316.67	2103.79
	T.S	1928.17	2249.17	2427.50	2320.50	2231.33
Mean		1789.94	2106.33	2375.61	2152.33	2106.06 a
	Control	1588.17	1762.17	1519.92	1626.63	1624.22 c
Bio × Mo	Cerealine	1568.75	1812.79	2132.42	2202.42	1929.19 a
	T.S	1688.88	1827.29	1833.88	1774.83	1781.22 b
Mean		1615.26 b	1800.75 a	1828.74 a	1868.08 a	1778.21

$LSD_{0.05}$			
Nitrogen (N):	156.53	N × Bio:	103.91
Biofertilizer (Bio):	51.98	N × Mo:	115.02
Molasses (Mo):	57.61	Bio × Mo:	99.61
		N × Bio × Mo:	199.23

Data in Table 8 showed that the combined analysis of nitrogen fertilization, bio-fertilizers and molasses and their interaction had significant effects on the total fresh weight in the 2019/2020 and 2020/2021 growing seasons. The highest total fresh weight of 2860.00 g/plant resulted from the application of 60 kg N/ fed^{-1} combined Cerealine and 60 kg molasses fed^{-1}, whereas the value (1415.00 g/plant) resulted from the application of 60 kg N fed^{-1} in combination with T.S and 60 kg fed^{-1} of molasses.

Discussion

Sugar beet plant growth and morphological characteristics were all significantly improved by increasing nitrogen fertilizer rates, according to the findings. Concisely, the results showed that nitrogen fertilizer, bio-fertilizer, molasses and their interaction had affirmative effects on leaf area index, root length, root diameter, root fresh weight, leaves fresh weight and total fresh weight throughout the two studied growing seasons of 2019/2020 and 2020/2021. Also, the growth characteristics were progressively increased with increasing nitrogen fertilizer levels. The importance of leaf area (LA) related to sugar beet root growth and sugar yield is a generally recognized factor. Sugar beet leaves early sowing reaches its maximum after three months, while towards the end of vegetation, it gradually decreases. The optimum leaf area index (LAI) for most field crops is around 3-4 m2 (Roslon et al. 2005). This was also the optimum LAI for sugar beet from the mid-3rd month after sowing till the end of the 4th month from sowing (Hoffmann and Blomberg 2003). Since, for many crops, LAI is one of the conclusive physiological indicators that demonstrate the intensity of biomass growth during the vegetation period. Additionally, it is closely related to the processes of photosynthesis and respiration. From the standpoint of cultivating sugar beets, it is required for the canopy to reach the LAI rate of 5 to 6 m2 as rapidly as possible and to sustain it for as long as possible. The restrictive factor in dry and warm areas, which often negatively influences the optimum process of LAI, is the scarcity of rainfall combined with high temperatures during the summer months which became the early cultivated date for sugar beet in Egypt.

The development of the leaves affects the productivity of photosynthesis and the sucrose storage in the root. In the conditions of reduced nitrogen supply, the development of sugar beet leaves at the first growth phases grow well because beets have enough nitrogen available (Vukadinovic et al. 2041). In the later growth phase of sugar beet, phenotypically the leaves are lighter in color, while the root lags behind growth. Sugar beet nitrogen fertilization has an important influence on plant growth and root yield and quality. Nitrogen fertilization in most soils in Croatia is 140–160 kg ha^{-1} N (Pospišil 2013) whereas in Germany and most countries of the European Union satisfactory yields were achieved with an amount of 120 kg ha^{-1} N applied, or even less due to mineralization of the N in the soil (80 kg ha^{-1} N) (Marlander et al. 2003).

According to Giannoulis et al. (2020), increased nitrogen fertilization reduced the N agronomic efficiency. Pyakurel et al. (2019) stated that Yield was found maximum when organic fertilizer was applied along with molasses increased root and shoot length, and also root and shoot dry weight (Suliasih and Widawati 2017). Sugarcane molasses showed better results in terms of shoot and root length, and fresh and dry weight of tomato plants than ash or other source of nutrients (Vawdrey and Stirling 1997; Elmasry and Al-Maracy 2023).

Conclusions

Throughout the first and second seasons, respectively, the highest nitrogen rates (100 and 80 kg N fed^{-1}) produced the highest morphological characteristics (leaf area index, root length, and root diameter), growth characteristics (root fresh weight, leaves fresh weight and total fresh weight) without significant differences. In addition, in the two seasons under investigation, bio-fertilizer treatments (TS®) produced the highest values for the leaf area index, root length, root diameter, root fresh weight, leaves fresh weight, and total fresh weight. During the first and second seasons, respectively, the highest rates of molasses (60 and 40 kg N fed^{-1}) produced the highest leaf area index, root length, root diameter, root fresh weight, leaf fresh weight, and total fresh weight without significant differences. The interaction between molasses, bio-fertilizers, and nitrogen rates (80 kg N fed^{-1} +40 kg molasses fed^{-1}+ plus T.S.) indicated that it produced the highest values for the majority of the growth characteristics that were analyzed. As a result, bio-fertilizer treatments were expected to lessen agricultural environmental pollution and proved crucial in optimizing crop production.

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