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IMPACT OF SOIL APPLIED MOLASSES AND FOLIAR SPRAYING WITH MAGNESIUM AND BORON ON SUGAR BEET YIELD AND QUALITY UNDER NITROGEN FERTILIZATION REGIME UNDER CLAY SOILS

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ABSTRACT: A field experiment was carried out on clay soil at El-Gemmeiza Agric. Res. Station, El-Gharbeya Governorate, Egypt, during two consecutive winter growing seasons 2023/2024 and 2024/2025. The investigation was aimed to enhance sugar beet (Auckland cv) production and quality by studying the effect of molasses (0 and 40 kg/fed. twice applications after 30 and 45 days after sowing) throughout irrigation under three nitrogen fertilization rates (60, 80 and 100% of the recommended rate) and foliar spray with both magnesium (Mg) at 0.5 % in the form of magnesium sulphate and boron (B) at 200 ppm in the form of boric acid three times 45, 60 and 75 days after sowing. The most important results were as follows: Sugar beet grown in clay soil treated with molasses at 40 kg/fed., fertilized with mineral nitrogen at 80% of the recommended rate (64 kg N/fed.), and sprayed with Mg at 0.5% increased chlorophyll a, b, total (a+b), and carotenoids in leaf tissues after 90 days of sowing, as well as the highest yield, K, and Mg contents in roots. Moreover, molasses application at 40 kg /fed., fertilizing with mineral nitrogen at 80% of the recommended rate (64 kg N/fed.), and spraying with B at 200 ppm increased root yield, root length, sucrose content (%), and sucrose yield (ton/fed.). These treatments reduced mineral nitrogen by about 20% in fertilization and increased root yield by 11.28% and sugar yield by 31.77% (averaged over the two growing seasons) compared with fertilizing with N at 100% of the recommended rate.

Keywords: Sugar beet, molasses, nitrogen, boron, magnesium, yield, and quality

INTRODUCTION

Sugar is considered a strategic food that is an inexpensive source of energy, and it is produced by two main crop Species, i.e., sugarcane and sugar beet (Beta vulgaris L.). Sugar beet is the second most vital sugar crop species after sugarcane. The sugar beet, which grows in all types of soils (clay, calcareous, sandy, salty, alkaline, and rich soils), has recently gained importance as a winter crop in Egypt's agricultural cycle. Egypt's primary crop for sugar production is now the sugar beet. Around 604104 Fadden were planted in the 2021–2022 season, and the total production surpassed 13.557 million tons of roots at an acreage of 22.442 tons/feddan (FAO,2024).

The potential use of safe and natural agents to increase crop growth and yield has recently gained significant attention, driven by the high cost of fertilizers and environmental protection concerns. For instance, using organic residues in agriculture helps to conserve natural resources by recycling carbon and mineral elements. There is significant potential for utilizing organic waste from sugar and alcohol agro-industry production in conservation agriculture. The leftover syrup from processing sugar cane and sugar beet (Honma *et al*., 2012) is called molasses. Large volumes of molasses are generated each year and used in a variety of sectors, such as fertilizers, alcohol, and animal feed. Because sugar beet molasses includes varying levels of humic, fulvic, and amino acids, its application in agriculture promotes the biological contents of the soil and the efficiency of nutritional element uptake (Samavat & Samavat, 2014).

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Accordingly, treated plants with molasses compared to untreated plants were the best for enhancing leaf pigments, yield, and their components and quality (Şanli *et al*., 2015 on sugar beets, Gaafar *et al*., 2019 on sweet pepper, Abofard *et al*., 2021 on sugar beet, Narmhikaa, 2022 on Radish, Al-Dhumri *et al*., 2023; Dawood *et al*., 2023 on sugar beet, Ibrahim *et al.*, 2024 on potato, and Mirakbari *et al*., 2025 on tomato).

Numerous metabolic processes in plants, such as photosynthesis and cell division, depend on the element nitrogen (N). It is also a necessary component of chlorophyll, protein synthesis, amino acids, nucleotides, phytohormones, nucleic acids, cytokinins, and coenzymes that trigger the synthesis of amino acids. Consequently, one of the most limiting factors for sugar beet growth, productivity, and quality has been identified as nitrogen. It was in charge of maximizing root growth, extractable sucrose content, and aboveground vegetative growth (Wang *et al*., 2011).

Increasing nitrogen fertilizer for sugar beet caused a significant increase in growth, productivity, and root quality (Abdelaal & Tawfik, 2015; Abido & Ibrahim, 2017; Leilah *et al*., 2017; Elwan & Helmy, 2018; Kandil *et al*., 2021; Gomaa *et al.*, 2022; Abdel-Moneam *et al*., 2023; Badr *et al*., 2024; Seadh *et al*., 2025).

In plants, magnesium serves a variety of biochemical and physiological purposes (Senbayram *et al*., 2015). The export of sucrose from leaves to roots is among the most significant. Early-growth sugar beet plants that receive adequate magnesium nutrition develop a substantial root system, which in turn influences how well the plants absorb nutrients from the soil solution (Hermans *et al*., 2005). It is well known that magnesium (Mg) plays a function in the fixation, transformation, and partitioning of carbon (C) and nitrogen (N) molecules in plants (Cakmak & Kirkby, 2008).

Many authors showed significant enhancement of growth, yield, and best quality with spraying Mg on sugar beet (Abou El-Magd *et. al*., 2013; Orlovius & McHoul, 2015; Enan *et al*., 2016; D'Egidio *et al*., 2019; Makhlouf *et al.*, 2020; Pogłodziński *et al*., 2021).

A vital trace element for the physiological operation of higher plants is boron (B). B deficiency can result in nutritional issues that impair the development and metabolism of plants. B. is by far the most crucial trace element that sugar beet needs to prevent declines in root quality and yield (Cooke & Scott, 1993). Additionally, according to Camacho-Cristobal and González-Fontes (2007), B supports essential processes in sugar beet, including preserving the equilibrium between sugar and starch and K transfer.

Spraying sugar beet during the growing season with boron had a significant effect on growth, yield of roots, quality, and improved the percentages of sugar (Enan *et al.,* 2016; Mohamed & Afifi, 2017; Dewdar *et al.,* 2018; Ghaly *et al.,* 2019; Sarhan *et al.,* 2020, and Tayyab *et al*., 2023).

Therefore, this work aimed to study the effect of molasses application and nitrogen fertilization levels as soil application and foliar spray with magnesium and boron on sugar beet root yield and quality under the Nile Delta clayey soil conditions.

MATERIALS AND METHODS

During two consecutive winter seasons of 2023/2024 and 2024/2025, a field experiment was conducted at El-Gemmeiza Agric. Res. Station, Gharbeya Governorate, Egypt, demonstrated alluvial clay soils of the Nile Delta (longitude 31 7º E, latitude 30 43º N). The purpose of this study was to examine how molasses and nitrogen fertilization levels as soil application and foliar spraying with magnesium and boron affected the leaf pigment, productivity, and root quality of sugar beet Aucklaned cv. Table 1 displays a few of the experimental soil's physical and chemical characteristics as measured according to Black *et al*. (1981).

Table (1). Some soil physical and chemical properties of the experimental site during the two growing seasons of 2023/2024 and 2024/2025.

Parameter	**Value**	
1**. Physical properties**	**2023/2024**	**2024/2025**
Coarse sand (%)	1.91	1.92
Fine sand (%)	14.37	15.37
Silt (%)	40.11	41.01
Clay (%)	43.61	42.0
Textural class	Clay loam	Clay loam
2. Chemical properties		
EC, dSm^{-1} (soil paste extract)	2.21	2.32
pH (1: 2.5 soil: water suspension)	8.1	7.98
$CaCO_3$ (%)	2.7	2.4
Organic matter (%)	1.94	1.79
Mineral nitrogen (ppm)	32.0	29
Available phosphorus (ppm)	7.9	8.2
Available potassium (ppm)	270	288
Available boron (ppm)	0.10	0.12
Available magnesium (ppm)	50	48

This experiment comprised 18 treatments, which were the combinations of two molasses levels (zero and 40 kg/fed), applied twice, 30 and 45 days after sowing throughout irrigation, and three levels of nitrogen (60, 80, and 100% of the recommended fertilization rate (RR) equivalent to 48, 64, and 80 kg N/fed, respectively, in the form of urea 46% N. Additionally, there were three foliar spray treatments (unsprayed control, Mg at a concentration of 0.5 % in the form of magnesium sulphate pentahydrate (16% MgO), and boron at 200 ppm in the form of boric acid (17% B). These treatments were arranged in a split-split plot in a complete block statistical design with three replications. Molasses levels were randomly distributed in the main plot, nitrogen rates were distributed in the sub-plot, while foliar spray treatments with Mg and B were randomly arranged in the sub-sub plots.

The compositions of molasses were 0.6% Ca, 3.2% K, 0.25% P, 1.3% N, 1.30% Na, 0.19% Mg, and 0.4% S, and were produced by the Animal Production Research Institute, ARC, Egypt.

The experimental unit area {(0.6 m × 4) × 5m} made up 12 m^2. It has four ridges, each 5 meters long and spaced 60 centimeters apart. One ridge was designated for collecting plant samples to measure morphological and physiological traits during the growing season, while the other three ridges were used to assess yield and its components.

In both growth seasons, the seeds were planted during the first week of November. On one side of the ridge in hills spaced 20 cm apart, sugar beet was manually sown using the dry sowing method in three to five seeds per hill. After 30 days of seeding, the plants were trimmed to one plant per hill.

Phosphorus fertilizer was applied at the rate of 30 kg P_2O_5/fed in the form of single calcium super phosphate (15.5% P_2O_5), which was added during land preparation. Different nitrogen levels were applied in two equal doses: half was applied before the second irrigation after thinning, and the other half 15 days later, before the third irrigation. Potassium fertilizer at the rate of 24 kg K_2O/fed in the form of potassium sulphate (50% K_2O) was applied with the second irrigation in one dose.

The plants were sprayed with Mg and B three times, i.e., 45, 60, and 75 days after sowing in both seasons. Each plot received two liters of solutions of different spraying treatments using a spreading agent (reflecting materials) in all treatments to improve adherence of the spray to the plant foliage for increasing absorption by the plants.

Other agricultural practices for the sugar beet field were carried out as recommended by the Sugar Crops Research Institute.

Recorded data

Photosynthetic Pigments

Disk samples from the fourth upper leaf were obtained at 90 days from sowing in both seasons to determine chlorophyll a and b as well as carotenoids according to the method described by Wettestein (1957).

Yield components

Root yields (ton/fed) were determined on a whole plot basis, and the plants were harvested, topped, and weighed to determine root yield. After that, a sample of 10 roots was randomly taken, and the following traits were recorded: root length (cm) and Root diameter (cm).

Determination of root ∝-amino-N, potassium, sodium, magnesium, and boron

At harvesting time, Potassium and sodium concentrations were determined using a flame photometer (%). Alpha amino nitrogen concentration (%) was determined using the Kjeldahl wet oxidation process as described by Blakemore et al. (1987), while Mg and B in roots were determined according to the method described by Cottenie *et al* (1982).

Root Juice Quality Parameters

All root juice quality parameters were determined at harvest in the Delta Sugar Company, Kafr El-Sheikh, Egypt, according to the following equation:

Purity % = 99.36-{14.27(V_1+V_2+ V_3/ V_4)}

Where:

V_1=Na , V_2= K, V_3= ∝-amino-N, V_4= sucrose %.

Sucrose% was determined according to the procedure of Le Docte (1927).

Total Sugar yield (fed), which was calculated according to the following equation: total sucrose yield (fed) = Roots yield (fed) x sucrose (%).

Statistical analysis: Statistical analysis was conducted for all collected data. The analysis of variance was calculated according to Snedecor and Cochran (1980), and means separation was done according to Duncan (1958) at a 0.05 level of probability.

RESULTS AND DISCUSSION

1. Photosynthetic pigments

1.1. Effect of molasses application

There are significant differences due to molasses application between with and without molasses in chlorophyll a, b, total (a+b), and carotenoids in leaf tissues of sugar beet at 90 days after sowing in both growing seasons (Table 2). Treating sugar beet plants with molasses at 40 kg/fed throughout irrigation water gave higher concentrations of chlorophyll a (2.778 and 2.803 mg/g FW), b (1.374 and 1.364 mg/g FW), and total (a+b) (4.153 and 4.167 mg/g FW) as well as carotenoides (1.516 and 1.506 mg/g FW) in leaf tissues in the 1st and 2nd growing seasons, respectively.

The increases in total chlorophyll (a+b) in leaf tissues due to application of molasses were about 20.97 and 18.68 % over untreated plants in the 1st and 2nd growing seasons, respectively.

The effect of molasses application as a soil conditioner via irrigation water in enhancing root yield could be attributed to its high calcium content that dramatically improves soil physical and chemical properties and hence enhances sugar beet growth and leaf pigments (Prado *et al*., 2013). Results are in harmony with those reported by Narmhikaa (2022), who showed that plants grown in 3 t/ha molasses recorded the best chlorophyll content of radish. Also, Dawood *et al.* (2023) on sugar beet and Ibrahim *et al.* (2024) on potato showed similar results in this regard.

1.2. Effect of nitrogen rates

Fertilizing sugar beet plants with 80% of the N recommended rates (RR), which equals 64 kg N/fed mineral nitrogen (MN), increased the concentrations of chlorophyll a, b, and total chlorophyll (a+b) and carotenoids in leaf tissues of sugar beet in both seasons (Table 2). The increases in total chlorophyll (a+b) in leaf tissues were about 27.19 and 26.07% over 60% RR of MN and were about 4.23 and 2.79% over 100% RR of MN in the 1st and 2nd growing seasons, respectively.

The positive influence of nitrogen could be due to its role in cell division and elongation as a principal component in chlorophyll (Makhlouf & Abd El-All, 2017). These results agree with Abdelaal and Tawfik (2015), Leilah *et al*. (2017), Idris *et al*. (2021), Abdel-Moneam *et al*. (2023), and Badr *et al.* (2024), who found that the leaf pigments of sugar beet had a significant effect on nitrogen fertilizer.

1.3. Effect of Mg and B as foliar application

Foliar spray with Mg at 0.5% and B at 200 ppm increased the concentrations of chlorophyll a, b, total chlorophyll (a+b), and carotenoids in leaf tissues compared to control (spraying with water), as shown in Table 2. Spraying with Mg at 0.5% gave the highest values of chlorophyll a, b, total chlorophyll (a+b), and carotenoids in leaf tissues of sugar beet in both growing seasons.

The increases in total chlorophyll (a+b) in leaf tissues due to spraying with Mg were about 8.18 and 7.97% over spraying with B at 200 ppm and 26.50 and 24.04% over control treatment in the 1st and 2nd growing seasons, respectively.

Table (2). Effect of molasses, N fertilization rates, and foliar spray with Mg and B on leaf pigments at 90 days after sowing sugar beet during 2023/24 and 2024/25 growing seasons.

Treatments	Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Total Chlorophyll a + b (mg/g FW)		Carotenoides (mg/g FW)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of molasses							
Control	2.362 b	2.408 b	1.070 b	1.102 b	3.433 b	3.511 b	1.182 b	1.152 b
40 kg/fed	2.778 a	2.803 a	1.374 a	1.364 a	4.153 a	4.167 a	1.516 a	1.506 a
LSD at 0.05 level	**0.031**	**0.059**	**0.029**	**0.086**	**0.100**	**0.125**	**0.089**	**0.060**
	Effect of N fertilization rates (RRD%)							
60 % RRD	2.222 c	2.235 c	1.036 c	1.068 b	3.258 c	3.303 c	1.261 b	1.238 b
80% RRD	2.818 a	2.844 a	1.326 a	1.320 a	4.144 a	4.164 a	1.418 a	1.378 a
100 % RRD	2.670 b	2.740 b	1.305 b	1.311 a	3.976 b	4.051 b	1.369 a	1.371 a
LSD at 0.05 level	**0.020**	**0.039**	**0.019**	**0.056**	**0.066**	**0.082**	**0.058**	**0.039**
	Effect of foliar spray with Mg and B							
0	2.289 c	2.360 c	1.024 c	1.038 c	3.313 c	3.398 c	1.260 c	1.232 c
Mg	2.819 a	2.820 a	1.372 a	1.394 a	4.191 a	4.215 a	1.451 a	1.409 a
B	2.602 b	2.638 b	1.271 b	1.266 b	3.874 b	3.904 b	1.336 b	1.345 b
LSD at 0.05 level	**0.018**	**0.035**	**0.017**	**0.050**	**0.059**	**0.073**	**0.052**	**0.035**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B

These findings might be explained by the biological roles of the element magnesium in plants, where it is crucial for photosynthesis, which captures solar energy and powers photochemistry (Pakrasi *et al.,* 2001). Additionally, magnesium plays a significant part in encouraging the production of photosynthetic pigments and chlorophyll (Abou El-Magd *et al*., 2013). Similar results agree with those reported by Enan (2016), who noticed that foliar application with magnesium had an obvious effect on photosynthetic pigments, such as chlorophyll a, B, and total chlorophyll a+b, as compared to the control treatment. As for the boron effect on leaf pigments in sugar beet compared to control (Abido, 2012; Masri & Hamza, 2015; Aly *et al*., 2017; Mohamed & Afifi, 2017; Sarhan *et al*., 2020).

1.4. Effect of the dual interaction between molasses and N fertilization rates

The interaction between molasses application at 40 kg/fed and N fertilizer at 80% RR recorded maximum values of chlorophyll a (3.070 and 3.081 mg/g FW), b (1.482 and 1.451 mg/g FW), total chlorophyll (a+b) (4.553 and 4.533 mg/g FW) and carotenoids (1.616 and 1.571 mg/g FW) in leaf tissues of sugar beet at 90 days after sowing in the both growing seasons respectively, followed by the interaction between molasses and N at 100% RR as shown in Table 3.

The increases in total chlorophyll (a+b) in leaf tissues due to the interaction between molasses application and fertilizing with N at 80% RR were about 22.925 and 18.70% over the interaction between zero molasses and N at 100% RR in the 1^{st} and 2^{nd} growing seasons, respectively.

The results align with those obtained by Gaafar et al. (2019). The interaction between nitrogen rates from recommended mineral fertilization at 75% and 100%, when treated with molasses, yielded the highest chlorophyll levels in sweet pepper leaves. Elmasry and Al-Maracy (2023) obtained comparable findings regarding sugar beet.

1.5. Effect of the dual interaction between molasses and both Mg and B

Data in Table 3 illustrate the dual interaction between molasses and an application rate of 40 kg/fed and foliar spray with Mg enhance the values of chlorophyll a (3.060 and 3.012 mg/g FW), b (1.513 and 1.519 mg/g FW), total chlorophyll (a+b) (4.573 and 4.532 mg/g FW) and carotenoids (1.667 and 1.651 mg/g FW) in leaf tissues of sugar beet at 90 days after sowing in the both seasons respectively, comparing with the interaction between molasses and spraying with B with application rate of 200 ppm.

The increases in total chlorophyll (a+b) in leaf tissues due to the interaction between molasses application and spraying with Mg at 0.5% were about 53.51 and 47.33% over the interaction between zero molasses and water spraying (control) and were about 7.90 and 6.61% over the interaction between molasses application and spraying with B at 200 ppm in the 1^{st} and 2^{nd} growing seasons, respectively.

1.6. Effect of the dual interaction between N rates and both Mg and B

The obtained results in Table 3 indicate that the dual interaction between N at 80% RR and foliar spray with Mg application rate 0.5% gave the values of chlorophyll a (3.138 and 3.107 mg/g FW), b (1.500 and 1.551 mg/g FW), total chlorophyll (a+b) (4.638 and 4.659 mg/g FW) and carotenoids (1.534 and 1.459 mg/g FW) in leaf tissues of sugar beet at 90 days after sowing in the both growing seasons respectively, followed by the interaction between N at 100% RR and spraying with Mg.

The increases in total chlorophyll (a+b) in leaf tissues due to the dual interaction between N at 80% RR and spraying with Mg application rate 0.5% were about 26.69 and 24.01% over the interaction between N at 100% RR and spraying with water and were about 12.19 and 14.25% over the interaction between N at 80% RR and spraying with B application rate 200 ppm in the 1^{st} and 2^{nd} growing seasons, respectively.

Table (3). Effect of dual interaction between molasses, N fertilization rates, and Mg and B on leaf pigments at 90 days after sowing of sugar beet during 2023/24 and 2024/25 growing seasons

Treatments		Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Total Chlorophyll a + b (mg/g FW)		Carotenoides (mg/g FW)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Molasses	**N rate**	**Effect of the interaction between molasses and N fertilization rates**							
Control	60% RRD	2.017 f	2.020 e	0.841 e	0.898 c	2.858 d	2.918 d	1.121 e	1.074d
	80% RRD	2.566 c	2.606 c	1.169 d	1.188 b	3.736 c	3.795 c	1.219 d	1.186 c
	100% RRD	2.503 d	2.600 c	1.201 c	1.219 b	3.704 c	3.819 c	1.207 d	1.197 c
40 kg/fed	60% RRD	2.428 e	2.450 d	1.230 c	1.237 b	3.658 c	3.688 c	1.400 c	1.403 b
	80% RRD	3.070 a	3.081 a	1.482 a	1.451 a	4.553 a	4.533 a	1.616 a	1.571 a
	100% RRD	2.837 b	2.880 b	1.410 b	1.402 a	4.248 b	4.282 b	1.532 b	1.545 a
LSD at 0.05 level		**0.029**	**0.055**	**0.027**	**0.079**	**0.093**	**0.116**	**0.083**	**0.055**
Molasses	**Mg and B**	**Effect of the interaction between molasses and Mg and B**							
Control	0	2.111 f	2.169 f	0.867 f	0.906 e	2.979 f	3.076 f	1.147 e	1.123 d
	Mg	2.578 c	2.628 c	1.230 c	1.269 c	3.809 c	3.898 c	1.236d	1.168 d
	B	2.396 e	2.428 e	1.114 e	1.130 d	3.510 e	3.558 e	1.164 de	1.166 d
40 kg/fed	0	2.467 d	2.551 d	1.180 d	1.169 d	3.647 d	3.720 d	1.373 c	1.342 c
	Mg	3.060 a	3.012 a	1.513a	1.519 a	4.573 a	4.532 a	1.667 a	1.651 a
	B	2.809 b	2.848 b	1.429 b	1.403 b	4.238 b	4.251 b	1.509 b	1.525 b
LSD at 0.05 level		**0.026**	**0.049**	**0.024**	**0.071**	**0.083**	**0.104**	**0.074**	**0.050**
N rate	**Mg and B**	**Effect of the interaction between N fertilization rates and Mg and B**							
60% RRD	0	1.835 h	1.844 h	0.783 g	0.839 e	2.618 f	2.683 f	1.149 e	1.122 f
	Mg	2.507 e	2.466 f	1.210 d	1.220 c	3.717 d	3.686 d	1.373 bc	1.329 cd
	B	2.325 g	2.395 g	1.115 e	1.145 cd	3.440 e	3.541 e	1.261 d	1.263 e
80% RRD	0	2.577 d	2.668 d	1.083 f	1.087 d	3.661 d	3.755 d	1.338 cd	1.291 de
	Mg	3.138a	3.107a	1.500 a	1.551a	4.638 a	4.659 a	1.534 a	1.459 a
	B	2.740 c	2.756 c	1.394 b	1.322 b	4.134 bc	4.078 c	1.382 bc	1.385 bc
100% RRD	0	2.455 f	2.569 e	1.205 d	1.188 c	3.661 d	3.757 d	1.293 cd	1.284 de
	Mg	2.813 b	2.888 b	1.406 b	1.412 b	4.219 b	4.300 b	1.448 ab	1.440 ab
	B	2.742 c	2.762 c	1.306 c	1.332 b	4.048 c	4.095 c	1.367 bc	1.389 bc
LSD at 0.05 level		**0.032**	**0.060**	**0.029**	**0.087**	**0.102**	**0.127**	**0.091**	**0.061**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

1.7. Effect of the three-way interaction among molasses application, N fertilization rates, and both Mg and B as foliar application

The obtained results in Table 4 indicate that the three way interaction among molasses application at 40 kg/fed, N at 80% RR and Mg was the optimum treatments for enhancing of chlorophyll a (3.351 and 3.270 mg/g FW), b (1.650 and 1.651 mg/g FW), total chlorophyll (a+b) (5.001 and 4.921 mg/g FW) and carotenoids (1.744 and 1.701 mg/g FW) in leaf tissues, in the 1st and 2nd growing seasons, respectively followed by the interaction between molasses using 40 kg/fed, N fertilization at 100% RR and spraying with Mg at 0.5% of sugar beet at 90 days after sowing in both growing seasons.

The enhancement in total leaf tissues chlorophyll (a+b) due to the triple interaction among molasses at 40 kg/fed, N fertilization at 80% RR, and spraying with Mg at 0.5 % was about 46.61% and 39.09 % over N at 100 % RR only in the 1st and 2nd seasons, respectively.

Application of molasses as a soil conditioner at 40 kg/fed via irrigation water, 80% RR of MN (64 kg N/fed), and foliar spray with Mg at 0.5% increased the concentrations of chlorophyll a, b, and (a+b) in addition to carotenoids in leaf tissues of sugar beet plants grown in clay soil.

Table (4). Effect of three-way interaction among molasses, N fertilization rates, and (Mg or B) foliar spray on leaf pigments at 90 days after sowing of sugar beet during 2023/24 and 2024/25 growing seasons.

Treatments			Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Total Chlorophyll a + b (mg/g FW)		Carotenoids (mg/g FW)	
Molasses	**N rate**	**Mg and B**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control	**60% RRD**	**0**	1.730 m	1.709 j	0.635 k	0.745 j	2.365 h	2.454 k	1.084 h	1.029 g
		Mg	2.206 j	2.216 h	1.035 h	1.045gh	3.241 f	3.261 i	1.160 gh	1.070fg
		B	2.115 k	2.135 h	0.855 j	0.906 i	2.970 g	3.041 j	1.121 gh	1.123ef
	80% RRD	**0**	2.300 i	2.375 g	0.861 j	0.862 ij	3.161 f	3.237 i	1.158 gh	1.162de
		Mg	2.925 c	2.945cd	1.351 d	1.452 b	4.276 c	4.397bc	1.324 ef	1.218 d
		B	2.475 h	2.500 f	1.296 e	1.252 e	3.771 d	3.752 g	1.177 gh	1.179de
	100% RRD	**0**	2.305 i	2.425fg	1.106 g	1.113 fg	3.411 e	3.538 h	1.199fgh	1.179de
		Mg	2.605 f	2.725 e	1.306 e	1.312 cde	3.911 d	4.037 ef	1.226 fg	1.216 d
		B	2.600 f	2.650e	1.191 f	1.233 ef	3.791 d	3.883 fg	1.196f gh	1.197de
40 kg/fed	**60% RRD**	**0**	1.940 l	1.979 i	0.931 i	0.933 hi	2.871 g	2.912 j	1.214 fg	1.216 d
		Mg	2.808 e	2.716 e	1.385cd	1.395 bc	4.193 c	4.111de	1.587 bc	1.589 b
		B	2.536 g	2.656 e	1.375 d	1.385 bcd	3.911 d	4.041 ef	1.401de	1.404 c
	80% RRD	**0**	2.855de	2.961 cd	1.306 e	1.312cde	4.161 c	4.273cd	1.519 cd	1.421 c
		Mg	3.351 a	3.270 a	1.650 a	1.651 a	5.001 a	4.921a	1.744a	1.701 a
		B	3.006 b	3.013 bc	1.492 b	1.392 bcd	4.498 b	4.405bc	1.587 bc	1.591 b
	100% RRD	**0**	2.606 f	2.713 e	1.305 e	1.264 de	3.911 d	3.977 ef	1.388 de	1.389 c
		Mg	3.021 b	3.052 b	1.506 b	1.512 b	4.527 b	4.564 b	1.670 ab	1.665 ab
		B	2.885 cd	2.875 d	1.421 c	1.432 bc	4.306 c	4.307 c	1.539 c	1.581 b
LSD at 0.05 level			**0.045**	**0.085**	**0.042**	**0.123**	**0.145**	**0.180**	**0.128**	**0.086**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

2. Yield and its components

2.1. Effect of molasses application

Data in Table 5 illustrates that the molasses application rate is 40 kg/fed throughout irrigation water produced higher root yield (30.653 and 30.882 ton/fed), top yield (11.602 and 11.860 ton/fed), root length (45.0 and 44.55 cm), and root diameter (41.42 and 41.55 cm) than without molasses in both seasons. The application of molasses at 40 kg/fed increased root yield/fed by approximately 9.64 and 10.75% over the control in the first and second seasons, respectively.

Applying molasses through irrigation water greatly increased root yield; this effect may be ascribed to the molasses's high calcium content, which significantly improves the physical and chemical characteristics of soil and, consequently, promotes the growth of sugar beets (Prado *et al.,* 2013). Additionally, molasses's polysaccharide content may encourage plant growth and soil microbes, which in turn produce certain regulators that support plant growth and yield (Honma *et al.,* 2012).

The obtained results are in harmony with those reported by Şanli *et al.* (2015), Abofard *et al.* (2021), and Al-Dhumri *et al.* (2023) on sugar beet. They showed that treated plants with molasses, compared to untreated plants, were the best for enhancing yield and its components.

2.2. Effect of N rates

Root yield, top yield, root length, and root diameter significantly increased with increasing N fertilization rates up to 100% RR, with no significant differences with N application level at 80% RR, with respect to root and top yield (Table 5). This means that N at 80% RR (64 kg N/fed) increased total yield of root (31.712 and 31.660 ton/fed) and top yield (11.040 and 11.228 ton/fed), whereas N at 100% RR (80 kg N/fed) increased root length (45.83 and 45.75 cm) and root diameter (42.16 and 42.48 cm) in both growing seasons.

The increases in root yield/fed were about 26.99 and 27.83 for N at 80% RR and were about 25.06 and 27.40 for N at 100% RR over fertilizing with 60% RR in the 1st and 2nd growing seasons, respectively.

These results can be attributed to the vital role of N as an essential and structural element in building up plant cells and enhancing plant growth, which in turn leads to an increased yield of tops and roots. These results agree with Abido and Ibrahim (2017), Elwan and Helmy (2018), Kandil *et al.* (2021), Gomaa *et al.* (2022), Elmasry and Al-Maracy (2023), and Seadh *et al.* (2025). They found that increasing nitrogen fertilizer for sugar beet caused a significant increase in yield and its components, such as root yield, root length, and root diameter.

2.3. Effect of Mg and B as foliar spray application

Foliar spray with Mg at 0.5% increased sugar beet top yield to (11.500 and 11.440 ton/fed), whereas foliar spray with B at 200 ppm increased root yield to (31.352 and 31.408 ton/fed), root length (45.66 and 46.08 cm) and root diameter (41.52 and 41.34 cm) in both growing seasons respectively (Table 5).

The increases in root yield/fed were about 6.83 and 4.42 for Mg spraying application, and were about 14.64 and 13.49 for B spraying application over control in the 1st and 2nd growing seasons, respectively. As for top yield, the increases were about 16.99 and 12.90% for Mg spraying and were about 9.54 and 6.17% form B spraying over control in the 1st and 2nd growing seasons, respectively.

In this context, the positive effect of boron on the top fresh weight of sugar beet can be attributed to its essential role in the activity of enzymes involved in photosynthesis and respiration systems. Additionally, this element plays a crucial role in the formation of new leaves. Moreover, it has an active role in the translation of assimilation products. Similar results were reported by Abido (2012), who found that the positive effect of boron may be due to the boron's role in cell elongation, where, in the case of boron deficiency, plant leaves were smaller, stiffer, and thicker. Boron is an essential micronutrient that is mainly required for the formation of the cell wall, and it is involved in many metabolic processes in the plant cell (Hu & Brown, 1994). Similarly, it plays an essential role in vegetative growth of all higher plants and then increases the yield of top and root (Kaya *et al.*, 2019). Also, Boron is regarded as a crucial nutrient, especially for sugar beet, where it plays a key part in sucrose transport from leaves to roots, in addition to other biological functions such as respiration, cell division, and water relations. Boron primarily affects the growth and strength of cell walls, as well as the stimulation or inhibition of metabolic processes (Nemeata Alla *et al*., 2021)

Similar findings were obtained by Abdel-Nasser and Ben-Abdalla (2019), Ibrahim *et al.* (2019), Sarhan *et al.* (2020), and Tayyab *et al.* (2023) as for the boron effect, and Makhlouf *et al.* (2020), and Pogłodziński *et al.* (2021) for the Mg effect.

Table (5). Effect of molasses, nitrogen fertilization rates, and foliar spray with Mg and B on yield and root traits of sugar beet during 2023/24 and 2024/25 growing seasons.

Treatments	Root yield (ton/fed)		Top yield (ton/fed)		Root length (cm)		Root diameter (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of molasses							
Control	27.958 b	27.831 b	9.797 b	9.694 b	43.27 b	43.83 b	39.11 b	39.47 b
40 kg/fed	30.653 a	30.822 a	11.602 a	11.860 a	45.00 a	44.55 a	41.42 a	41.55 a
LSD at 0.05 level	0.952	0.634	0.310	0.339	0.27	0.41	0.34	0.69
	Effect of N fertilization rates							
60% RRD	24.973 b	24.767 b	9.945 b	9.827 b	41.25 c	41.16 b	37.22 c	37.79 c
80% RRD	31.712 a	31.660 a	11.040 a	11.228 a	45.33 b	45.66a	41.41 b	41.27 b
100% RRD	31.232 a	31.553 a	11.113 a	11.277 a	45.83 a	45.75a	42.16 a	42.48 a
LSD at 0.05 level	0.625	0.416	0.210	0.222	0.18	0.27	0.22	0.45
	Effect of foliar spray with magnesium and boron							
0	27.348 c	27.675 c	9.830 c	10.133 c	42.16 c	42.00 c	39.04 c	39.31 c
Mg	29.217 b	28.897 b	11.500 a	11.440 a	44.58 b	44.50 b	40.23 b	40.85 b
B	31.352 a	31.408 a	10.768 b	10.758 b	45.66 a	46.08 a	41.52 a	41.39 a
LSD at 0.05 level	0.559	0.373	0.188	0.199	0.16	0.24	0.20	0.40

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

2.4. Effect of dual interaction between molasses and N fertilization rates

The interaction between molasses application at 40 kg/fed via irrigation water and N fertilization at 80% RR (64 kg N/fed) produced the highest values of root yield (32.867 and 33.027 ton/fed), top yield (12.120 and 12.530 ton/fed) and root diameter (42.80 and 42.82 cm) with no significant differences with molasses application and N fertilizer at 100% RR (80 kg N/fed), whereas the interaction between molasses application and N fertilization at 100% RR produced the highest values of root length in both growing seasons (Table 6).

The increases in root yield/fed due to the interaction between molasses application and fertilizing with N at 80% RR were about 9.16 and 9.14%, 20.60 and 24.55% for top yield over the interaction between zero molasses and N fertilizer at 100% RR in the 1st and 2nd growing seasons, respectively.

These results are in harmony with those reported with Dawood *et al*. (2023) showed that the interaction between nitrogen and molasses (40 kg molasses/fed and N at 100 kg/fed) gave the highest values of root yield and top yield, whereas the lowest root yield value was obtained with realized by (20 kg molasses/fed and N at 60 kg/fed).

Table (6). Effect of dual interaction between molasses, N rates, and foliar spray with Mg and B on yield and root traits of sugar beet during 2023/24 and 2024/25 growing seasons

Treatments		Root yield (ton/fed)		Top yield (ton/fed)		Root length (cm)		Root diameter (cm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Molasses	**N rate**	**Effect of the interaction between molasses and N rates**							
Control	60% RRD	23.207 d	22.947 d	9.380 d	9.097 d	39.83 f	40.50 e	35.91 e	36.83 e
	80% RRD	30.557 b	30.293 b	9.960 c	9.927 c	44.66 d	45.83 b	40.03 c	39.70 c
	100% RRD	30.110 b	30.253 b	10.050 c	10.060 c	45.33 c	45.16 c	41.38 b	41.90 b
40 kg/fed	60% RRD	26.740 c	26.587 c	10.510 b	10.557 b	42.66 e	41.83 d	38.53 d	38.75 d
	80% RRD	32.867 a	33.027 a	12.120 a	12.530 a	46.00 b	45.50bc	42.80a	42.85 a
	100% RRD	32.353 a	32.853 a	12.177 a	12.493 a	46.33a	46.33 a	42.93a	43.07 a
LSD at 0.05 level		**0.884**	**0.589**	**0.297**	**0.315**	**0.25**	**0.38**	**0.32**	**0.64**
Molasses	**Mg and B**	**Effect of the interaction between molasses and Mg and B foliar application**							
Control	0	25.830 d	26.110 e	8.887 e	8.850 f	41.33 f	41.33 e	37.58 e	38.08 d
	Mg	27.810 c	27.167 d	10.763 c	10.593 d	43.83 d	44.16 c	39.03 d	39.96 c
	B	30.233 b	30.217 b	9.740 d	9.640 e	44.66 c	46.00 a	40.72 c	40.38 c
40 kg/fed	0	28.867 c	29.240 c	10.773 c	11.417 c	43.00 e	42.66 d	40.50 c	40.53 c
	Mg	30.623 b	30.627 b	12.237 a	12.287 a	45.33 b	44.83 b	41.43 b	41.74 b
	B	32.470 a	32.600 a	11.797 b	11.877 b	46.66 a	46.16 a	42.33 a	42.39 a
LSD at 0.05 level		**0.791**	**0.527**	**0.266**	**0.282**	**0.22**	**0.34**	**0.28**	**0.57**
N rates	**Mg and B**	**Effect of the interaction between N rates and Mg and B foliar application**							
60% RRD	0	22.610 f	22.925 f	9.160 e	9.150 e	38.00 g	38.25 g	35.12 g	35.87 f
	Mg	25.110 e	24.225 e	10.635 c	10.485 c	41.75 f	41.75 f	37.25 f	38.22 e
	B	27.200 d	27.150 d	10.040 d	9.845 d	44.00 e	43.50 e	39.30 e	39.27 d
80% RRD	0	29.715 c	29.715 c	10.175 d	10.635 c	43.75 e	43.25 e	40.50 d	40.25 c
	Mg	31.600 b	31.425 b	11.865 a	11.885 a	45.50 c	46.00 c	41.42 c	41.70 b
	B	33.820 a	33.840 a	11.080 b	11.165 b	46.75a	47.75a	42.32 b	41.87 b
100% RRD	0	29.720 c	30.385 c	10.155 d	10.615 c	44.75 d	44.50 d	41.50 c	41.80 b
	Mg	30.940 b	31.040 b	12.000 a	11.950 a	46.50ab	45.75 c	42.02 b	42.63 a
	B	33.035 a	33.235 a	11.185 b	11.265 b	46.25 b	47.00 b	42.95 a	43.02 a
LSD at 0.05 level		**0.969**	**0.646**	**0.325**	**0.345**	**0.28**	**0.42**	**0.35**	**0.70**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

2.5. Effect of dual interaction between molasses and both Mg and B

Data in Table 6 show that the interaction between molasses application at 40 kg/fed via irrigation water and spraying with B at 200 ppm increased root yield (32.470 and 32.600 ton/fed), root length (46.66 and 46.16 cm) and root diameter (42.33 and 43.39 cm), whereas the interaction between molasses application at 40 kg/fed and foliar spraying with Mg at 0.5% increased top yield (12.237 and 12.287 ton/fed) in both growing seasons.

The increases in root yield/fed were about 18.56 and 17.30 for the interaction between molasses application and foliar spraying with Mg, and were about 25.71 and 24.86% for the interaction between molasses application and foliar spraying with B over the interaction between zero molasses and spraying with water (control treatment) in the 1st and 2nd seasons, respectively. Furthermore, the relative increases in top yield due to the interaction between molasses application and foliar spraying with Mg were about 37.70% and 38.84% respectively, and were about 32.74% and 34.20% over the interaction between zero molasses (control) and spraying with water in the 1st and 2nd growing seasons, respectively.

These findings are consistent with those published by Elmasry and Al-Maracy (2023), who showed that the highest root diameter and root yield, as well as the recoverable sugar yield, were produced by applying 80 or 100 kg N/fed with 240 ppm boron in sugar beet.

2.6. Effect of dual interaction between N rates and both Mg and B

The interaction between N fertilization at 80% RR (64 kg/fed) and foliar spraying with B at 200 ppm increased root yield (33.820 and 33.840 ton/fed) in both seasons (Table 6). While the interaction between N fertilization at 100% RR (80 kg/fed) and spraying with Mg at 0.5 % increased top yield (12.865 and 11.950 ton/fed), with no significant differences, the interaction between N fertilization at 100% RR and foliar spraying with Mg at 0.5%.

This means that the interaction between N fertilization at 80% RR (64 kg/fed) and foliar spraying with Mg increased top yield. As for root length, the interaction between N at 80% RR (64 kg/fed) and foliar spraying with B at 200 ppm increased root length in both seasons.

These results are in harmony with Mekdad (2015), who indicated that maximum root, top, and sugar yields/fed and root quality were produced by 140 kg N/ha and 120 and/or 150 ppm boron. Also, Azaryar *et al.* (2024) showed that the highest root yield was recorded in the N at 450 kg of urea/ha, with 50% applied at planting and 50% at the 8-12 leaf stage, and boron at a liquid fertilizer with 10% boron, used at the 6-8 leaf and 8-12 leaf stages.

2.7 Effect of the three-way interaction among molasses application, N fertilization rates, and both Mg and B as foliar spray

As for root yield, data in Table 7 indicate that the interaction among molasses application at 40 kg/fed, N at 80% RR and foliar spray with B increased root yield (34.950 and 34.700 ton/fed) with no significant differences with the interaction between molasses application, N fertilizer at 100% RR and foliar spray with B at 200 ppm in both growing seasons (12.430 and 12.580 ton/fed).

This means that the quantity of root yield/fed for treating with molasses, N at 80% RR (64 kg N/fed) and B at 200 ppm is equal to adding molasses, N at 100% RR (80 kg N/fed) and B at 200 ppm (reducing about 20% of mineral nitrogen by using molasses and B spraying). In addition, the increases in root yield were about 13.11% and 9.46% for the interaction among molasses application N at 80% RR and spraying with B at 200 ppm over fertilizing with N at 100% RR only in the 1st and 2nd growing seasons, respectively.

Respecting top yield, to the interaction among molasses application at 40 kg/fed, N fertilizer at 80% RR and foliar spray with Mg at 0.5% increased top yield (12.780 and 12.880 ton/fed) without significant differences comparing with the interaction among molasses application at 40 kg/fed, N at 80% RR and foliar spray with B at 200 ppm (11.250 and 12.080 ton/fed).

This means that production of top yield/fed for treatment with molasses, N fertilizer at 80% RR (64 kg N/fed) and foliar spray Mg at 0.5% is equal with adding molasses, N fertilizer at 100% RR (80 kg N/fed) and B at 200 ppm (reducing about 20% of mineral nitrogen by using molasses and Mg spraying). In addition, the increases in top yield were about 10.58 and 5.25% for the interaction among molasses application, N at

80% RR, and spraying with Mg at 0.5% over fertilizing with N at 100% RR only in the 1st and 2nd growing seasons, respectively.

As for root length, in the 1st growing season the interaction among molasses application using 40 kg/fed, Fertilization with 80% RR and foliar spray with B at 200 ppm concentration indicate the highest root length (47.5 cm), while the interaction among without molasses application, N fertilization with 80% RR and foliar spray with B in the 2nd seasons increased root length (48.5 cm). With respect to root diameter, the interaction among molasses application at 40 kg/fed, N fertilization at 100% RR, and foliar spray with B increased root diameter significantly (43.75 and 43.88 cm) in both growing seasons.

From the foregoing results, it could be concluded that managing each of the molasses at 40 kg/fed via irrigation water twice, fertilizing with N at 80% RR (64 kg N/fed) and foliar spraying with B at 200 ppm increased root yield (34.950 ton/fed) and root length (47.5 cm), whereas application of molasses at 40 kg/fed, fertilizing with N at 100% RR (80 kg N/fed) and foliar spray with B at 200 ppm increased root diameter of sugar beet roots grown in clay soil (43.75 cm). Finally, the regulation of molasses at 40 kg/fed via irrigation water twice, fertilizing with N at 80% RR (64 kg N/fed), and foliar spray with Mg at 0.5% increased the top yield of sugar beet (12.88 ton/fed) in both growing seasons.

Table (7). Effect of the three-way interaction among molasses, N fertilizer rates, and foliar spray with Mg and B on yield and root traits of sugar beet during 2023/24 and 2024/25 seasons.

Treatments			Root yield, (ton/fed)		Top yield, (ton/fed)		Root length, (cm)		Root diameter, (cm)	
Molasses	N	Mg and B	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	60% RRD	0	20.220k	21.160 i	8.400 i	8.130 j	36.50 m	37.50 k	33.00 i	34.50 i
		Mg	23.450 j	22.300h	10.290ef	9.890 g	40.50 k	41.00 i	36.25 h	37.50h
		B	25.950hi	25.380 fg	9.450gh	9.270 hi	42.50 j	43.00gh	38.50 f	38.50 g
	80% RRD	0	28.730 g	28.100 e	9.100 h	9.190 i	43.50 h	43.00 gh	38.75 f	38.25 gh
		Mg	30.250 f	29.800 d	10.950cd	10.890de	44.50 f	46.00 de	39.85 e	40.35 f
		B	32.690bc	32.980 b	9.830 fg	9.700gh	46.00 d	48.50 a	41.50 d	40.50 ef
	100% RRD	0	28.540 g	29.070 d	9.160 h	9.230 hi	44.00 g	43.50 fg	41.00 d	41.50 de
		Mg	29.730fg	29.400 d	11.050cd	11.000 d	46.50 c	45.50 e	41.00 d	42.05 cd
		B	32.060cde	32.290 bc	9.940 f	9.950 fg	45.50 e	46.50 cd	42.16 c	42.16 cd
40 kg/fed	60% RRD	0	25.000 i	24.690 g	9.920 f	10.170 fg	39.50 l	39.00 j	37.25 g	37.25 h
		Mg	26.770 h	26.150 f	10.980 cd	11.080 d	43.00 i	42.50 h	38.25 f	38.95 g
		B	28.450 g	28.920 de	10.630 de	10.420 ef	45.50 e	44.00 f	40.10 e	40.05 f
	80% RRD	0	30.700 ef	31.330 c	11.250 c	12.080 bc	44.00 g	43.50 fg	42.25 c	42.25 bcd
		Mg	32.950 bc	33.050 b	12.780 ab	12.880 a	46.50 c	46.00 de	43.00 b	43.05 abc
		B	34.950 a	34.700 a	12.330 b	12.630 a	47.50 a	47.00 bc	43.15 b	43.25 a
	100% RRD	0	30.900def	31.700 c	11.150 c	12.000 c	45.50 e	45.50 e	42.01 c	42.11 cd
		Mg	32.150 cd	32.680 b	12.950 a	12.900 a	46.50 c	46.00 de	43.05 b	43.22 ab
		B	34.010 ab	34.180 a	12.430 b	12.580 ab	47.00 b	47.50 b	43.75a	43.88 a
LSD at 0.05 level			1.370	0.913	0.460	0.488	0.39	0.59	0.49	0.99

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

3. Root chemical constituents

3.1. Effect of molasses application

Molasses application at 40 kg/fed via irrigation water significantly increased $\propto$-amino-N (3.83 and 3.84%), K (4.76 and 4.52%), Mg (0.570 and 0.570%) contents, and B concentrations (11.58 and 11.53 ppm) in the root of sugar beet compared to the control treatment (without molasses) in both growing seasons (Table 8). The increase in root nitrogen contents due to the application of molasses at 40 kg/fed were about 11.99 and 12.61% over the control in the 1st and 2nd growing seasons, respectively.

When molasses was applied to the soil via irrigation water, the amount of Na, K, and α-amino-N in the root juice decreased. This could be because there were too many Ca^{2+} and Mg^{2+} ions, which decreased the absorption of Na+ and K^+ and therefore impacted membrane permeability, which regulates the absorption of Na and K (Wakeel, 2013). Furthermore, depending on the type of elements and amendments, soil amendments (such as applying molasses) can have conflicting effects on phytoavailability and element mobilization (Shaheen *et al.,* 2017).

These results agree with Al-Dhumri *et al.* (2023), who showed the lowest K% and α-amino N values resulted from the surface application of 360 L ha^{-1} molasses to sugar beet compared to the control treatment.

3.2. Effect of N fertilization rates

Treating sugar beet plants with 100% RR of N fertilizer (80 kg/fed) Recorded the highest values of ∝-amino-N (4.42 and 4.45%), K (5.33 and 5.08%), and Mg (0.611 and 0.597%) in roots, whereas N at 80% RR (64 kg/fed) increased B concentrations (12.21 and 12.17 ppm) in roots in both seasons (Table 8).

These results agree with Abido and Ibrahim (2017), Elwan and Helmy (2018), and Gomaa *et al.* (2022), all of whom showed that increasing nitrogen fertilizer for sugar beet caused a significant increase in root quality.

3.3. Effect of Mg and B as foliar application

Data in Table 8 indicate that foliar spray with B at 200 ppm increased ∝-amino-N (3.88 and 3.96%) and B (12.63 and 12.62 ppm) in roots, whereas spraying with Mg at 0.5% increased K (4.87 and 4.59%) and Mg (0.677 and 0.675%) in roots.

Table (8). Effect of molasses, N fertilization rates, and (Mg and B) foliar spray on root chemical constituents of sugar beet during 2023/24 and 2024/25 seasons

Treatments	∝-amino-N		K (%)		Mg (%)		B (ppm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of molasses							
Control	3.42 b	3.41 b	4.59 b	4.36 b	0.516 b	0.506 b	10.35 b	10.44 b
40 kg/fed	3.83 a	3.84 a	4.76 a	4.52 a	0.570 a	0.570 a	11.58 a	11.53 a
LSD at 0.05 level	**0.05**	**0.03**	**0.12**	**0.08**	**0.006**	**0.004**	**0.18**	**0.20**
	Effect of N fertilization rates							
60% RRD	2.54 c	2.55 c	4.21 c	3.98 c	0.415 c	0.417 b	9.30 c	9.35 c
80 % RRD	3.92 b	3.88 b	4.50b	4.26 b	0.603 b	0.599 a	12.21 a	12.17 a
100 % RRD	4.42 a	4.45 a	5.33 a	5.08 a	0.611 a	0.597 a	11.39 b	11.44 b
LSD at 0.05 level	**0.03**	**0.02**	**0.08**	**0.05**	**0.004**	**0.003**	**0.12**	**0.13**
	Effect of foliar spray with Mg and B							
Control	3.34 c	3.32 c	4.69 b	4.47 b	0.365 c	0.356 c	9.56 c	9.65 c
Mg	3.65 b	3.60 b	4.87 a	4.59 a	0.677 a	0.675 a	10.71 b	10.69 b
B	3.88 a	3.96 a	4.47 c	4.27 c	0.587 b	0.582 b	12.63 a	12.62 a
LSD at 0.05 level	**0.03**	**0.02**	**0.07**	**0.05**	**0.003**	**0.003**	**0.11**	**0.11**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

The increases in Mg concentration in the roots due to spraying with Mg were about 85.48% and 89.61% and were about 32.11% and 30.78% for B spraying over the control (spraying with water) in the 1st and 2nd growing seasons, respectively.

Spraying sugar beet during the growing season with boron had a significant effect on growth, yield of roots, quality, and improved the percentages of sugar (El-Sherief *et al.,* 2016; Aly *et al.,* 2017; Dewdar *et al.,* 2018; Ghaly *et al.,* 2019; Sarhan *et al.,* 2020, and Tayyab *et al.,* 2023). They demonstrated that spraying sugar beet plants with B resulted in the best root chemical constituents compared to control plants.

3.4. Effect of dual interaction between molasses and N rates

The interaction between molasses at 40 kg/fed and fertilizing with N at 100% produced the highest values of ∝-amino-N (4.55 and 4.54%) and K (5.48 and 5.22%) contents in roots, whereas the interaction between molasses at 40 kg /fed and fertilizing with N at 80% produced the highest values of Mg (0.641 and 0.634%) and B (12.75 and 12.69 ppm) in roots with no significant differences with the interaction between molasses at 40 kg/fed and fertilizing with N at 100% with respect to Mg content (Table 9).

The increases in Mg in the root due to the interaction between molasses and N at 80% RR were about 9.57 and 13.01% and increases in B were about 19.05 and 19.15% over the interaction between control (without) molasses and 100% RR of N in the 1st and 2nd growing seasons, respectively.

3.5. Effect of dual interaction between molasses and both Mg and B

Data in Table 9 indicate that the interaction between molasses via irrigation water and foliar spray with B at 200 ppm increased ∝-amino-N (4.02 and 4.17%) and B (13.48 and 13.17 ppm) in roots, whereas the interaction between molasses application and spraying with Mg at 0.5% increased K (4.91 and 4.65%) and Mg (0.706 and 0.717%) in roots in both growing seasons. On the other hand, control treatment (without molasses and without Mg or B) produced the lowest values of ∝-amino-N, K, Mg, and B in roots in both seasons.

3.6. Effect of dual interaction between N rates and both Mg and B foliar spray

The interaction between 100% RR of N (80 kg/fed.) and spraying with B at 200 ppm scored the highest ∝-amino-N (4.58 and 4.64%) in roots, whereas the interaction between 80% RR of N (64 kg/fed) and spraying with B at 200 ppm increased B concentration (14.00 and 13.94 ppm) in roots in both seasons (Table 9). The interaction between 100% RR of N (80 kg/fed) and Mg as foliar spray increased K (5.44 and 5.22%) and Mg (0.779 and 0.748%) in roots in both seasons.

The increases in B in the root due to the interaction between N at 80% RR and spraying with B were about 38.48% and 37.20% over the interaction between N at 100% RR only in the 1st and 2nd seasons, respectively.

Table (9). Effect of dual interaction between molasses, N fertilization rates, and Mg and B foliar spray on root chemical constituents of sugar beet during 2023/24 and 2024/25 seasons.

Treatments		∝-amino-N		K (%)		Mg (%)		B (ppm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Molasses	**N rate**	**Effect of the interaction between molasses and nitrogen rates**							
Control	60% RRD	2.31 f	2.31 f	4.20 e	3.96 e	0.397 e	0.393 d	8.69 f	9.03 f
	80% RRD	3.67 d	3.57 d	4.41 d	4.19 d	0.566 c	0.564 b	11.66 c	11.64 c
	100% RRD	4.29 b	4.35 b	5.18 b	4.95 b	0.585 b	0.561 b	10.71 d	10.65 d
40 kg/fed	60% RRD	2.76 e	2.79 e	4.21 e	4.01 e	0.432 d	0.442 c	9.92 e	9.68 e
	80% RRD	4.18 c	4.19 c	4.60 c	4.34 c	0.641 a	0.634 a	12.75 a	12.69 a
	100% RRD	4.55 a	4.54 a	5.48 a	5.22 a	0.637 a	0.634 a	12.08 b	12.23 b
LSD at 0.05 level		**0.05**	**0.03**	**0.12**	**0.08**	**0.006**	**0.004**	**0.17**	**0.18**
Molasses	**Mg and B**	**Effect of the interaction between molasse and Mg and B**							
Control	0	3.05 f	3.10 f	4.65 c	4.42 c	0.350 f	0.332 f	9.01 e	8.98 e
	Mg	3.46 e	3.38 e	4.84 ab	4.53 b	0.648 b	0.634 b	10.26 d	10.25 d
	B	3.75 c	3.75 c	4.30 d	4.15 d	0.550 d	0.551 d	11.79 b	12.08 b
40 kg/fed	0	3.63 d	3.54 d	4.73 bc	4.52 b	0.380 e	0.380 e	10.11 d	10.31 d
	Mg	3.84 b	3.82 b	4.91 a	4.65 a	0.706 a	0.717 a	11.16 c	11.12 c
	B	4.02 a	4.17 a	4.65 c	4.38 c	0.624 c	0.613 c	13.48 a	13.17 a
LSD at 0.05 level		**0.04**	**0.02**	**0.10**	**0.07**	**0.005**	**0.004**	**0.15**	**0.16**
N rates	**Mg and B**	**Effect of the interaction between nitrogen rates and Mg and B**							
60% RRD	0	2.20 i	2.23 i	4.17 ef	3.95 g	0.285 h	0.285 h	7.92 h	7.92 h
	Mg	2.51 h	2.42 h	4.40 d	4.17 e	0.501 e	0.510 d	8.99g	9.32 g
	B	2.90 g	3.00 g	4.05 f	3.84 h	0.458 f	0.457 e	10.99 d	10.83 e
80% RRD	0	3.57 f	3.53 f	4.63 c	4.33 d	0.403 g	0.383 g	10.65 e	10.87 de
	Mg	4.03 e	3.86 e	4.68 c	4.39 d	0.751 b	0.767 a	11.97 c	11.69 c
	B	4.18 d	4.25 c	4.20 e	4.07 f	0.657 c	0.647 c	14.00a	13.94 a
100% RRD	0	4.26 c	4.20 d	5.28 b	5.13 b	0.408 g	0.401 f	10.11 f	10.16 f
	Mg	4.42 b	4.51 b	5.54 a	5.22 a	0.779 a	0.748 b	11.16 d	11.05 d
	B	4.58 a	4.64 a	5.17 b	4.89 c	0.645 d	0.643 c	12.91 b	13.10 b
LSD at 0.05 level		0.05	0.03	0.13	0.08	0.006	0.005	0.19	0.20

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

3.7. Effect of the three-way interaction among molasses application, N rates, and both Mg and B as foliar application

Data presented in Table 10 demonstrated the interaction among molasses application at 40 kg/fed. via irrigation water, N fertilization at 100% RR and foliar spray with B at 200 ppm gave the highest values of ∝-amino-N in root (4.68 and 4.77%), whereas the interaction between molasses application, N at 80% RR and foliar spray with B gave the highest values of B concentration (15.03 and 14.64 ppm) in both growing seasons.

Table (10). Effect of three-way interaction among molasses, N fertilization rates, and foliar spray of Mg and B on root chemical constituents of sugar beet during 2023/24 and 2024/25.

Treatments			∝-amino-N		K (%)		Mg (%)		B (ppm)	
Molasses	**N rate**	**Mg and B**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control	**60% RRD**	**0**	2.02l	1.98 n	4.18 h	3.92 ij	0.275 m	0.265m	6.98 l	7.56 l
		Mg	2.21 k	2.13 m	4.40fg	4.12 h	0.493h	0.496h	8.68k	8.73 j
		B	2.72 i	2.82 j	4.03 h	3.86 j	0.424 i	0.418i	10.41h	10.80f
	80% RRD	**0**	3.09 g	3.18 i	4.59 ef	4.29 fg	0.381 k	0.348k	10.27h	10.35g
		Mg	3.86 f	3.61 h	4.64 e	4.35 ef	0.699 c	0.720 b	11.75ef	11.33e
		B	4.07 e	3.92 g	4.00 h	3.93 ij	0.620 e	0.624 e	12.98 c	13.25c
	100% RRD	**0**	4.06 e	4.16 f	5.19 c	5.05 c	0.395 j	0.385 j	9.80 i	9.05 i
		Mg	4.33 c	4.40 d	5.48 ab	5.13 bc	0.754 b	0.686 c	10.35 h	10.70 f
		B	4.48 b	4.51 c	4.88 d	4.67 d	0.606 f	0.612 f	11.98 de	12.20 d
40 kg/fed	**60% RRD**	**0**	2.39 j	2.48 l	4.17h	3.99 i	0.295 l	0.305 l	8.87k	8.28 k
		Mg	2.81 h	2.72 k	4.40 g	4.22 gh	0.510 g	0.525 g	9.31 j	9.91h
		B	3.09 g	3.18 i	4.08h	3.82 j	0.493 h	0.496 h	11.58 f	10.87 f
	80% RRD	**0**	4.05 e	3.89 g	4.67 e	4.37 ef	0.425 i	0.418 i	11.04 g	11.39 e
		Mg	4.21 d	4.12f	4.73 de	4.43e	0.803 a	0.815a	12.20 d	12.06 d
		B	4.29 cd	4.58 b	4.40 g	4.22 gh	0.695 c	0.670 d	15.03 a	14.64 a
	100% RRD	**0**	4.46 b	4.25 e	5.37 bc	5.22 ab	0.421 i	0.417 i	10.42 h	11.28 e
		Mg	4.51 b	4.62 b	5.60 a	5.32 a	0.805 a	0.811a	11.97 de	11.41 e
		B	4.68 a	4.77 a	5.47 ab	5.12 bc	0.685 d	0.675 d	13.85 b	14.00 b
LSD at 0.05 level			**0.08**	**0.05**	**0.18**	**0.12**	**0.009**	**0.007**	**0.27**	**0.29**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

The interaction among molasses application at 40 kg/fed, N at 100% RR, and foliar spray with Mg at 0.5% gave the highest values of K (5.60 and 5.32%) and Mg (0.805 and 0.811%) in roots in both seasons.

The increases in B in the root due to the triple interaction among Molasses, N at 80% RR, and spraying with B were about 53.37% and 61.77% over the interaction between N at 100% RR only in the 1st and 2nd growing seasons, respectively.

4. Root quality

4.1. Effect of molasses application

Molasses application at 40 kg/fed via irrigation water significantly produced higher sucrose content (16.59 and 16.58%), sucrose yield (5.112 and 5.133 ton/fed), and purity (90.81 and 90.91%) of sugar beet than without molasses in both growing seasons (Table 11). No significant differences were found between molasses application and non-application in terms of Na content in roots during the 1st growing season. However, non-application resulted in a higher Na content in the 2nd growing season. In the first and second growing seasons, the increases in sugar yield (ton/fed) due to adding molasses at 40 kg/fed were approximately 10.55 and 12.59% higher than without molasses application, respectively.

The high calcium content of molasses, which is antagonistic to sodium ions and promotes soil aggregation, enhancing soil properties, plant growth, and yield, may be the cause of the notable rise in sugar content that occurs when molasses is applied to the soil via irrigation water. Additionally, the increased plant growth that results in the partitioning of more photoassimilates in the roots may be the cause of the high sugar content generated by applying 40 kg/fed. of molasses via irrigation water (Hosseini *et al*., 2019).

4.2. Effect of N fertilization rates

Fertilizing sugar beet plants with N at 80% RR (64 kg/fed) induced the highest values of sucrose content (16.99 and 16.74%), sucrose yield (5.399 and 5.311 ton/fed) in both growing seasons, whereas N at 60% RR (48 kg/fed) gave the highest purity (92.35 and 92.35%) and Na in roots in both growing seasons (Table 11). There were no significant differences between N at 80 and 100% RR for the yield of sucrose in both growing seasons.

These results could be attributed to the reason that high levels of nitrogen fertilizer increased non-sugar substances such as protein, amino acids, and other substances (impurities), which led to decreasing purity percentage, extractable sugar percentage, and sugar loss to molasses (Gobarah *et al*., 2010). Also, the excessive N administration results in an unbalanced assimilation distribution between storage roots and leaves, which lowers the content of sucrose (ElGeddawy & Makhlouf, 2015). This result coincides with those found by Gomaa *et al.* (2022), Elmasry and Al-Maracy (2023), and Badr *et al.* (2024), who showed that the moderate level of nitrogen fertilizer for sugar beet caused a significant increase in root quality.

Table (11). Effect of molasses, N fertilization rates, and Mg and B foliar spray on root quality of sugar beet during 2023/24 and 2024/25 seasons.

Treatments	Sucrose content (%)		Sucrose yield (ton/fed)		Purity (%)		Na content (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of molasses							
Control	16.43 b	16.29 b	4.624 b	4.559 b	89.57 b	89.52 b	1.96 a	1.93 a
40 kg/fed	16.59 a	16.58 a	5.112 a	5.133 a	90.81 a	90.91 a	1.88 a	1.84 b
LSD at 0.05 level	**0.06**	**0.14**	**0.169**	**0.200**	**0.38**	**0.48**	**NS**	**0.07**
	Effect of N fertilization rates							
60% RRD	15.70 c	15.73 b	3.933 c	3.909 b	92.35a	92.35 a	2.04 a	2.05 a
80% RRD	16.99 a	16.74 a	5.399a	5.311 a	90.56 b	90.44 b	2.05 a	1.95 b
100% RRD	16.85 b	16.83 a	5.271 b	5.319 a	87.65 c	87.86 c	1.67 b	1.65 c
LSD at 0.05 level	**0.03**	**0.09**	**0.111**	**0.131**	**0.32**	**0.22**	**0.06**	**0.05**
	Effect of foliar spray with Mg and B							
0	16.01 c	15.89 c	4.398 c	4.420 c	89.51 c	89.58 c	2.06 a	2.00 a
Mg	16.29 b	16.26 b	4.779 b	4.715 b	90.06 b	90.11 b	1.95 b	1.92 b
B	17.24 a	17.15 a	5.426 a	5.404 a	90.99 a	90.96 a	1.75 c	1.73 c
LSD at 0.05 level	**0.03**	**0.08**	**0.099**	**0.117**	**0.17**	**0.15**	**0.05**	**0.04**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

4.3. Effect of Mg and B as foliar application

Foliar spray with B as boric acid at 200 ppm increased sucrose content (17.24 and 17.15%) and sucrose yield (5.426 and 5.404 ton/fed) and purity (90.99 and 90.96%), whereas the control treatment increased Na content in the root in both growing seasons (Table 11).

The increases in sugar yield (ton/fed) due to spraying with Mg were about 8.66 and 6.67%; 23.37 and 22.26% for spraying with B over without molasses in the 1st and 2nd growing seasons, respectively.

In this connection, spraying boron had a positive effect on root diameter, root top, and sugar yields/fed and sucrose content (%), extractable sugar, sugar yield, and quality index (Shritinnahar *et al*., 2020). Otherwise, impurity contents (K, Na, α-amino N) and sugar lost to molasses% decreased (Nemeata Alla, 2017).

In this regard, Abbas *et al.* (2014) found that increasing boron applied as a foliar spray recorded the lowest values of ∝-amino nitrogen, potassium, and sodium contents in roots as compared to unsprayed sugar beet plants. These results were in line with those findings by Dewdar *et al*. (2018), Abdel-Nasser and Ben-Abdalla (2019), Ibrahim *et al.* (2019), Kandil *et al*. (2020), and Sarhan et al. (2020) regarding the boron effect.

4.4. Effect of dual interaction between molasses and N rates

Data in Table 12 indicate that the interaction between molasses at 40 kg/fed via irrigation water and N fertilization at 80% RR gave the highest values of sucrose (17.01 and 16.93%) and yield of sucrose (5.606 and 5.600 ton/fed) with no significant differences with the interaction between molasses at 40 kg/fed via irrigation water and N fertilization at 100% RR in both growing seasons, while the interaction between molasses and N fertilization at 60% RR gave the highest values of purity (92.77 and 92.84%) and Na content (2.04 and 2.05%) in roots.

The increases in sugar yield (ton/fed) due to the interaction between molasses at 40 kg/fed and N fertilization at 80% RR were about 11.16 and 10.65% over fertilizing sugar beet plants with N fertilizer at 100% RR only in the 1st and 2nd growing seasons, respectively.

These findings are consistent with those reported by Dawood *et al.* (2023), who found that the interaction between molasses and nitrogen (40 kg/fed molasses and 100 kg N/fed) resulted in the highest sugar yield (ton/fed), while the lowest sugar yield value was achieved with (20 kg molasses per fed and 60 kg N/fed).

4.5. Effect of dual interaction between molasses and both Mg and B

The interaction between molasses application at 40 kg /fed and spraying with B at 200 ppm produced the highest results of sucrose content (17.36 and 17.33%) and yield of sucrose (5.662 and 5.668 ton/fed) and purity (91.71 and 91.76%) in sugar beet roots in both growing seasons (Table 12). On the other hand, the control treatment (zero molasses and zero magnesium or boron) produced the lowest values for all the above-mentioned traits and also recorded the highest percentage of root sodium content (2.09 and 2.05%) in both growing seasons.

The increases in sugar yield (ton/fed) due to the interaction between molasses at 40 kg/fed and spraying with Mg were about 21.08 and 21.57% and were about 36.11 and 37.21 for the interaction between molasses at 40 kg/fed and spraying with B over control treatment (zero molasses and zero Mg or B) in the 1st and 2nd growing seasons, respectively.

Table (12). Effect of dual interaction between molasses, N fertilization rates, and Mg and B foliar spray on root quality of sugar beet during 2023/24 and 2024/25 growing seasons

Treatments		Sucrose content (%)		Sucrose yield (ton/fed)		Purity (%)		Na content (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Molasses	**N rates**	**Effect of the interaction between molasses and nitrogen**							
Control	**60% RRD**	15.60 d	15.61 e	3.635 d	3.596 d	91.92 b	91.87 b	2.05 a	2.05 a
	80% RRD	16.97 a	16.55 c	5.193 b	5.021 b	89.98 d	89.74 d	2.09 a	2.00 a
	100% RRD	16.73 b	16.71 b	5.043 b	5.061 b	86.81 f	86.96 f	1.75 b	1.74 c
40 kg /fed.	**60% RRD**	15.81 c	15.86 d	4.232 c	4.223 c	92.77 a	92.84a	2.04 a	2.05 a
	80% RRD	17.01 a	16.93 a	5.606 a	5.600 a	91.15 c	91.14 c	2.01 a	1.90 b
	100% RRD	16.97 a	16.95 a	5.498 a	5.576 a	88.50 e	88.77	1.59 c	1.57 d
LSD at 0.05 level		**0.05**	**0.13**	**0.157**	**0.186**	**0.46**	**0.32**	**0.09**	**0.07**
Molasses	**Mg and B**	**Effect of the interaction between molasses and Mg and B**							
Control	**0**	16.00 e	15.72 e	4.160 d	4.131 e	88.97 e	89.05 e	2.09 a	2.05 a
	Mg	16.18 d	16.16 d	4.521 c	4.407 d	89.46 d	89.35 d	2.04 a	2.01 ab
	B	17.13 b	16.98 b	5.191 b	5.140 b	90.28bc	90.16 c	1.75bc	1.72 d
40 kg/fed	**0**	16.02 e	16.06 d	4.636 c	4.709 c	90.05 c	90.12 c	2.03 a	1.95 b
	Mg	16.40 c	16.35 c	5.037 b	5.022 b	90.66 b	90.87 b	1.85 b	1.83 c
	B	17.36 a	17.33 a	5.662 a	5.668 a	91.71 a	91.76 a	1.75 c	1.73 d
LSD at 0.05 level		**0.05**	**0.11**	**0.141**	**0.166**	**0.25**	**0.22**	**0.08**	**0.05**
N rates	**Mg and B**	**Effect of the interaction between nitrogen, Mg, and B**							
60% RRD	**0**	15.27 i	15.12 f	3.459 h	3.473 g	91.53 c	91.67 c	2.11bc	2.11 a
	Mg	15.46 h	15.62 e	3.886 g	3.786 f	91.96 b	92.02 b	2.01 c	2.02 b
	B	16.39 f	16.47 bc	4.456 f	4.469 e	93.56a	93.38 a	2.02 c	2.03 b
80% RRD	**0**	16.31 g	16.15 d	4.846 e	4.802 d	89.78 e	89.67 f	2.25 a	2.11 a
	Mg	16.89 c	16.62 b	5.339 c	5.224 b	90.56 d	90.57 e	2.18ab	2.07ab
	B	17.77 a	17.44 a	6.014 a	5.906 a	91.36 c	91.08 d	1.72 e	1.67 d
100% RRD	**0**	16.45 e	16.40 c	4.890 e	4.985 cd	87.23 h	87.42 i	1.83 d	1.79 c
	Mg	16.52 d	16.54 bc	5.112 d	5.135 bc	87.67 g	87.74 h	1.66 e	1.68 d
	B	17.58 b	17.55 a	5.810 b	5.837 a	88.07 f	88.43 g	1.52 f	1.49 e
LSD at 0.05 level		**0.06**	**0.14**	**0.172**	**0.203**	**0.31**	**0.27**	**0.10**	**0.07**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

4.6. Effect of dual interaction between N fertilization rates and foliar spray of Mg and B

The interaction between N fertilization at 80% RR and foliar spray with B at 200 ppm gave the highest values of sucrose content (17.77 and 17.44%) and yield of sucrose (6.014 and 5.906 ton/fed), whereas the interaction between N fertilization at 60% RR and foliar spray with B produced the highest purity (93.56 and 93.38%) in sugar beet roots in both seasons (Table 12). As for Na content, the interaction between N fertilization at 80%RR and without Mg and B (control) increased Na (2.25 and 2.11%) in roots in both growing seasons.

The increases in sugar yield (ton/fed) over control treatment due to the interaction between N fertilization at 80% RR and spraying with 0.5% Mg were about 9.18 and 4.79% and were about 22.99 and 18.48% for the interaction between N fertilization at 80% RR and spraying with B over the interaction between N at 100% RR only in the 1st and 2nd growing seasons, respectively.

These results are harmony with those reported with Mekdad (2015) who indicated that the highest values of loss sugar (%), loss sugar yield and impurities in terms of (α- amino- N, Na and K) were recorded due to the interaction between 100 (N1) kg N/fed and zero (B0) ppm boron as compared to N at 120 kg/fed and spraying with B at 120 or 150 ppm.

4.7 Effect of the three-way interaction among molasses application, N fertilization rates, and both Mg and B as foliar spray

Data in Table 13 indicate that the interaction among molasses application at 40 kg/fed, N fertilization at 80% RR and foliar spray with B in the form of boric acid at 200 ppm increased sucrose content by (17.99 and 17.83%) and sucrose yield to (6.288 and 6.187 ton/fed), whereas the interaction between molasses application at 40 kg/fed, N fertilization at 60% RR and foliar spray with B at 200 ppm gave the highest purity (93.91 and 93.73%) in roots in both growing seasons. As for Na content, the interaction among treatments without molasses application, N fertilization at 80 % RR, and foliar spray with Mg at 0.5% increased Na content to (2.36 and 2.26%) in roots in both growing seasons.

Table (13). Effect of three-way interaction among molasses, N fertilization rates, and foliar spray of Mg and B on root chemical constituents of sugar beet during 2023/24 and 2024/25.

Treatments			Sucrose content (%)		Sucrose yield (ton/fed)		Purity (%)		Na content (%)	
Molasses	**N rate**	**Mg and B**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control	**60% RRD**	**0**	15.04 m	14.72j	3.041l	3.115 k	91.01 fg	91.22 d	2.11 bc	2.10bcd
		Mg	15.22 l	15.52 i	3.569 k	3.461 j	91.56 de	91.37 d	2.01 cd	2.02 cd
		B	16.56 fg	16.60de	4.297 i	4.213 h	93.21 b	93.03 b	2.03 cd	2.04 cd
	80% RRD	**0**	16.48 gh	16.07h	4.735f gh	4.516 g	89.51 ij	89.23 g	2.27a	2.18ab
		Mg	16.88 e	16.52def	5.106 de	4.923 def	89.91 i	89.86ef	2.36a	2.26a
		B	17.56 c	17.06 c	5.740 b	5.626 b	90.52gh	90.13 e	1.65 fg	1.56 g
	100%RRD	**0**	16.49 gh	16.38 fg	4.706 gh	4.762 fg	86.41 m	86.72k	1.89de	1.88 e
		Mg	16.44 h	16.46 ef	4.888efg	4.839 ef	86.91l	86.83k	1.77ef	1.76 f
		B	17.27 d	17.29 b	5.537bc	5.583 b	87.12 l	87.34 j	1.59gh	1.58 g
40 kg/fed	**60% RRD**	**0**	15.51 k	15.52 i	3.878 j	3.832 i	92.06cd	92.12 c	2.11 bc	2.12 bc
		Mg	15.70 j	15.72 i	4.203i	4.111 hi	92.36 c	92.67 b	2.01 cd	2.02 d
		B	16.22 i	16.34 fg	4.615 h	4.726 fg	93.91 a	93.73 a	2.01 cd	2.02 d
	80% RRD	**0**	16.15 i	16.24 gh	4.958ef	5.088 de	90.05 hi	90.12 be	2.23ab	2.04 cd
		Mg	16.91 e	16.72 d	5.572 bc	5.526 b	91.21 ef	91.28 d	2.01 cd	1.88 e
		B	17.99 a	17.83 a	6.288 a	6.187 a	92.21 c	92.03 c	1.79ef	1.78 ef
	100%RRD	**0**	16.42 h	16.43 efg	5.074e	5.208 cd	88.06 k	88.12 i	1.77ef	1.70 f
		Mg	16.60 f	16.62 de	5.337 cd	5.431 bc	88.43 k	88.66 h	1.55gh	1.60 g
		B	17.89 b	17.82 a	6.084 a	6.091 a	89.02 j	89.53 fg	1.45 h	1.41 h
LSD at 0.05 level			**0.08**	**0.05**	**0.08**	**0.20**	**0.244**	**0.288**	**0.44**	**0.38**

Molasses at 40 kg/fed throughout irrigation water, Nitrogen recommended rate 80 kg N/fed, Magnesium in the form of ($MgSO_4.7H_2O$) 9.8% Mg, was added at 0.5% and Boron in the form of boric acid 17% B at 200 ppm B.

For all treatments, sucrose levels (%) ranged from 15.04 to 14.72% and 17.99 to 17.83% in roots. Sucrose yield (ton/fed) increased from 3.041 to 3.115 and from 6.288 to 6.187 in the 1st and 2nd growing seasons, respectively. There was a positive correlation between root yield and sucrose (ton/fed).

The increases in sugar yield (ton/fed) due to the interaction among Molasses at 40 kg/fed, N fertilization at 80% RR and spraying with Mg were about 18.40% and 16.04% respectively, and were about 33.62% and 29.92% for the interaction between molasses, N fertilization at 80% RR, and spraying with B, compared to the interaction between N at 100% RR only in the 1st and 2nd seasons, respectively.

CONCLUSION

Treating sugar beet plants grown in clay soil with molasses at 40 kg/fed twice throughout irrigation water (30 and 45 days after sowing), fertilizing with mineral nitrogen at 80% of the recommended rate (64 kg N/fed) as soil application and spraying with Mg at 0.5% increased chlorophyll a, b, total (a+b) and carotenoides in leaf tissues at 90 days after sowing, top yield and K contents and Mg in roots. Moreover, molasses at 40 kg/fed, fertilizing with mineral nitrogen at 80% of the recommended rate (64 kg N/fed) as soil application and spraying with B at 200 ppm increased root yield, root length, sucrose content (%), and sucrose yield (ton/fed). This treatment reduced mineral nitrogen by 20% and increased root yield by 11.28% and sugar yield by 31.77% (average over two growing seasons) compared with fertilizing with N at 100% RR.

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تأثير الإضافة الأرضية للمولاس والرش بالمغنيسيوم والبورون تحت مستويات من التسميد النيتروجينى على إنتاجية وجودة جذور بنجر السكرفى الأراضى الطينيه

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معهد بحوث الاراضى والمياه والبيئة – مركز البحوث الزراعية

الملخص العربى

أجريت تجربة حقلية في فى الأرض الطينية بمحطة البحوث الزراعية بالجميزة ، محافظة الغربية ، مصر خلال موسمي شتاء ٢٠٢٤/٢٠٢٣ و٢٠٢٥/٢٠٢٤ لتحسين انتاجيه وجوده صنف بنجر السكراوكلاند وهدف هذا البحث إلى دراسة تأثير اضافه المولاس (٠ و٤٠ كجم/فدان مرتين (بعد ٣٠ ، ٤٥ يومًا من الزراعة) من خلال ماء الرى ، وثلاث معدلات النيتروجين (٦٠ و٨٠ و١٠٠% من المعدل الموصى به) كإضافة للتربة ، والرش الورقي بالمغنيسيوم بنسبة ٠,٥٪ فى صوره كبريتات المغنيسيوم والبورون بتركيز ٢٠٠ جزء في المليون فى صوره حمض البوريك ثلاث مرات (بعد ٤٥ و٦٠ ، ٧٥ يومًا من الزراعة).

سجلت معاملة بنجر السكر المنزرع في أرض طينية بالمولاس بمعدل ٤٠ كجم / فدان من خلال مياه الري، والتسميد بالنيتروجين المعدني بنسبه ٨٠٪ من المعدل الموصى به (٦٤ كجم نيتروجين / فدان) اضافه ارضيه والرش بالمغنيسيوم بنسبة ٠,٥٪ زيادة لمحتوى اوراق البنجر من كلوروفيل أ، ب، الكلي (أ + ب) والكاروتينويدات بعد ٩٠ يومًا من الزراعة، وكذلك محصول العرش ومحتوى الجذور من كل من البوتاسيوم والمغنيسيوم. علاوة على ذلك، فإن إضافة المولاس بمعدل ٤٠ كجم / فدان، والتسميد بالنيتروجين المعدني بنسبة ٨٠٪ من المعدل الموصى به (٦٤ كجم نيتروجين / فدان) والرش بالبورون بتركيز ٢٠٠ جزء في المليون أدى إلى زيادة محصول الجذور وطول الجذر ونسبه السكروز فى الجذور ومحصول السكروز (طن / فدان). وقد أدت هذه المعامله إلى خفض النيتروجين المعدني بنحو ٢٠% في التسميد وزيادة فى محصول الجذور بنسبة ١١,٢٨% وكذلك محصول السكر بنسبة ٣١,٧٧% (متوسط الموسمين) مقارنة بالتسميد بالنيتروجين المعدنى بنسبة ١٠٠% من الموصى به فقط.