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RESEARCH ARTICLE

Influence of compost type, nitrogen fertilizer level and micronutrients on growth, productivity and quality of sugar beet cultivated in sandy soil

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Abstract

At a private farm located at the 64th km of Cairo-Alexandria Desert Road (latitude of 30o27'05" N and longitude of 30o19'09" E), Giza Governorate, Egypt, two field experiments were carried out in the 2018/2019 and 2019/2020 seasons to determine the influence of compost type (without, garbage compost and botanical compost), nitrogen fertilizer levels (60, 80 and 100 kg N fed^{-1}) and foliar application with micronutrients levels (without, 1 and 2 L of Citreen "as commercial foliar fertilizer contains micronutrients"/300 liter of water/fed) as well as their interactions on growth, productivity and quality of sugar beet. Randomized complete block design in a split-split plot arrangement was used.

The obtained results showed that the organic fertilization of sugar beet fields with botanical compost produced the highest values of growth characters, root yield and quality parameters of sugar beet in both seasons. Supplying sugar beets with 100 kg N/fed resulted in the highest growth, yield and quality traits of the crop in the two growing seasons.

Foliar application of micronutrients in the form of Citreen at 2 liter/300 liters of water/fed attained the highest values of growth characters, root yield and quality parameters as well as nitrogen use efficiency (NUE). Under the environmental condition of the present work, the addition of 5 ton of botanical compost/fed + 80 kg N/fed combined with spraying Citreen at 2 L/fed can be concluded to improve productivity and quality of sugar beet

Keywords: Beta vulgaris; Organic fertilizers; Mineral fertilizers; Micronutrients; Juice quality.

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Introduction

Sugar beet (*Beta vulgaris var. saccharifera L.*) is one of the sugar crops, which is widely grown in different regions of the world due to its advantages over sugarcane.

It has an important position in the Egyptian crop rotation as a winter crop for sugar production not only in the fertile soils of the Nile valley but also can be economically grown in the newly reclaimed salt-affected soils, such as that at the Northern parts of the Nile delta, as one of the most tolerant crops to salinity and wide range of climates Abou-Elwafa et al. (2020), Seadh et al. (2008).

The expansion of the sugar beet cultivated area has been and will still be one of the available strategies to minimize the gap between sugar consumption and production due to the rapid increase in Egypt, s population. Moreover, there will be a need to find out some agricultural treatments to raise the low productivity and quality of sugar beet per unit area in such new areas, of which the addition of compost, nitrogen fertilization and foliar application with micronutrients Alotaibi et al. (2021), Aljabri et al. (2021).

Compost is a natural way to rejuvenate and feed the poor soil. Compost recycles nutrient elements such as carbon, nitrogen, magnesium, sulfur, calcium phosphorus, and trace minerals. These nutrients not only directly feed plants but also sustain the natural life cycles of the soil by feeding the microorganisms that live there.

The organic humic acid and fulvic acids resulting from the decomposition of compost make elements in the soil more available for plants to uptake Odlare et al. (2008), It was found that the application of compost improved the physical properties of the soil, increased the amount of organic matter content and supplied plants with available important nutrients such as nitrogen, phosphorus and potassium Ali et al. (2003).

While the contamination with heavy metals and other toxic substances was kept at very low levels, which ultimately led to increasing plant growth Ali (2004) , Likewise, El-Agamy (2006), and El-Banna et al. (2020), mentioned that the usage of organic fertilization as compost plays a major role in crop production and became necessary in the agriculture process because compost supplies ants with essential nutrients and reduces pollution caused by using mineral fertilizers. Moreover, positive effects of compost on soil structure, aggregate stability and water-holding capacity were reported Odlare et al. (2008), Soliman et al. (2014), indicated that the highest values of growth parameters and sugar percentage were recorded in plants treated with 30 m3/fed. of compost produced from animal waste. While the highest value of juice purity was obtained by using 10 m3/fed. of compost produced from town refuse. Marajan et al. (2021) revealed the application of compost (5 t/ha) displayed a significant increase in leaf dry weight, root diameter and root fresh weight compared to the control treatment. Generally, the usage of organic fertilization as compost plays a major role in crop production and became necessary in the agriculture process because compost supplies plants with essential nutrients and reduces pollution caused by using mineral fertilizers El-Agamy (2006), El-Banna et al. (2020).

Nitrogen is an essential and structural element for sugar beet growth and yield. The application of mineral nitrogen fertilizer plays a vital role in cell division and elongation, where it is a crucial part of various types of metabolically active compounds like amino acids, proteins, nucleic acids, flavins, purines, nucleotides, enzymes, coenzymes and alkaloids Murtaza et al. (2013). Many studies found that increasing nitrogen mineral fertilizer levels up to 100 or 110 kg N/fed. significantly increased root length, root diameter, top yield/fed., root yield/fed. and sugar yield/fed. Jahedi and Noroozi (2010), Attia et al. (2011), Ferweez et al. (2011), Sarhan (2012), Shaban et al. (2014), Mekdad (2015), Nemeata Alla (2016). On the other hand, Monreala et al. (2007), El-Geddawy et al. (2008), Abdelaal and Tawfik (2016), reported that there was a decrease in root quality parameters due to increasing mineral nitrogen levels, which cause an increase in amino compounds caused by the extreme of nitrogen uptake. Nitrogen is a vital nutrient for sugar beet and its management is very important for maximizing yield and quality Mahapatra et al. (2020). Although micronutrients are required in small quantities as compared with macronutrients in the completion of the life cycle of a crop, they play a vital role in the regulation of plant growth and harvestable yield. Utilization of micronutrients such as iron, zinc and manganese with balance can enhance and increase the productivity of yield sugar beet Rassam et al. (2015), Fathy et al. (2009), found that foliar application on sugar beet tops with Zn increased the photosynthetic pigment content of the treated plants compared to the control. Abdelaal et al. (2015), reported that foliar application of B, Fe, Zn and Mn at the concentration of 1.5 l/fed. resulted in the widest root diameter and root fresh weight/plant, as well as sucrose%, root and sugar yields/fed. Mekdad and Rady (2016), showed that adding micronutrient mixtures (Fe + Zn + Mn) improved yield and its attributes of sugar beet crops. Dewdar et al. (2018),concluded that the application of nano-microelements mixtures (Zn, Fe, B, Mn) at 200 mg/l as foliar application significantly produced higher yields with improved quality traits of sugar beet. Zewail et al. (2020), showed that the Zn, B, and Mo foliar application increased the root length and diameter, root fresh and dry weight, sugar and root yields and improved crop quality (sucrose% and purity%). Hefny and Said (2021), stated that foliar application sugar beet with Magrow Nano mix (Fe 6%, Zn 6%, MN 5%, Cu 1%, B 2%, Mo 0.1%, citric acid 4%) as nano-micronutrients fertilizer significantly affected yield and quality This investigation was carried out to find out the appropriate combination including compost type, nitrogen fertilizer level and foliar application with micronutrients that attain good growth and the highest productivity and quality of sugar beet under the environmental conditions of Giza Governorate, Egypt.

Materials and methods

Two field experiments were carried out at a private farm located at the 64th km, Cairo-Alexandria Desert Road (latitude of 30o 27' 05" N and longitude of 30o 19' 09" E), Giza Governorate, Egypt in the 2018/2019 and 2019/2020 seasons. The objective of this study was to find out the appropriate type of compost, level of nitrogen fertilizer, micronutrients levels, as well as their combinations to get the highest productivity and quality of sugar beet. A randomized complete block design in a split-split plot arrangement in three replications was used. The main plots were assigned to compost types (without, garbage compost and botanical compost), which were added at the rate of 5 ton/fed. after determining the experimental units on the soil surface and then turned over. The sub-plots were occupied with nitrogen fertilizer levels (60, 80 and 100 kg N fed-1). Nitrogen was added in the form of urea (46.5 % N) as a side-dressing in three equal doses; after thinning of sugar beet plants (30 days from sowing), after 45 and 60 days from sowing. Micronutrients were added as a foliar application in the sub-sub plots (without "control", 1 and 2 L Citreen/300 liter of water/fed.). Citreen is a commercial foliar fertilizer, which contains 15 % citric acid, 2% chelated iron (Fe), 2% chelated zinc (Zn) and 2% chelated manganese (Mn). Citreen was applied using a hand sprayer twice at 45 and 60 days from sowing. Each experimental basic unit included 5 ridges, each 60 cm apart and 3.5 m long, comprising an area of 10.5 m2 (1/400 fed.). Chemical analysis of the tested garbage and botanical compost in both seasons is presented in Table 1.

Table 1. Chemical analysis of the tested compost types*in the two growing seasons.

Properties	Garbage compost	Botanical compost
Weight/m^3 (kg)	695.00	560.00
Moisture %	24.00	32.00
pH (1:10)	7.34	6.18
EC (1:10) (dS/m)	1.90	5.74
Available N%	1.07	1.47
Available P% (P_2O_5)	0.71	0.93
Available K% (K_2O)	1.45	0.84
OM %	23.39	49.82
OC %	13.57	28.90
Ash %	76.61	50.18
C/N ratio	12.6:1	20:1
Weed seeds	-	-
Nematode	-	-

* Analysis was done at Soil, Water and Environ. Res. Inst., Agric. Res. Center (ARC).

Soil samples were taken at random from the experimental field area at a depth of 0-30 cm from soil surface before soil preparation to measure the physical and chemical soil properties as shown in Table 2.

Table 2. Physical and chemical properties of soil of the experimental field in 2018/2019 and 2019/2020 seasons.

Property		2018/2019	2019/2020
Sand (%)		93.20	93.50
Silt (%)		3.95	4.15
Clay (%)		2.85	2.35
Soil texture class		Sandy	Sandy
Bulk density		1.65	1.70
Soil pH		8.00	8.15
$EC_{(1:5)}$ (dS m^{-1})		1.25	1.30
Organic matter (%)		0.20	0.22
Macronutrients (mg kg^{-1})	N	28.00	30.00
	P	4.15	4.55
	K	80.00	85.50
Soluble cations (meq L^{-1})	Ca^{++}	4.85	4.85
	Mg^{++}	0.95	0.92
	Na^{+}	4.75	4.95
	K^{+}	0.45	0.50
Soluble cations (meq L^{-1})	CO_3^{--}	0.00	0.00
	HCO_3^{-}	0.75	0.83
	SO_4^{--}	6.25	6.65
	Cl^{-}	3.95	4.15
Water status	Saturation %	22.50	23.20
	Field capacity %	12.25	13.00
	Wilting point %	5.35	5.00
	Available water %	6.85	7.10

Calcium superphosphate (15 % P2O5) at 200 kg/fed. was applied during soil preparation. Sugar beet seeds of multi-germ of Faten variety were sown in the first week of October in both growing seasons.

Potassium sulfate (48 % K_2O) at the rate of 24 kg/fed. was applied after 30 days from sowing.

Plants were thinned at the age of 30 days from sowing. The other recommended agricultural practices for growing sugar beet were applied by Sugar Crops Research Institute.

Data recorded

Growth characters

After 120 and 150 days from sowing, samples of five plants were collected randomly from each sub-sub plot to estimate the root dry weight of chosen plants, where the portions of all plants were air-dried, then at 70 ºC, it was oven dried till constant weight, to calculate the following traits:

Crop growth rate (CGR) in g/day was calculated by using the equation described by Radford (1967).

$$CGR = \frac{W_2 - W_1}{T_2 - T_1}$$

Where:

W_1 and W2 refer to plant dry weight at sampling recorded at time (T_1) and time (T_2) after 120 and 150 DFS, respectively.

2. Relative growth rate (RGR) in g/g/day as described by Radford (1967), was estimated by using the following equation:

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1}$$

Where: Loge = In, refers to the natural log, and W_1 and W_2, refer to plant dry weight at sampling recorded at time (T_1) and time (T_2) after 120 and 150 DFS, respectively.

Yield components

At harvest, five plants were randomly collected of each sub-sub plot to determine the following:

- Root fresh weight (g plant-1).
- Root length (cm).
- Root diameter (cm).

Root juice quality parameters

The following root juice quality parameters were determined at Dakahlia Sugar Company, Bilkas Sugar Factory Laboratories.

Impurity percentage (%) in sugar beet roots.

Gross sucrose percentage (%). It was determined Polari metrically on a lead acetate extract of fresh macerated roots according to the method of Carruthers and Old Field (1960).

Extracted sucrose percentage (%).

Extractable white sucrose (correct sugar content) of beet roots was calculated by linking the beet non-sugar, K, Na and α-amino nitrogen (expressed as a mill equivalent/100 g of beet) as reported by Harvey and Dutton (1993) using the following equation:

Extractable white sugar (%) = Gross sugar (%) - [0.343 (K+Na) + 0.094 α-amino-N + 0.29]

Quality index (%) of sugar beet root juice.

It was determined according to the method reported by Carruthers and Old Field (1960).

Sugar beet yields

The harvested plants were cleaned, separated into roots and tops and weighed in kilograms, which was converted into tons/fed. to estimate:

1. Root yield (ton/fed.).

2. Top yield (ton/fed).

3. Corrected sugar yield/fed (ton). It was calculated by multiplying root yield by extracted sucrose percentage.

4. Nitrogen use efficiency (NUE) of root yield/fed. It was calculated by using the following equation

$$NUE_{Root\ yield} = \frac{Root\ yield\ (ton)}{Nitrogen\ level (kg)} \times 1000$$

5. Nitrogen use efficiency (NUE) of corrected sugar yield/fed. It was calculated by using the following equation

$$NUE_{Sugar\ yield} = \frac{Corrected\ sugar\ yield\ (ton)}{Nitrogen\ level (kg)} \times 1000$$

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split-split plot design as published by Gomez and Gomez (1984), using the software package "MSTAT-C".

The least significant difference (LSD) method was used to compare the differences among treatment means at a 5% level of probability as described by Snedecor and Cochran (1980).

Results and discussion

Effect of compost type

As for growth traits, data in Table 3 show that the tested compost types (garbage compost and botanical compost) had a significant influence on CGR and RGR (in the 1st season) without an appreciable variance between the botanical and garbage compost on these two traits in the second season. All of the yield component traits (root fresh weight/plant, root length and diameter) were markedly affected by compost types in both seasons. It was noticed that enriching the sandy soil of the experimental site with 5 tons of botanical compost/fed. significantly increased CGR and RGR (in the 1st season), root fresh weight/plant, root length and diameter (in both seasons) compared with that given garbage compost and the control treatment. Concerning root juice quality parameters (Table 4), the results pointed out that the impurity percentage in sugar beet roots (K, Na and α-amino nitrogen) was insignificantly affected by the applied compost types in both seasons. However, compost types significantly index percentages in sugar beet roots in both seasons. affected gross sucrose, extracted sucrose and quality. The addition of botanical compost substantially improved gross sucrose, extracted sucrose and quality index percentages in sugar beet roots compared to garbage compost and the control treatment in both seasons. The results in Table 5 pointed to an appreciable effect of the used compost types on sugar beet root and sugar yields/fed., as well as, nitrogen use efficiency "NUE" calculated on root and sugar yields in both seasons. The addition of garbage and/or botanical compost to the sandy experimental soil increased the harvestable root yield by 1.266 and 1.599 ton/fed. over that produced if neither of them was added (control), respectively in the 1st season, being 0.975 and 2.027 ton/fed. in the 2nd one. Likewise, an increase of 0.552 and 0.640 ton of sugar/fed. was gained in the case of using garbage and/or botanical compost, successively, in the 1st season, corresponding to 0.259 and 0.577 ton/fed., in the 2nd one. The results indicated that mixing the botanical compost with the sandy soil resulted in the highest value of "NUE" compared with garbage compost and the control. These results were true, whether "NUE" was calculated on root and/or sugar basis in both seasons. The increments in growth characters, yield components, root juice quality parameters and yields of sugar beet associated with organic fertilizing sugar beet fields with botanical compost may be due to the application of compost improved soil structure and physical properties, aggregate stability and water-holding capacity Odlare et al. (2008). In addition, increased the amount of organic matter content in the soil and the supply of available macro and micronutrients to plants (Ali et al. (2003),Ali (2004), which leads to an increase the plant growth, nutrients uptake, photosynthesis rate and hence higher values of fresh weight of the plant, root length and diameter, which participated in increasing root, top and sugar yields/fed. These results are in harmony with those reported by Soliman et al. (2014), and Marajan et al. (2021).

Table 3: Crop growth rate (CGR), relative growth rate (RGR), root fresh weight, root length and diameter of sugar beet as affected by compost type, nitrogen fertilizer level and foliar application with micronutrients levels, as well as their interactions during 2018/2019 and 2019/2020 seasons.

Characters Treatments Seasons	Crop growth rate "CGR" (g/day)		Relative growth rate "RGR" (g/g/day)		Root fresh weight (g plant^{-1})		Root length (cm)		Root diameter (cm)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
A- Compost type:										
Without	1.929	2.518	0.132	0.141	1118.7	1110.0	26.97	23.54	10.81	10.58
Garbage compost	2.153	2.523	0.136	0.142	1125.3	1153.6	28.27	24.89	10.93	11.29
Botanical compost	2.331	2.534	0.139	0.142	1144.8	1254.3	28.97	25.39	11.25	11.50
LSD (at 5%)	0.296	NS	0.006	NS	20.5	23.6	0.83	0.74	0.20	0.15
B- Nitrogen fertilizer level:										
60 kg N fed^{-1}	1.794	2.204	0.131	0.139	1033.7	1106.2	25.99	23.22	10.58	9.76
80 kg N fed^{-1}	2.145	2.561	0.136	0.140	1147.5	1185.1	28.22	24.28	11.05	11.34
100 kg N fed^{-1}	2.473	2.810	0.141	0.147	1207.6	1226.7	30.01	26.31	11.36	12.27
LSD (at 5%)	0.278	0.275	0.006	0.005	36.2	35.2	0.41	0.33	0.10	0.07
C- Foliar application with Citreen (chelated Fe + Zn + Mn micronutrients) levels:										
Without	2.024	2.083	0.134	0.136	1033.0	1049.7	27.01	23.74	10.46	10.44
1 L/fed	2.135	2.588	0.136	0.144	1146.5	1192.6	28.17	24.55	10.95	11.15
2 L/fed	2.253	2.904	0.138	0.146	1209.2	1275.7	29.03	25.52	11.59	11.78
LSD (at 5%)	0.244	0.258	0.003	0.004	35.5	30.7	0.21	0.15	0.19	0.16
D- Interactions:										
A × B	NS	*	*	*	*	NS	NS	*	*	*
A × C	*	*	NS	*	NS	*	*	*	*	*
B × C	NS	*	NS	*	NS	*	NS	*	NS	*
A × B × C	*	*	*	*	*	*	*	*	*	*

Table 4. Impurities, gross sucrose, extracted sucrose and quality index percentages in sugar beet roots as affected by compost type, nitrogen fertilizer level and foliar application with micronutrients levels, as well as their interactions during 2018/2019 and 2019/2020 seasons.

Characters Treatments Seasons	Impurities (%)		Gross sucrose (%)		Extracted sucrose (%)		Quality index (%)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
A- Compost type:								
Without	2.71	2.49	17.55	18.09	14.84	15.59	84.16	85.98
Garbage compost	2.70	2.47	18.92	18.50	16.21	16.02	85.41	86.37
Botanical compost	2.65	2.45	19.00	18.95	16.35	16.50	85.61	86.89
LSD (at 5%)	NS	NS	0.28	0.26	0.38	0.39	0.65	0.68
B- Nitrogen fertilizer level:								
60 kg N fed^{-1}	2.58	2.39	18.55	18.45	15.96	16.05	85.72	86.87
80 kg N fed^{-1}	2.70	2.47	18.96	18.86	16.25	16.38	85.41	86.64
100 kg N fed^{-1}	2.78	2.55	17.96	18.24	15.18	15.68	84.05	85.73
LSD (at 5%)	0.11	0.12	0.35	0.33	0.40	0.43	0.76	0.79
C- Foliar application with Citreen (chelated Fe + Zn + Mn micronutrients) levels:								
Without	2.84	2.62	17.80	17.85	14.96	15.23	83.55	85.10
1 L/fed	2.69	2.45	18.40	18.48	15.70	16.02	85.03	86.47
2 L/fed	2.53	2.34	19.27	19.21	16.74	16.86	86.60	87.66
LSD (at 5%)	0.13	0.13	0.48	0.45	0.57	0.51	1.02	0.92
D- Interactions:								
A × B	NS	NS	NS	*	NS	*	*	NS
A × C	NS	NS	*	NS	*	*	NS	*
B × C	*	*	NS	*	*	NS	*	NS
A × B × C	*	*	*	*	*	*	*	*

Effect of nitrogen fertilizer levels

All of the studied growth traits (crop growth rate and relative growth rate) and yield components (root fresh weight, root length and diameter in both seasons) of sugar beet were significantly affected by the applied nitrogen levels (Table 3).

A gradual increase in root fresh weight, root length and diameter were observed accompanying the increase in N-level from 60 up to 100 kg N/fed. in both seasons.

These findings could be attributed to the role of nitrogen in building up metabolites and activation of enzymes that associate with the accumulation of carbohydrates, which translated from leaves to developing roots as well as increasing division and elongation of cells, consequently increasing root size Murtaza et al. (2013). However, insignificant variance was noticed between 80 and 100 kg N/fed. in their influence on RGR and RGR in the 1^{st} and 2^{nd} seasons.

The present results are in line with those obtained by Attia et al. (2011), Ferweez et al. (2011), Sarhan (2012) , Shaban et al. (2014), Mekdad (2015), Nemeata Alla (2016).Data in Table 4 reveal that the studied beet quality characteristics were markedly affected by the applied N-fertilizer levels in both seasons.

A gradual increase was recorded in beet impurities % as N-level was raised from 60 to 80 and 100 kg N/fed., without significant variance between 80 and 100 kg N/fed. in both seasons. An opposite trend was observed in respect to gross sucrose, extractable sucrose and quality index percentages, in their response to the increase in N-fertilization level in both seasons.

These findings could be due to excessive nitrogen application can be ascribed to its role in increasing root weight and diameter, tissue water content as well as increasing non-sucrose substances such as proteins and alpha-amino acid, and hence decreasing sucrose content in roots and purity percentage (Murtaza et al. 2013). Monreala et al. (2007), El-Geddawy et al. (2008), and Abdelaal and Tawfik (2016), confirm this conclusion. Nitrogen fertilizer levels caused a significant effect on all yield characters (root, top and corrected sugar yields/fed.) as well as nitrogen use efficiency (NUE) of root and corrected sugar yields/fed. in the two growing seasons (Table 5). The highest values of root (29.473 and 28.244 t/fed.) and top yield (11.239 and 12.839 t/fed.) and lowest values of NUE of root yield (294.7 and 282.4 kg/fed.) and corrected sugar yield (44.90 and 44.57 kg/fed.) were produced from fertilizing beet plants with 100 kg N/fed. in the first and second seasons, respectively. However, the application of 80 kg N/fed. induced the highest values of corrected sugar yield (4.490 and 4.458 t/fed.) and the second-best values of root and top yields/fed. as well as nitrogen use efficiency (NUE) of root and corrected sugar yields/fed. after fertilizing with 100 kg N/fed. with little differences between them in the first and second seasons, respectively. The lowest values of root (27.497 and 26.462 t/fed.), top (10.955 and 11.727 t/fed.) and corrected sugar yields (4.412 and 4.2808 t/fed.) and highest values of NUE of root yield (458.2 and 441.0 kg/fed.) and corrected sugar yield (73.53 and 71.32 kg/fed.) were obtained from fertilizing sugar beet plants with the lowest level of nitrogen fertilizer (60 kg N/fed.) in the first and second seasons, respectively. The increase in yield characters due to the application of nitrogen fertilization can be explained through the fact that nitrogen fertilizer plays a vital role in cell division and elongation by virtue of being a crucial part of various types of metabolically active compound like amino acids, proteins, nucleic acids, prophyrins, flavins, purines and pyramidine nucleotides, enzymes, coenzymes and alkaloids Murtaza et al. (2013), therefore enhanced root length, diameter as well as root fresh weight and finally root and sugar yields per unit area. Mekdad (2015), Nemeata Alla (2016), and Mahapatra et al. (2020), recorded comparable tendency.

Effect of foliar application with micronutrients

Data in Table 3 show that the foliar application with Citreen as a source of chelated Fe, Zn and Mn caused significant effects on CGR, RGR, root fresh weight/plant, root length and diameter in both seasons. Foliar spraying on sugar beet foliage at the rate of 2 liter of Citreen/300 liters of water/fed. after 45 and 60 days from sowing resulted markedly in the highest values of CGR, RGR, root fresh weight/plant, root length and diameter in both seasons. It was followed by spraying plants with Citreen at the rate of 1 liter/300 liter of water/fed. after 45 and 60 days from sowing also with regard to its effect on growth characters and yield components in the two growing seasons. From obtained results under the environmental conditions of this research, it could be observed that using of micronutrients in the form of Citreen either at 2 L/300 liter of water/fed. or at 1 L/300 liter of water/fed. surpassed control treatment during both seasons.

With respect to root impurity % (Table 4), the results showed a beneficial and substantial influence of increasing the rate of Citreen up to 2 liter /300 liter of water/fed. on the recorded beet quality traits, in both seasons, where impurities % was decreased, while gross sucrose, extractable sucrose and quality index percentages were raised. Generally, it can be observed that foliar application with Citreen as commercial micronutrient fertilizer either at 1 or 2 liter/300 liter of water/fed. led to a gradual tendency to improve all quality determinations as compared with control treatment in both seasons.

Data in Table 5 show that root, top and corrected sugar yields/fed., nitrogen use efficiency (NUE) of root and corrected sugar yields/fed. of sugar beet were significantly responded due to foliar application with Citreen as commercial micronutrients foliar fertilizer levels (without, 1 and 2 liter/300 liter of water/fed.) in both seasons.

Noteworthy, foliar spraying sugar beet plants with micronutrients in the form of Citreen as commercial fertilizer at the rate of 2 liter/300 liter of water/fed. after 45 and 60 days from sowing yielded the highest values of root (29.557 and 27.897 t/fed.), top (11.574 and 12.751 t/fed.), corrected sugar yield (4.980 and 4.736 t/fed.), NUE-root yield (384.3 and 362.3 kg/fed.) and NUE-corrected sugar yield (64.94 and 61.63 kg/fed.) in the first and second seasons, respectively.

Concerning foliar spraying sugar beet plants with micronutrients in the form of Citreen at the rate of 1 liter/300 liter of water/fed., it is ranked after the aforementioned treatment, respectively with respecting their effect on root, top and corrected sugar yields/fed., nitrogen use efficiency of root and corrected sugar yields/fed. in the two seasons.

On the other hand, control treatment (without foliar application with micronutrients) resulted in the lowest means of root, top and corrected sugar yields/fed., NUE of root and corrected sugar yields/fed. in both seasons.

These increases in growth characters, yield components, root juice quality parameters, yield and nitrogen use efficiency (NUE) as a result of foliar application with micronutrients (Fe, Zn and Mn) may be due to its role in carbohydrate metabolism and reproductive phase of the plants along with photosynthesis or various enzymatic activities, which stimulating establishment and vegetative growth, hence increasing root and foliage fresh weights and also root length and diameter. Fathy et al. (2009), Abdelaal et al. (2015), Mekdad and Rady (2016), Dewdar et al. (2018), Zewail et al. (2020) and Hefny and Said (2021) confirm this conclusion.

Effect of the interactions

There are many significant interaction effects among compost type, nitrogen fertilizer level and foliar application with the levels of micronutrients on most of the studied characters in both seasons as shown in Tables 3, 4 and 5. We present only the significant triple interactions among compost type, nitrogen fertilizer level and foliar application with micronutrients level on all studied characters in both seasons.

The interaction among compost type, nitrogen fertilizer level and foliar application with micronutrients level significantly influenced crop growth rate (CGR), relative growth rate (RGR), root fresh weight, root length and diameter, impurities, gross sucrose, extracted sucrose and quality index percentages, root, top and corrected sugar yields/fed., nitrogen use efficiency "NUE" of root and corrected sugar yields/fed. in both seasons as shown from results in Table 3, 4 and 5.

The recommended treatment that produced the highest values of growth characters (crop growth rate "CGR" and relative growth rate "RGR"), yield components (root fresh weight, root length and diameter) and yields (root, top and corrected sugar yields/fed.) in both seasons was organic fertilizing sugar beet fields with botanical compost at the rate of 5 t/fed. and mineral fertilizing plants with 100 kg N/fed. in addition foliar spraying plants after 45 and 60 days from sowing with micronutrients in the form of Citreen at 2 L/300 liter of water/fed. as illustrated in Tables 6 and 8.

This treatment was followed by organic fertilizing sugar beet fields with botanical compost and mineral fertilizing plants with 80 kg N/fed. besides foliar spraying plants with Citreen at 2 LITER/300 liter of water/fed. without significant differences between them in most cases in both seasons.

On the other hand, the lowest values of growth characters, yield components and yields resulted from control treatment of three studied factors (without organic fertilizing with compost and mineral fertilizing plants with 60 kg N/fed. without foliar spraying plants with micronutrients) in both seasons.

Table 5. Root, top and corrected sugar yields/fed, nitrogen use efficiency (NUE) of root and corrected sugar yields/fed of sugar beet as affected by compost type, nitrogen fertilizer level and foliar application with micronutrients levels, as well as their interactions during 2018/2019 and 2019/2020 seasons.

Treatments / Characters / Seasons	Root yield (t/fed)		Top yield (t/fed)		Corrected sugar yield (t/fed)		NUE- Root yield (kg/fed)		NUE- Corrected sugar yield (kg/fed)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
A- Compost type:										
Without	27.756	26.196	10.649	11.883	4.161	4.118	360.7	339.3	54.29	53.34
Garbage compost	29.022	27.171	10.891	12.604	4.713	4.377	374.9	352.7	60.92	56.88
Botanical compost	29.355	28.223	11.748	12.716	4.801	4.696	381.8	367.4	62.87	61.34
LSD (at 5%)	0.685	0.705	0.358	0.368	0.198	0.201	11.5	12.0	3.25	3.32
B- Nitrogen fertilizer level:										
60 kg N fed^{-1}	27.497	26.462	10.955	11.727	4.412	4.280	458.2	441.0	73.53	71.32
80 kg N fed^{-1}	29.164	26.884	11.094	12.637	4.490	4.458	364.5	336.0	59.66	55.67
100 kg N fed^{-1}	29.473	28.244	11.239	12.839	4.773	4.454	294.7	282.4	44.90	44.57
LSD (at 5%)	0.789	0.885	0.285	0.274	0.165	0.178	12.0	14.0	4.42	4.34
C- Foliar application with Citreen (chelated Fe + Zn + Mn micronutrients) levels:										
Without	28.006	26.520	10.692	12.065	4.196	4.070	362.7	344.3	54.54	52.85
1 L/fed	28.571	27.173	11.022	12.387	4.499	4.386	370.4	352.8	58.60	57.08
2 L/fed	29.557	27.897	11.574	12.751	4.980	4.736	384.3	362.3	64.94	61.63
LSD (at 5%)	0.813	0.801	0.475	0.465	0.185	0.180	13.0	12.7	2.69	2.47
D- Interactions:										
A × B	*	*	*	*	*	*	NS	NS	*	NS
A × C	*	*	*	*	*	*	*	NS	NS	*
B × C	*	*	*	*	*	*	NS	*	*	*
A × B × C	*	*	*	*	*	*	*	*	*	*

Table 6: Crop growth rate (CGR), relative growth rate (RGR), root fresh weight, root length and diameter of sugar beet as affected by the interaction among compost type, nitrogen fertilizer level and foliar application with micronutrients levels, during 2018/2019 and 2019/2020 seasons.

Compost type	N-levels (kg fed^{-1})	Micro-nutrients levels	CGR (g/day) 2018/2019	CGR (g/day) 2019/2020	RGR(g/g/day) 2018/2019	RGR(g/g/day) 2019/2020	Root fresh weight(g $plant^{-1}$) 2018/2019	Root fresh weight(g $plant^{-1}$) 2019/2020	Root length(cm) 2018/2019	Root length(cm) 2019/2020	Root diameter(cm) 2018/2019	Root diameter(cm) 2019/2020
Without	60	Without	1.120	1.511	0.114	0.124	832.3	1044.6	21.13	21.10	9.83	8.200
		1 L/fed	1.272	1.700	0.121	0.135	979.3	1104.3	22.53	21.66	10.23	8.867
		2 L/fed	1.480	2.025	0.125	0.137	1046.6	1164.3	23.66	22.40	10.70	9.000
	80	Without	1.889	2.686	0.123	0.138	997.6	890.3	26.23	21.70	10.20	10.267
		1 L/fed	1.422	2.870	0.132	0.145	1206.0	1165.3	27.53	24.66	10.60	11.000
		2 L/fed	2.809	3.066	0.148	0.149	1250.6	1284.6	28.20	25.13	11.36	11.000
	100	Without	2.244	2.672	0.138	0.126	1172.0	1008.6	29.93	24.70	10.66	11.667
		1 L/fed	2.295	2.986	0.139	0.155	1256.3	1132.3	31.33	24.90	11.40	12.233
		2 L/fed	2.631	3.195	0.120	0.152	1327.3	1195.6	32.23	25.60	12.33	13.000
Garbage compost	60	Without	1.317	1.619	0.126	0.128	944.0	967.0	27.16	23.13	10.30	10.000
		1 L/fed	1.819	1.936	0.130	0.135	1065.0	1096.3	28.40	23.56	10.40	10.667
		2 L/fed	1.664	2.072	0.133	0.136	1148.3	1169.6	29.13	23.80	10.50	11.000
	80	Without	1.858	2.103	0.127	0.128	1118.3	1080.3	27.13	22.40	10.76	10.733
		1 L/fed	2.231	2.619	0.140	0.149	1156.6	1127.3	27.86	23.36	11.23	11.000
		2 L/fed	2.472	2.956	0.140	0.158	1201.6	1221.3	28.56	26.73	11.60	11.733
	100	Without	2.525	1.978	0.143	0.137	1106.3	1125.3	28.06	25.90	10.83	11.633
		1 L/fed	2.628	3.536	0.144	0.145	1182.0	1249.6	28.90	26.73	11.33	12.000
		2 L/fed	2.667	3.839	0.145	0.158	1206.0	1346.0	29.26	28.40	11.46	12.867
Botanical compost	60	Without	1.516	1.667	0.145	0.130	1050.6	957.6	26.33	24.06	10.23	9.733
		1 L/fed	2.117	1.919	0.138	0.130	1099.6	1187.3	27.43	24.43	11.23	10.000
		2 L/fed	2.131	2.003	0.138	0.137	1137.3	1265.0	28.13	24.83	11.86	10.400
	80	Without	1.825	1.569	0.133	0.146	937.0	1185.3	27.80	24.23	10.33	11.333
		1 L/fed	2.372	3.008	0.141	0.148	1187.6	1304.6	29.80	24.93	10.76	12.000
		2 L/fed	3.053	3.881	0.150	0.151	1272.3	1406.6	30.90	26.76	11.00	13.000
	100	Without	2.125	2.111	0.138	0.146	1139.0	1188.0	29.36	25.43	11.83	10.400
		1 L/fed	2.883	2.581	0.147	0.149	1186.6	1366.3	29.80	26.50	11.40	12.633
		2 L/fed	3.350	4.064	0.154	0.160	1293.3	1428.3	31.20	27.36	12.66	14.067
LSD (at 5%)			0.704	0.644	0.016	0.013	96.6	92.3	0.53	0.46	0.56	0.51

Table 7: Impurities, gross sucrose, extracted sucrose and quality index percentages in sugar beet roots as affected by the interaction among compost type, nitrogen fertilizer level and foliar application with micronutrients levels, during 2018/2019 and 2019/2020 seasons.

		Characters	Impurities (%)		Gross sucrose (%)		Extracted sucrose (%)		Quality index (%)	
Compost type	N-levels (kg fed^{-1})	Micro-nutrients levels	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Without	60	Without	2.66	2.64	16.47	17.14	13.81	14.50	81.15	84.39
		1 L/fed	2.59	2.33	17.71	18.24	15.12	15.90	84.95	87.05
		2 L/fed	2.53	2.23	18.73	18.35	16.20	16.12	86.18	87.74
	80	Without	2.83	2.58	17.79	17.74	14.96	15.16	84.12	85.12
		1 L/fed	2.74	2.47	18.12	18.67	15.38	16.20	84.76	86.59
		2 L/fed	2.69	2.37	18.36	19.03	15.66	16.66	85.09	87.31
	100	Without	3.00	2.65	16.40	17.08	13.40	14.43	82.42	84.57
		1 L/fed	2.87	2.60	16.72	18.08	13.85	15.48	83.58	85.07
		2 L/fed	2.50	2.57	17.69	18.45	15.18	15.88	85.21	85.96
Garbage compost	60	Without	2.72	2.48	18.48	17.56	15.76	15.08	85.01	85.61
		1 L/fed	2.67	2.47	18.60	18.37	15.93	15.90	85.50	86.46
		2 L/fed	2.46	2.30	19.79	19.21	17.33	16.91	87.42	87.99
	80	Without	2.78	2.56	18.48	18.30	15.70	15.73	84.85	85.45
		1 L/fed	2.63	2.49	18.63	18.36	16.00	15.87	85.75	86.15
		2 L/fed	2.61	2.37	19.30	19.80	16.68	17.42	86.40	87.88
	100	Without	2.88	2.61	18.65	17.89	15.76	15.28	84.46	85.14
		1 L/fed	2.82	2.57	19.03	18.02	16.21	15.45	85.14	85.45
		2 L/fed	2.72	2.41	19.29	19.00	16.57	16.59	85.96	87.22
Botanical compost	60	Without	2.83	2.64	18.54	18.38	15.71	15.74	84.44	85.49
		1 L/fed	2.54	2.28	19.07	18.98	16.53	16.69	86.12	87.94
		2 L/fed	2.23	2.17	19.54	19.79	17.31	17.61	88.28	88.98
	80	Without	2.82	2.70	18.68	18.48	15.85	15.78	83.42	85.35
		1 L/fed	2.66	2.42	20.50	19.37	17.83	16.94	86.83	87.41
		2 L/fed	2.57	2.29	20.81	19.97	18.23	17.67	87.50	88.47
	100	Without	3.02	2.73	16.73	18.11	13.71	15.37	80.92	84.83
		1 L/fed	2.71	2.46	17.19	18.21	14.48	15.75	83.84	86.14
		2 L/fed	2.50	2.38	19.99	19.33	17.48	16.94	87.33	87.42
	LSD (at 5%)		0.26	0.28	0.68	0.71	0.88	0.83	1.35	1.41

The interaction among compost type, nitrogen fertilizer level and foliar application with micronutrients level significantly influenced crop growth rate (CGR), relative growth rate (RGR), root fresh weight, root length and diameter, impurities, gross sucrose, extracted sucrose and quality index percentages, root, top and corrected sugar yields/fed., nitrogen use efficiency "NUE" of root and corrected sugar yields/fed. in both seasons as shown from results in Table 3, 4 and 5. The recommended treatment that produced the highest values of growth characters (crop growth rate "CGR" and relative growth rate "RGR"), yield components (root fresh weight, root length and diameter) and yields (root, top and corrected sugar yields/fed.) in both seasons was organic fertilizing sugar beet fields with botanical compost at the rate of 5 t/fed. and mineral fertilizing plants with 100 kg N/fed. in addition foliar spraying plants after 45 and 60 days from sowing with micronutrients in the form of Citreen at 2 L/300 liter of water/fed. as illustrated in Tables 6 and 8. This treatment was followed by organic fertilizing sugar beet fields with botanical compost and mineral fertilizing plants with 80 kg N/fed. besides foliar spraying plants with Citreen at 2 LITER/300 liter of water/fed. without significant differences between them in most cases in both seasons. On the other hand, the lowest values of growth characters, yield components and yields resulted from control treatment of three studied factors (without organic fertilizing with compost and mineral fertilizing plants with 60 kg N/fed. without foliar spraying plants with micronutrients) in both seasons. However, the lowest impurities percentages were obtained when organic fertilizing sugar beet fields with botanical compost and mineral fertilizing plants with 60 kg N/fed. besides foliar spraying plants with Citreen at 2 LITER/300 liter of water/fed. in both seasons. Nevertheless, the highest gross sucrose, extracted sucrose and quality index percentages were recorded when organic fertilizing sugar beet fields with botanical compost and mineral fertilizing plants with 80 kg N/fed. besides foliar spraying plants with Citreen at 2 LITER/300 liter of water/fed. in both seasons (Table 7). fertilizing plants with 60 kg N/fed. without foliar spraying plants with micronutrients in both seasons.

Data in Table 8 reveal that the highest values of nitrogen use efficiency (NUE) of root and corrected sugar yields/fed. in both seasons were produced from organic fertilizing sugar beet fields with botanical compost and mineral fertilizing plants with 80 kg N/fed. besides foliar spraying plants with Citreen at 2 LITER/300 liter of water/fed. While the lowest values of nitrogen use efficiency (NUE) of root and corrected sugar yields/fed. were produced from organic fertilizing sugar beet fields with botanical compost and mineral fertilizing plants with 100 kg N/fed. without foliar spraying plants with micronutrients in both seasons.On the contrary, the lowest gross sucrose, extracted sucrose and quality index percentages were produced without organic fertilizing with compost and mineral

Table 8. Root, top and corrected sugar yields/fed, nitrogen use efficiency (NUE) of root and corrected sugar yields/fed of sugar beet as affected by the interaction among compost type, nitrogen fertilizer level and foliar application with micronutrients levels, during 2018/2019 and 2019/2020 seasons.

Characters			Root yield (t/fed)		Top yield (t/fed)		Corrected sugar yield (t/fed)		NUE- Root yield (kg/fed)		NUE- Corrected sugar yield (kg/fed)	
Compost type	N-levels (kg fed^{-1})	Micro-nutrients levels	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
Without	60	Without	25.503	24.197	10.333	10.850	3.679	3.513	441.6	403.2	61.32	58.54
		1 L/fed	26.627	24.970	10.333	11.230	4.046	3.966	443.7	416.1	67.44	66.09
		2 L/fed	27.493	25.890	10.553	11.760	4.486	4.204	458.2	431.5	74.76	70.07
	80	Without	27.630	25.250	10.333	11.877	4.161	3.856	345.3	315.6	52.01	48.20
		1 L/fed	28.180	25.593	10.333	12.230	4.382	4.153	352.2	319.9	54.77	51.91
		2 L/fed	28.740	27.480	11.333	12.367	4.553	4.658	359.2	343.5	56.91	58.22
	100	Without	27.020	26.570	10.667	11.593	3.658	3.869	270.2	265.7	36.58	38.68
		1 L/fed	28.347	27.893	10.813	12.337	3.976	4.387	283.4	278.9	39.75	43.86
		2 L/fed	29.273	27.917	11.140	12.700	4.507	4.453	292.7	279.1	45.07	44.53
Garbage compost	60	Without	26.497	25.640	10.483	10.850	3.975	3.894	425.0	427.3	66.25	64.90
		1 L/fed	26.853	26.467	10.537	11.523	4.247	4.222	447.5	441.1	70.79	70.37
		2 L/fed	28.693	27.343	11.563	12.290	5.017	4.626	478.2	455.7	83.62	77.09
	80	Without	29.263	25.977	10.587	12.770	4.604	4.151	365.7	324.7	57.54	51.89
		1 L/fed	29.503	26.753	10.833	13.000	4.717	4.302	368.7	334.4	58.96	53.77
		2 L/fed	30.000	27.090	11.280	13.000	5.024	4.754	375.0	338.6	62.80	59.42
	100	Without	30.283	27.643	10.480	13.333	4.780	4.228	302.8	276.4	47.80	43.82
		1 L/fed	30.147	28.510	10.763	13.333	4.946	4.408	303.8	285.1	49.46	44.08
		2 L/fed	30.387	28.463	11.493	13.333	5.107	4.809	307.1	291.2	51.07	48.09
Botanical compost	60	Without	27.400	27.463	11.140	11.850	4.308	4.352	456.6	457.7	71.80	72.53
		1 L/fed	28.260	27.920	11.667	12.190	4.694	4.707	471.0	465.3	78.23	78.46
		2 L/fed	30.140	28.267	11.983	13.000	5.253	5.032	385.1	353.0	69.99	62.99
	80	Without	29.020	27.590	11.270	12.603	4.659	4.383	362.7	344.8	58.23	54.78
		1 L/fed	29.323	27.983	11.850	12.680	5.260	4.786	366.5	349.7	65.74	59.82
		2 L/fed	30.710	29.120	12.067	13.103	5.273	5.040	502.4	471.1	87.54	83.85
	100	Without	29.433	28.240	10.937	12.857	3.938	4.382	294.3	283.5	39.37	42.28
		1 L/fed	29.660	28.350	12.027	12.957	4.225	4.539	296.6	284.6	42.25	45.39
		2 L/fed	30.813	29.727	12.790	13.203	5.599	5.045	301.4	297.2	52.72	50.45
	LSD (at 5%)		1.235	1.245	0.562	0.578	0.278	0.286	21.5	22.0	5.65	5.74

Conclusions

From obtained results of this study, it could be concluded that organic fertilizing sugar beet fields with botanical compost at the rate of 5 t/fed. and mineral fertilizing plants with 80 kg N/fed. besides foliar spraying plants with Citreen at 2 liter/300 liter of water/fed. after 45 and 60 days from sowing is recommended to improve productivity and quality at the same time reduce production costs and environmental pollution resulted from excess addition of mineral nitrogen fertilizer under the environmental conditions of Giza Governorate, Egypt.

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