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Impact of Micronutrients Spraying on Yield and Quality of Sugar Cane in heavy textured soil at Upper Egypt

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Abstract

This study investigates the impact of micronutrient spraying on the yield and quality of sugar cane (*Saccharum officinarum* L.) under Upper Egypt agro climatic condition. A field experiment was conducted during two seasons 2021/2022 and 2022/2023 on eight sugar cane varieties. Three micronutrients' spraying treatments as control (untreated), 1g/L and 2g/L of Iron, Zinc, and Manganese mixtures were applied at the two seasons. Yield parameters such as millable cane length, diameter, cane yield and sugar yields were determined. The quality indicators of brix, sucrose, reducing sugars, juice purity and sugar recovery percentages were measured to evaluate sugar cane quality. Two representative soil profiles were sampled from the studied fields and analyzed using the standard methods of soil analysis to be characterized as well as identified for the micronutrients' situation. These soil profiles were used to assess the suitability of the study area to be cultivated with sugar cane. The salient findings of this study revealed that the level-2 micronutrients (2g/L) significantly affected the yield and quality of the cultivated varieties at in the two investigated seasons. These findings contributed to the understanding of micronutrient management practices in sugar cane farming, specifically tailored to the needs of this region, with implications for optimizing agricultural productivity and crop quality.

Keywords: Sugar cane, micronutrients, Upper Egypt, Cane varieties.

INTRODUCTION

The cultivation of sugar cane (*Saccharum officinarum L.*) holds significant importance for Egypt due to several reasons such as economic impact through the production of sugar, molasses, and ethanol, creating employment opportunities and supporting the agricultural sector. Sugar cane products are staple commodity used in various food and beverage industries (Eladawy, 2017). Moreover, sugar cane cultivation adds to the agricultural diversity of Egypt, providing farmers with an alternative crop that can thrive in the country's climate and soil conditions. Furthermore, Egypt can export sugar and other byproducts derived from sugar cane, potentially contributing to foreign exchange earnings. Regarding the environmental benefits, sugar cane cultivation can contribute to soil conservation and carbon sequestration, thus supporting environmental sustainability (Kassim et al., 2018).

In the other hand, the cultivation of sugar cane in Egypt faces several challenges. The intensive water requirements of sugar cane cultivation place strain on Egypt's limited water resources, particularly as the country is already experiencing water scarcity issues (Abdrabbo et al., 2021). Moreover, continuous cultivation of sugar cane can lead to soil erosion and degradation, impacting the long-term sustainability of agricultural land.

Micronutrients play a crucial role in the growth and development of sugar cane crop. Micronutrients such as iron, zinc, and manganese are essential for various physiological processes in sugar cane, including photosynthesis, enzyme activation, and nutrient uptake (Abd El-Mageed et al., 2021). On the other hand, micronutrients act as catalysts for many plants' metabolic pathways, supporting processes such as energy production, chlorophyll synthesis, and protein formation (Fanjana, 2020). Moreover, adequate micronutrient levels help sugar cane plants tolerate environmental stressors such as drought, salinity, and temperature fluctuations, which are common challenges in Egyptian agricultural conditions (Mekdad and Shaaban 2020). Additionally, proper micronutrient application can contribute to increased sugar cane yield and improved sugar content, leading to better economic returns for farmers (Fanjana, 2020). Furthermore, some micronutrients play a role in strengthening sugar cane's resistance to certain diseases, helping to maintain crop health and productivity. Also, balancing micronutrient levels in the soil contributes to overall soil health and fertility, ensuring the long-term sustainability of sugar cane cultivation in Egypt (Nakhla, 2015).

Assessing the quality of sugar cane varieties is crucial. The quality parameters of sugar cane crop are essential indicators that determine the overall value and suitability of the crop for various end uses (Johnson and Richard 2005). Some of the key quality parameters for sugar cane include brix percentage, fiber content, moisture content, juice purity and pH, nutrient content, sucrose percentage, reducing sugars percentage, and etc. These parameters help in assessing the quality of sugar cane varieties (Xiao et al., 2017).

Similarly, there are some parameters for evaluating the sugar cane productivity and yield of the varieties. These yield parameters are like tonnage per hectare, stalk count, stalk height and girth, sugar content, extraction rate, cane to sugar conversion efficiency, crop duration, etc. (Marin et al., 2019). These yield parameters collectively determine the overall productivity and economic viability of sugar cane cultivation, and their careful management is essential for maximizing the crop's output (Inman-Bamber, 2013).

Based on the previous introduction about sugar cane importance, challenges, micronutrients benefits, yield and quality parameters, the objectives of the research are (i) to investigate the impact of micronutrients spraying on the growth, development, and yield of sugar cane in the specific agro climatic condition and heavy textured soil at Upper Egypt; and (ii) to examine the interactions between the applied micronutrients and various investigated varieties.

MATERIALS AND METHODS

Experiment site

The experiment has been conducted at the experimental farm of El-Mattaena Agricultural Research Station, Luxor Governorate, Upper Egypt, which is located at a 25° 42/ latitude and 32° 53/ longitude, at altitude of about 82m above sea level. The location of the study area is demonstrated in Figure (1).

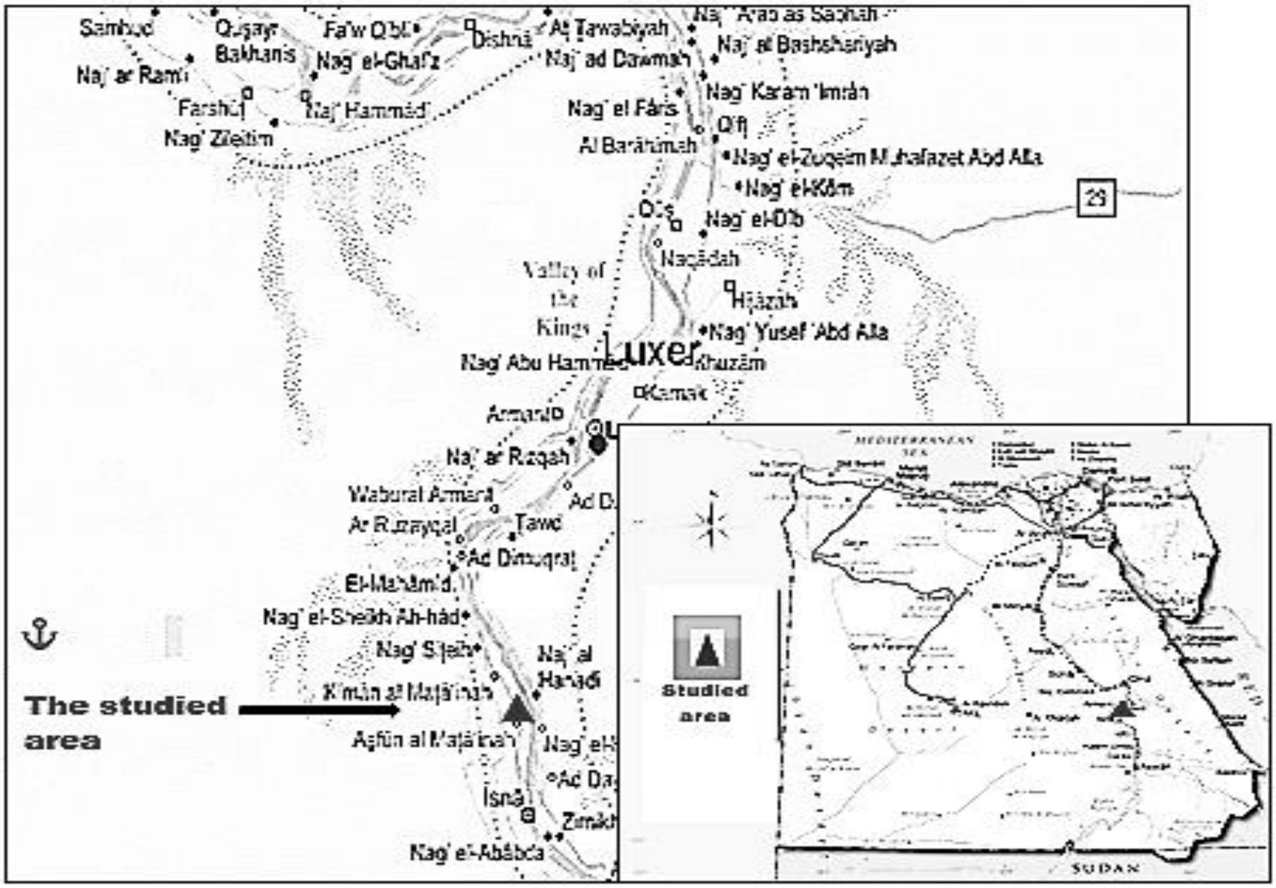

Figure (1). Location map of the study area

Agroclimatic conditions

Monthly means of minimum and maximum temperature (C°), relative humidity (%), wind speed (km/day), solar radiation (MJ/m²/day) and ETo data for the experimental site during the growing seasons (2021/2022 and 2022/2023) are presented in figures 2 and 3 as recorded by the central laboratory of agricultural climate, Giza, Egypt. Reference evapotranspiration (ETo) values were computed using Eto Calculator (version 3.2.) developed by FAO (2012).

Soil sampling and preparation

Two soil profiles were selected to represent the studied area. Soil profiles were excavated and soil samples were collected from each layer of these two soil profiles. Soil samples were shifted to soil testing laboratory for analysis. Soil samples were air-dried for a week on the laboratory bench. Then the soil samples were grounded and sieved through a 2mm sieve and then stored in plastic jars for further analysis.

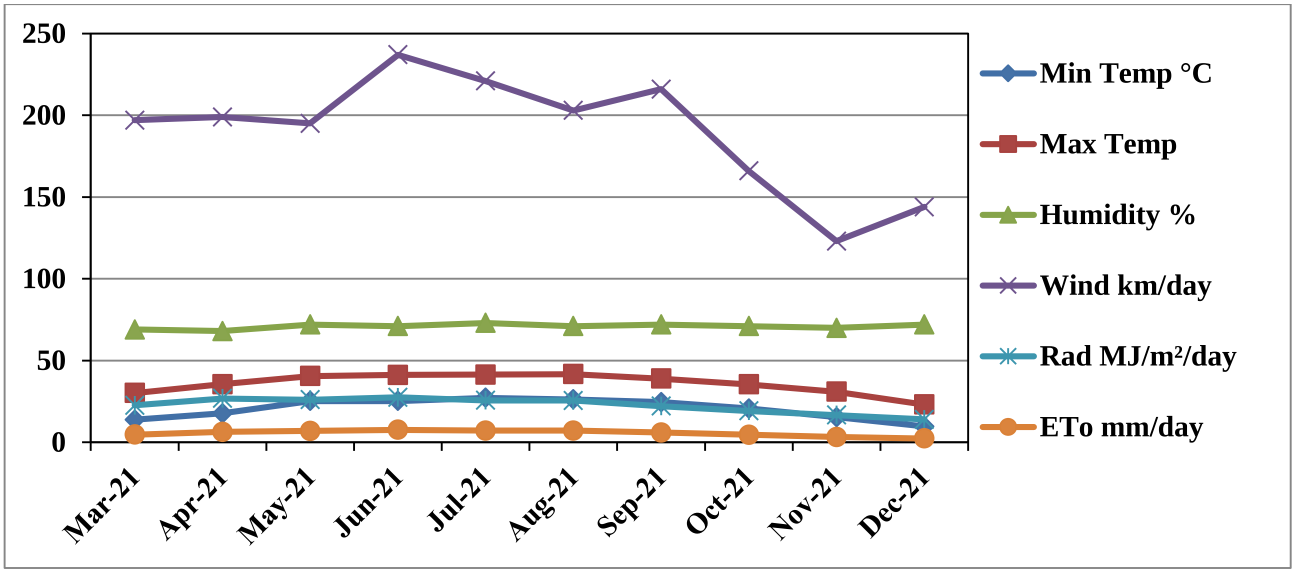

Figure (2). Agroclimatic condition of El-Mattana Agricultural Research Station, and reference evapotranspiration (ETo) during the growing season of 2021/2022.

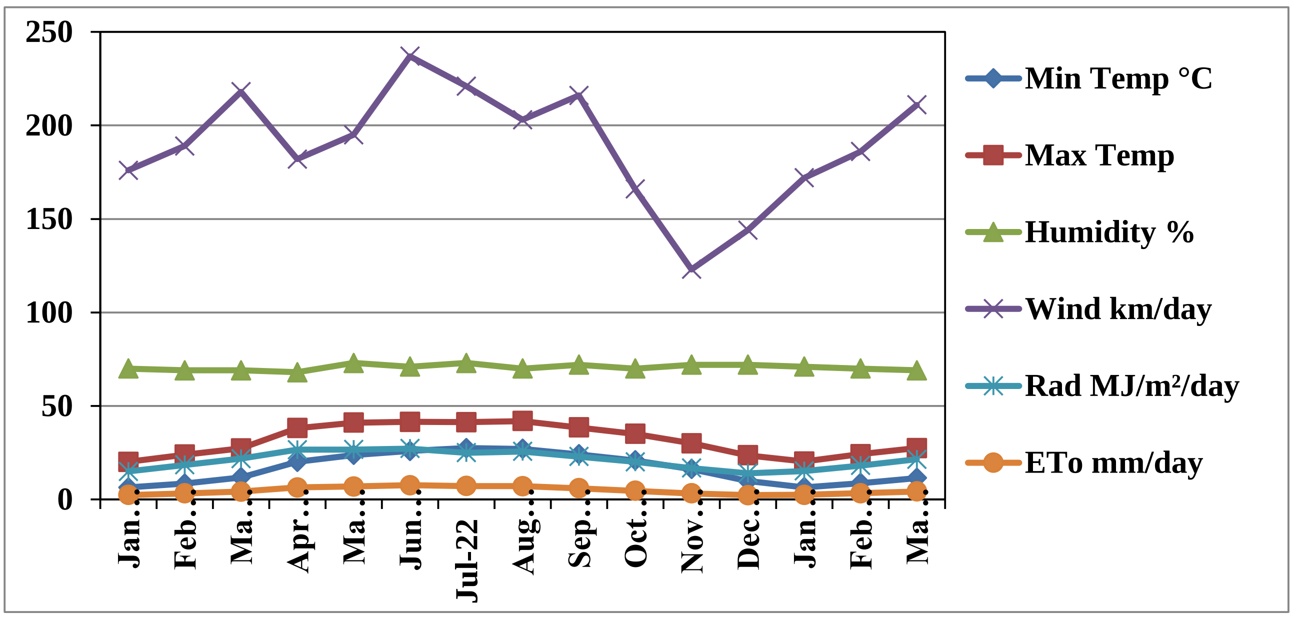

Figure (3). Agroclimatic condition of El-Mattana Agricultural Research Station, and reference evapotranspiration (ETo) during the growing season of 2022/2023.

Soil samples' analysis

Soil texture was determined as particle size distribution analysis was conducted according to the hydrometer method (Bouyoucos, 1962). The sand, silt, and clay percentages' values were calculated from the hydrometer reads after correction by recording laboratory temperature by thermometer. However, soil texture grade was identified using USDA soil texture triangle. The prepared soil samples were used to make 1:5 water suspension, and then Shaked for 30 minutes and pH was measured in each sample using pH-meter. Suspensions were filtered using filter papers and then the EC (Electrical Conductivity as indicator of salinity) was measured using EC meter. Organic matter content was determined in each sample using Walkley and Black wet oxidation method (Walkley A and Black 1934). Available nitrogen was determined using Kjeldahl distillatory instrument. Available content of phosphorus was estimated after soil extracting with sodium bicarbonates and then measured calorimetrically according to Olsen et al. (1954). Available potassium was determined using flame photometer instrument in ammonium acetate extract based on Jackson (1973) method. Iron, Manganese, Zinc and Copper were measured using atomic absorption spectrometer. All concentration values of the measured parameters were calculated to suitable units.

The investigated sugar cane varieties

Eight sugar cane varieties were examined for their yield and quality. These varieties are G.T.54-9; G.99-103; G.2004-27; G.2003-44; G.48-47; G.2007-61; G.2003-49; and G.2003-47 (G.3). The selected sugar cane varieties are suited to be cultivated in the alluvial soils and under agroclimatic conditions of upper Egypt.

The field experimental design

The field experiment was conducted in two seasons, the first in 2021/2022 for sugar cane varieties and the second in 2022/2023 for sugar cane cultivated verities. The experiment was laid out in Randomized Complete Block Design (RCBD) using a split plot arrangement with three replications that were used in both growing seasons. The experiment included 2 factors, and 24 treatments. The area of each experimental unit was 42 m^2 (1/100 feddan), which included six rows of 7m length and 1m width.

The three levels of Zn, Fe and Mn foliar application were distributed in the main plots, while the eight sugarcane genotypes were planted randomly in the sub plots. Sugarcane varieties were planted in mid-March using two rows of three budded/sets and harvested at the age of 12 months.

Nitrogen was applied as urea (46% N) at the rate of 230 kg N/fed in three equal doses, (after the 1st and 2nd hoeing and 30 days later, i.e. 45, 75 and 105 days from planting). Phosphorus fertilizer was added during land preparation at 60 kg P_2O_5/fed as calcium super phosphate (15% P_2O_5), meanwhile, potassium fertilizer was added at 48 kg K_2O/ fed as potassium sulphate (48% K_2O) once, with the second N-dose. The other agronomic practices for growing sugarcane were done as recommended by the Sugar Crops Research Institute. Foliar application of Zn, Fe and Mn compounds chelated on EDTA were done at 120 days after sowing with doses 0, 1 and 2 g/L.

The observed field and laboratory data

Sugar cane yield parameters

At harvest (mid-March), four guarded rows of each treatment were harvested, topped and cleaned to estimate the following traits, which were calculated as a mean of the values measured from a stalk sample taken from one meter portion of plot:

a. Millable cane length (cm), which was measured from land level to the top visible dewlap.
b. Millable cane diameter (cm), which was measured at the middle part of stalk.
c. Number of internodes per stalk.
d. Internode length (cm) per stalk: was calculated by dividing stalk length by its corresponding number of internodes.
e. Millable cane weight (kg) was determined by dividing cane weight of one meter sample by its corresponding number of millable canes.

Sugar cane quality parameters

At each harvesting season, 20 millable canes were collected immediately after harvest, stripped and squeezed then juice was extracted using three-roll laboratory mill, filtrated and weighed to determine the following quality traits:

a. The Brix percentage (total soluble solids, TSS %) in cane juice was determined using Brix Hydrometer according to A.O.A.C .(2005) .
b. Sucrose percentage was determined using a Saccharometer according to the method of A.O.A.C.(2005) .
c. Juice purity percentage was calculated according to the following formula

Juice purity percentage =
(Sucrose percentage/Brix percentage) x 100

d. Sugar recovery percentage was calculated according to the following formula described by Yadav and Sharma (1980).

Sugar recovery % =

[Sucrose% - 0.4 (brix % - sucrose %)] x 0.73

e. Reducing sugars percentage: It was determined using the Fehling method according to A.O.A.C. (1995).
f. Cane yield (ton/fad.): it was determined from the weight of the three middle guarded rows of each plot converted into value per fad .
g. Sugar yield (tons/fad.): was calculated according to the following formula described by Mathur (1981).

Sugar yield =

Cane yield (ton/fad.) x sugar recovery%.

Statistical analysis

The collected data were statistically analyzed using M stat software according to the method described by Snedecor and Cochran (1981). Treatment means were compared using LSD at 5% level of difference as outlined by Steel and Torrie (1980).

RESULTS AND DISCUSSIONS

Soil characterization

The physico-chemical characterization of soil profiles is shown in Table (1). The soil texture grade of the soil profiles was clay loam whereas the fine fractions (clay and silt) are dominant in the soil particle size distribution. The soil bulk density was low (weighted mean value was about 1.1 Mg m^{-3}). The water content in the field capacity ranged from 43.34 to 34.80% of soil weight. The permanent welting point appeared when the moisture content was about 17% of soil weight, while available water was about 26%. The obtained data revealed that soil pH varied from slightly to moderately alkaline whereas pH weighted mean values were 7.83 and 7.73 for the analyzed soil profiles. Regarding the soil EC, it was non saline whereas weighted mean values of soil profiles were 1.43 and 1.33 dS/m. The soil was non-calcareous whereas values did not exceed 5%. The soluble cations data revealed that sodium was the dominant cation and followed by calcium, magnesium and potassium. Regarding soluble anions, the dominant anion was sulphates and chloride, and followed by carbonates and bicarbonates. The soil organic matter of the studied soil profiles was low of 0.21 to 0.28% as content. Regarding the macronutrients, the available nitrogen was low which the weighted mean values were around 60 mg/kg. The soils have moderate content of phosphorus (9.5 and 9.13 mg/kg) for the studied soil profiles, respectively. The available potassium ranged from low to moderate from 260 to 270 mg/kg through the studied profiles. The micronutrients data showed that inadequate content was presented in soil profiles.

These soil profiles were suitable for cultivating sugar cane, whereas their characteristics matched with the crop requirements.

Sugar cane yield characteristics

Millable cane length (cm)

Table (2) demonstrated the millable cane length (cm) at the two seasons of different varieties of sugar cane under the treatments of micronutrients' spraying. The significant differences in millable cane length (cm) were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. At the first season, the sugar cane varieties of G.2007-61 and G.99-103 recorded the minimum and maximum mean values of cane length with the values of 276.3 and 341.9 cm, respectively. The same trend was recorded at the second season for the same varieties whereas the minimum and maximum mean values of cane length were 274.4 and 340 cm, respectively. Regarding the effect of the micronutrients' spraying on the millable cane length, at the first season, the minimum mean value was 290.8 cm for control and the maximum was 325.1 cm as observed for 2g/L treatment. At the second season, same trend of the data was observed as the minimum and maximum mean values were 290 and 322.2 cm for the control and 2g/L treatments, respectively.

The findings of Ghaffar et al. (2012); Naga et al. (2013); and Mangrio et al. (2020) are in harmony with our results. They showed that the application of micronutrients on the different sugar cane varieties affected the millable cane length.

Table (1). Soil profiles' characterization

Properties	Unit	Layers (cm) - Soil profile 1				Layers (cm) - Soil profile 2				
		0 – 30	30 - 60	60 - 90	Weighted mean	0 - 30	30 - 60	60 - 90	Weighted mean	Average of profiles
Sand	%	34.98	35.16	35.89	35.34	35.41	36.29	36.84	36.18	35.76
Silt		29	31.25	39.75	33.33	31.52	33.11	32.95	32.53	32.93
Clay		36.02	33.59	24.36	31.32	33.07	30.6	30.21	31.29	31.31
Texture grade		cl.L								
B.D.	Mg m-3	1.09	1.11	1.13	1.11	1.12	1.13	1.15	1.13	1.12
F.C.	%	47.96	41.73	40.33	43.34	46.05	44.12	44.23	44.80	44.07
P.W.P.		18.96	17.16	16.22	17.45	17.55	17.29	17.12	17.32	17.38
A.W.		29	24.57	24.11	25.89	28.27	26.18	24.85	26.43	26.16
pH	1:2.5	7.75	7.82	7.91	7.83	7.69	7.71	7.79	7.73	7.78
EC	dS/ m	1.3	1.4	1.6	1.43	1.2	1.3	1.5	1.33	1.38
SOM	%	0.32	0.25	0.18	0.21	0.39	0.41	0.22	0.28	0.25
CaCO3		3.5	3.9	3.7	3.70	3.4	3.2	3.6	3.40	3.55
CO3--	meq/ L Soluble	-	-	-	-	-	-	-	-	-
HCO3-		1.14	1.11	1.13	1.13	1.12	1.09	1.12	1.11	1.12
Cl-		6	4	5	5.00	5	4	4	4.33	4.67
SO4--		6	5	5	5.33	5	6	5	5.33	5.33
Na+		5	5	4	4.67	4	5	5	4.67	4.67
K+		0.4	0.5	0.4	0.43	0.5	0.4	0.3	0.40	0.42
Ca++		4	5	5	4.67	5	4	4	4.33	4.50
Mg++		3.5	3.2	3.3	3.33	2.9	3.1	3.2	3.07	3.20
N	mg/kg Available	57	61	59	59.00	63	61	55	59.67	59.33
P		10.4	9.3	9	9.57	9.7	8.9	8.8	9.13	9.35
K		282	246	251	259.67	291	280	246	272.33	266.00
Fe		0.3	0.2	0.2	0.23	0.2	0.2	0.2	0.20	0.22
Mn		0.2	0.1	0.2	0.17	0.1	0.2	0.2	0.17	0.17
Zn		0.1	0.1	0.1	0.10	0.1	0.1	0.1	0.10	0.10
Cu		0.1	0.1	0.1	0.10	0.1	0.1	0.1	0.10	0.10

Millable cane diameter (cm)

The millable cane diameter data was shown in table (3). The significant differences of millable cane diameter (cm) were observed among the sugar cane varieties, micronutrients' levels while no significant difference was detected for the interaction between the varieties and micronutrients spraying at the two seasons. The data obtained for the first season of cultivating different sugar cane verities under micronutrients' treatments revealed that the minimum mean value of the cane diameter was 2.7 cm for the control and the maximum value was 2.9 cm for the 2g/L treatment. At the second season, the minimum and maximum mean diameter values were 2.6 and 2.8 cm and recorded for control and 2g/L treatments, respectively. Regarding the effect of micronutrients treatments on the varieties, at the first season, the minimum and maximum mean diameter values were 2.4 and 3.3 cm for the G.84-47 and G.99-103 varieties, respectively. At the second seasons, the same verities recorded the minimum and maximum mean values of diameters of 2.4 and 2.6 cm, respectively. The findings of Mangrio et al. (2020) and Yadav et al. (2016) are matched with our results. They showed that the application of micronutrients on the different sugar cane varieties affected the millable cane diameter.

Table (2). Millable cane length (cm) as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	2021/2022 season				2022/2023 season			
	Millable cane length (cm)							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	296.7	305.6	329.4	310.6	298.3	308.9	326.7	311.3
G.99-103	317.2	338.9	369.4	341.9	316.1	337.2	365.6	340.0
G.2004-27	315.6	340.0	356.7	337.4	324.4	345.0	350.6	339.6
G.2003-44	283.3	301.1	300.0	294.8	278.9	297.2	300.6	292.2
G. 84-47	320.0	327.8	367.2	338.3	315.0	323.9	364.4	334.4
G.2007-61	262.2	281.7	285.0	276.3	263.3	280.0	280.0	274.4
G.2003-49	267.8	279.4	293.9	280.4	263.9	281.7	291.7	279.1
G.2003-47	263.3	298.9	299.4	287.2	260.0	285.6	298.3	281.3
Mean	290.8	309.2	325.1		290.0	307.4	322.2	
LSD at 0.05 level of significance								
Micronutrients (M)				7.30				7.47
Varieties (V)				7.84				8.01
M x V				13.59				13.87

Table (3). Millable cane diameter (cm) as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Millable cane diameter (cm)							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	2.8	2.9	2.9	2.9	2.5	2.5	2.7	2.6
G.99-103	3.3	3.3	3.3	3.3	2.9	3.0	3.2	3.0
G.2004-27	2.7	3.0	3.1	2.9	2.7	2.9	3.1	2.9
G.2003-44	2.6	2.6	2.7	2.6	2.5	2.6	2.7	2.6
G. 84-47	2.3	2.4	2.4	2.4	2.2	2.4	2.5	2.4
G.2007-61	2.7	2.8	2.9	2.8	2.6	2.7	2.8	2.7
G.2003-49	2.7	2.7	2.8	2.7	2.7	2.8	2.8	2.8
G.2003-47	2.7	2.7	2.9	2.8	2.6	2.7	2.8	2.7
Mean	2.7	2.8	2.9		2.6	2.7	2.8	
LSD at 0.05 level of significance								
Micronutrients (M)				0.07				0.14
Varieties (V)				0.09				0.24
M x V				ns				ns

Number of internodes per stalk

The number of internodes data was shown in table (4). The significant differences of the number of the internodes were observed among the sugar cane varieties, micronutrients' levels while no significant difference was detected for the interaction between the varieties and micronutrients spraying at the two seasons. The data obtained for the first season of cultivating different sugar cane verities under micronutrients' treatments revealed that the minimum mean value of the number of internodes was 17.5 for the control and the maximum value was 19.3 for the 2g/L treatment. At the second season, the minimum and maximum mean number of internodes' values 18.1 and 19.7 and recorded for control and 2g/L treatments, respectively. Regarding the effect of micronutrients treatments on the varieties, at the first season, the minimum and maximum mean number of internodes' values were 15.8 and 21.7 for the G.2003-47 and G.84-47 varieties, respectively. At the second seasons, the same verities recorded the minimum and maximum mean values of number of internodes of 17.2 and 22.2, respectively.

The findings of Mishra et al. (2014) and Naga et al. (2013) are agreed with our results. They showed that the application of micronutrients on the different sugar cane varieties affected the number of internodes. They found similar effects as they observed that the micronutrients spraying application could affect the number of internodes.

Table (4). Number of internodes (cm) per stalk as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Number of internodes							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	16.2	17.4	19.2	17.6	18.8	17.4	18.6	18.3
G.99-103	18.2	17.7	21.6	19.2	19.8	21.9	21.0	20.9
G.2004-27	19.0	18.3	18.9	18.7	19.0	19.1	19.1	19.0
G.2003-44	16.2	19.4	19.2	18.2	17.2	16.7	18.6	17.5
G. 84-47	19.5	21.5	24.0	21.7	19.5	22.1	24.9	22.2
G.2007-61	18.7	19.8	18.0	18.8	17.5	19.1	19.2	18.6
G.2003-49	16.3	17.0	17.6	16.9	16.3	17.7	18.5	17.5
G.2003-47	16.0	15.3	16.2	15.8	16.8	16.8	17.9	17.2
Mean	17.5	18.3	19.3		18.1	18.8	19.7	
LSD at 0.05 level of significance								
Micronutrients (M)				0.71				1.08
Varieties (V)				1.92				1.44
M x V				ns				ns

Internode length (cm)

The internode length (cm) per stalk data was shown in table (5). The significant differences of internode length (cm) per stalk were observed for micronutrients' levels while no significant difference was detected for the sugar cane varieties as well as the interaction between the varieties and micronutrients spraying at the two seasons. The data obtained for the first season of cultivating different sugar cane verities under micronutrients' treatments revealed that the minimum mean value of the internode length (cm) per stalk was 16.7 cm for the control and the maximum value was 17.2 cm for the 2g/L treatment. At the second season, the minimum and maximum mean internode length (cm) per stalk values 16.1 and 16.5 cm and recorded for control and 2g/L treatments, respectively. Regarding the effect of micronutrients treatments on the varieties, at the first season, the minimum and maximum mean internode length (cm) per stalk values were 14.8 and 18.5 cm for the G.2007-61 and G.2004-27 varieties, respectively. At the second seasons, the same verities recorded the minimum and maximum mean values of internode length (cm) per stalk of 14.8 and 17.9 cm, respectively.

The findings of Xu et al. (2021) and Ghaffar et al. (2012) are in harmony with our results. They showed that the application of micronutrients on the different sugar cane varieties affected the internode length (cm) per stalk. They found similar effects as they observed that the micronutrients spraying application could affect the internode length (cm) per stalk.

Table (5). Internode length (cm) as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Internode length (cm)							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	18.4	17.6	17.2	17.7	15.8	17.8	17.6	17.1
G.99-103	17.5	19.2	17.1	17.9	16.1	15.4	17.4	16.3
G.2004-27	16.8	18.9	19.6	18.5	17.1	18.1	18.5	17.9
G.2003-44	17.6	15.8	15.6	16.3	16.4	18.0	16.2	16.9
G. 84-47	16.4	15.3	15.3	15.7	16.2	14.7	14.6	15.2
G.2007-61	14.1	14.3	16.0	14.8	15.1	14.7	14.7	14.8
G.2003-49	16.5	16.5	17.4	16.8	16.2	16.0	15.9	16.1
G.2003-47	16.5	19.6	19.3	18.4	15.6	17.3	16.7	16.5
Mean	16.7	17.1	17.2		16.1	16.4	16.5	
LSD at 0.05 level of significance								
Micronutrients (M)				ns				ns
Varieties (V)				2.16				1.31
M x V				ns				ns

Millable cane weight (kg)

The millable cane weight (kg) data was shown in table (6). The significant differences in millable cane weight (kg) were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. The data obtained for the first season of cultivating different sugar cane verities under micronutrients' treatments revealed that the minimum mean value of the millable cane weight (kg) was 1.3 kg for the control and the maximum value was 1.7 kg for the 2g/L treatment. At the second season, the minimum and maximum mean millable cane weight (kg) values 1.5 and 1.9 kg and recorded for control and 2g/L treatments, respectively. Regarding the effect of micronutrients treatments on the varieties, at the first season, the minimum mean millable cane weight (kg) value was 1.3 kg for G.2003-47 and G.84.47 varieties. The maximum value was recorded for G.99-103 variety as 2.0 kg. At the second season, the G.99-103 variety recorded the maximum mean values of millable cane weight (kg) of 2.4 kg while the minimum value was 1.4 kg which recorded for G.2003-49 and G.2007-61 varieties.

The findings of Mangrio et al. (2020) and Xu et al. (2021) are in harmony with our results and showed that the application of micronutrients on the different sugar cane varieties affected the millable cane weight (kg). They found similar effects as they observed that the micronutrients spraying application could affect the millable cane weight (kg).

Many previous research works studied the effect of spraying micronutrients on the yield and quality of various sugar cane varieties. Sasy and Abu-Ellail (2021) investigated two seasons of various sugar cane varieties' cultivating in a part of Egypt to examine the effect of phenotypes and some fertilizer's types on the yield and quality. They found that the increase in fertilization by nitrogen, potassium and press-mud fertilizers lead to increase the sugar cane productivity and quality for some varieties during the cultivation seasons. Another study was carried out by Abd El-Hadi (2015) at Nile- delta, middle and upper Egypt to study the effect of Zn, Mn and Fe chelates and some different foliar fertilizers on three sugar cane varieties. He found that yield of millable cane and sugar yield were significantly increased by spraying micronutrients. Khalifa et al. (2016) studied the effect of nitrogenous and micronutrients' fertilizers on the yield and quality for two seasons of some sugar cane varieties at Aswan, Egypt. They found that significant variations were recorded between the tested foliar Zn +Fe micronutrients' mixture for growth characters, yield and sugarcane quality among the investigated varieties.

Table (6). Millable cane weight (kg) as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Millable cane weight (kg)							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	1.4	1.5	1.7	1.6	1.4	1.5	1.6	1.5
G.99-103	1.9	2.0	2.0	2.0	2.1	2.5	2.7	2.4
G.2004-27	1.4	1.8	1.8	1.7	1.8	1.9	2.0	1.9
G.2003-44	1.2	1.5	1.4	1.4	1.3	1.6	1.7	1.5
G. 84-47	1.0	1.3	1.5	1.3	1.6	1.7	1.9	1.7
G.2007-61	1.5	1.6	1.7	1.6	1.2	1.4	1.6	1.4
G.2003-49	1.4	1.4	1.7	1.5	1.3	1.4	1.5	1.4
G.2003-47	0.9	1.5	1.6	1.3	1.2	1.5	1.9	1.5
Mean	1.3	1.6	1.7		1.5	1.7	1.9	
LSD at 0.05 level of significance								
Micronutrients (M)				0.04				0.09
Varieties (V)				0.07				0.04
M x V				0.13				0.07

Quality parameters of sugar cane plants

Brix percentage

Data in table (7) showed the Brix percentage of the harvested sugar cane plants' samples under the micronutrients' levels. The significant differences of brix percentage were observed for micronutrients' levels and among sugar can varieties, while no significant difference was detected for the interaction between the varieties and micronutrients spraying at the two seasons. Highest value of brix percentage (21.5 and 20.7%) in two respectively seasons was recorded for G.2003-49 variety. Regarding the micronutrients' levels, the highest sucrose percentage values were 20.8 and 20.5% for the two seasons, respectively under the 2g/L micronutrients spraying level. Non-significant interaction was observed between varieties and micronutrients' levels in brix percentage. The slight variation between the examined varieties in brix percentage may be due to the differences in growth and response to the surrounding environmental conditions prevailing during the formation of soluble solids in the cane plants. These results were confirmed with those obtained by Mishra et al. (2014) and Yadav et al. (2016).

Table (7). Brix percentage as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Brix percentage							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	19.7	20.0	21.0	20.2	20.0	20.4	21.0	20.5
G.99-103	19.3	19.4	20.0	19.6	19.0	19.3	19.6	19.3
G.2004-27	19.3	19.9	19.9	19.7	19.1	19.7	20.0	19.6
G.2003-44	19.6	20.8	21.0	20.5	18.6	20.0	20.3	19.6
G. 84-47	20.0	20.7	21.0	20.6	20.2	20.6	20.8	20.5
G.2007-61	20.1	20.3	20.3	20.2	19.7	20.0	20.2	20.0
G.2003-49	21.4	21.5	21.5	21.5	20.5	20.7	20.9	20.7
G.2003-47	20.7	21.1	21.6	21.1	20.7	20.9	21.3	21.0
Mean	20.0	20.5	20.8		19.7	20.2	20.5	
LSD at 0.05 level of significance								
Micronutrients (M)				0.34				0.34
Varieties (V)				0.43				0.43
M x V				ns				ns

Sucrose percentage

Data in table (8) showed the sucrose percentage of the harvested sugar cane plants' samples under the micronutrients' levels. The significant differences in sucrose percentage were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. The highest value of sucrose percentage was 19% for the G.2003-49 variety at the first season and 19.4% for the G.2003-47 at the second season. Regarding micronutrients' spraying levels, the maximum mean values of sucrose percentage were recorded for the 2g/L level with values of 18.6 and 18.3% for the first and second seasons, respectively. A significant interaction was observed between varieties and micronutrients' levels in sucrose percentage. Results were reported by Ghaffar et al. (2012) and Mangrio et al. (2020) are like to our results. They reported that, micronutrients spraying showed a highly considerable influence on sucrose percentages' values.

The increase in sucrose% at the different varieties might be due to the enzymes which change the reducing sugars to sucrose, or it could be due to positive impact of cane maturity which allow translocation and accumulation of additional sucrose on the growth stage. These results may be due to the genetic differences among varieties in their ability of the formation of internodes. Differences among varieties in sucrose % depend on the interaction between varieties and environmental factors during growth and maturing stage (Chen et al., 2019).

Juice purity percentage

Data in table (9) showed that juice purity percentage in the two cultivated seasons. The significant differences in juice purity percentage were observed among the sugar cane varieties and micronutrients' levels while no significant difference was detected for the interaction between the varieties and micronutrients spraying at the two seasons. The data obtained for the first season of cultivating different sugar cane verities under micronutrients' treatments revealed that the minimum mean value of the juice purity percentage 85.2 % for the control and the maximum value was 89.1 % for the 2g/L treatment. At the second season, the minimum and maximum mean juice purity percentage's values 85.1 and 87.4 % as recorded for control and 2g/L treatments, respectively. Regarding the effect of micronutrients treatments on the varieties, at the first season, the minimum mean juice purity percentage value was 84.3 % for G.2007-61 variety. The maximum value was recorded for G.84.47 variety as 89.8 %. At the second season, the G.2003-47 variety recorded the maximum mean values of juice purity percentage of 92.3 % while the minimum value was 83.7 % which recorded for G.84-47 variety.

The findings of Xu et al. (2021) and Majeed et al. (2022) are in harmony with our results and showed that the application of micronutrients on the different sugar cane varieties affected the juice purity percentage. They found similar effects as they observed that the micronutrients spraying application could affect the juice purity percentage.

Table (8). Sucrose percentage as affected by sugarcane varieties, micronutrients and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Sucrose percentage							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	17.4	17.5	18.6	17.8	17.3	17.6	18.3	17.7
G.99-103	15.7	16.9	17.0	16.6	15.9	16.2	16.5	16.2
G.2004-27	16.6	16.8	18.3	17.2	16.2	16.5	17.3	16.7
G.2003-44	16.1	17.4	19.3	17.6	16.6	17.5	18.2	17.4
G. 84-47	17.5	18.8	19.2	18.5	16.2	17.7	17.6	17.2
G.2007-61	16.8	17.0	17.4	17.1	16.6	17.0	17.3	17.0
G.2003-49	18.3	19.2	19.5	19.0	17.5	17.6	18.1	17.7
G.2003-47	17.9	18.1	18.8	18.3	17.9	20.0	20.2	19.4
Mean	17.4	17.5	18.6		17.3	17.6	18.3	
LSD at 0.05 level of significance								
Micronutrients (M)				0.88				0.25
Varieties (V)				0.42				0.43
M x V				0.72				0.75

Sugar recovery percentage

Results presented in Table (10) revealed that sugar recovery percentage was significantly affected by micronutrients' spraying. The significant differences in sugar recovery percentage were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. Sugar recovery percentage reached maximum mean value (89.8%) at the first season for the variety G.84-47 under the level-2 of micronutrients spraying treatment. At the second season the maximum mean value of sugar recovery percentage was recorded as 92.3% for G.2003-47 variety under the level-2 treatment also. The increase in recovery percentage among various varieties is due to the increase in sucrose content in sugar cane juice. These results are similar as Sohu et al. (2015) and Vallejo-Torres and López-Hernández (2001). They reported that the micronutrients' spraying had a significant effect on sugar recovery percentage in cultivating seasons.

Table (9). Juice purity percentage as affected by sugarcane varieties, micronutrients, and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Juice purity percentage							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	88.6	87.3	88.7	88.2	86.5	86.4	87.0	86.6
G.99-103	81.4	87.1	85.0	84.5	83.8	84.2	84.0	84.0
G.2004-27	85.9	84.6	91.9	87.5	84.6	84.2	86.4	85.1
G.2003-44	82.1	83.5	92.1	85.9	89.1	87.6	90.0	88.9
G. 84-47	87.3	90.6	91.4	89.8	80.6	85.9	84.5	83.7
G.2007-61	84.0	83.5	85.6	84.3	84.2	85.0	85.5	84.9
G.2003-49	85.3	89.6	90.6	88.5	85.3	85.0	86.7	85.7
G.2003-47	86.7	85.9	87.2	86.6	86.5	95.8	94.6	92.3
Mean	85.2	86.5	89.1		85.1	86.8	87.4	
LSD at 0.05 level of significance								
Micronutrients (M)				3.94				0.44
Varieties (V)				3.00				2.73
M x V				ns				ns

Table (10). Sugar recovery percentage as affected by sugarcane varieties, micronutrients, and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Sugar recovery percentage							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	12.0	12.0	12.9	12.3	11.8	12.0	12.5	12.1
G.99-103	10.4	11.6	11.5	11.2	10.7	11.0	11.1	10.9
G.2004-27	11.3	11.4	12.9	11.8	11.0	11.2	11.8	11.3
G.2003-44	10.7	11.7	13.6	12.0	11.5	12.1	12.7	12.1
G. 84-47	12.0	13.1	13.5	12.9	10.7	12.1	11.9	11.6
G.2007-61	11.4	11.4	11.8	11.5	11.2	11.5	11.8	11.5
G.2003-49	12.4	13.4	13.6	13.1	11.9	11.9	12.4	12.1
G.2003-47	12.3	12.4	12.9	12.5	12.2	14.4	14.4	13.7
Mean	11.6	12.1	12.9	Mean	11.4	12.0	12.3	
LSD at 0.05 level of significance								
Micronutrients (M)				0.86				0.16
Varieties (V)				0.47				0.45
M x V				0.81				0.79

Reducing sugars percentage

Table (11) showed the obtained data of reducing sugars percentage from the harvested sugar cane plants during the two investigated seasons under micronutrients spraying treatments of different sugar cane varieties. The significant differences in reducing sugar percentage were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. The obtained data at the first season reflected null to slight changes in the reducing sugars percentage among all sugar cane varieties and the two applied treatments of micronutrients. However, the minimum mean value of reducing sugars percentage was 0.2 % and recorded for the 1g/L and 2g/L of micronutrients treatments while the maximum mean values was 0.3 % as observed for the control treatment. At the second season mean value of the three treatments (control, 1g/L, and 2g/L) was 0.2% and no differences were recorded.

Regarding the effect of the micronutrients spraying on the different sugar cane varieties, the obtained data from the first season revealed that the minimum mean value of reducing sugars percentage was 0.2% as recorded for all investigated varieties except G.2003-44, G.84-47, and G.2003-49 varieties which scored 0.3% as maximum mean value. There are no differences in mean values of the reducing sugars percentage among sugar cane varieties at the second season.

Similar findings were obtained by Raposo Junior et al. (2013) and Naga et al. (2013) whereas found that the micronutrients' spraying affected the cultivated sugar cane varieties regarding the reducing sugars percentage.

Table (11). Reducing sugars percentage as affected by sugarcane varieties, micronutrients, and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane Varieties	first season 2021/2022				second season 2022/2023			
	Reducing sugars percentage							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	0.31	0.22	0.18	0.24	0.20	0.22	0.22	0.21
G.99-103	0.24	0.22	0.22	0.23	0.22	0.24	0.17	0.21
G.2004-27	0.28	0.24	0.18	0.23	0.19	0.23	0.23	0.22
G.2003-44	0.30	0.26	0.22	0.26	0.19	0.25	0.15	0.20
G. 84-47	0.29	0.25	0.22	0.25	0.18	0.17	0.18	0.18
G.2007-61	0.28	0.25	0.21	0.25	0.17	0.22	0.31	0.23
G.2003-49	0.34	0.31	0.21	0.29	0.17	0.16	0.19	0.17
G.2003-47	0.25	0.24	0.20	0.23	0.18	0.18	0.27	0.21
Mean	0.29	0.25	0.21		0.19	0.21	0.22	
LSD at 0.05 level of significance								
Micronutrients (M)				0.005				0.002
Varieties (V)				0.001				0.002
M x V				0.002				0.003

Cane yield (tons/fed)

Data in table (12) revealed that the spraying of micronutrients harvesting times had a highly significant effect on cane yield (Ton/fad.). The significant differences in cane yield (tons/fd) were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. At the first season, the minimum mean value of the yield was observed for the control treatment (51.0 Ton/fd.) while the maximum value was 58.6 Ton/fd., for the level-2 micronutrients spraying. Regarding the obtained data from the second season, the minimum mean value of yield obtained for control treatment was 47.5 ton/fd., and the maximum value was 62.8 ton/fd and recorded also for the 2g/L micronutrients' spraying treatment. According to the varieties of sugar cane, the minimum and maximum yield values were 43.9 and 70.5 ton/fd and recorded for G.2003-44 and G.99-103, respectively at the first season. At the second season, the minimum mean value was 44.3 ton/fd for G.2003-44 variety while the maximum mean value obtained for G.99-103 variety whereas it was 72.0 ton/fd.

Studies of Naga et al. (2013) and Mellis et al. (2016) were in harmony with our findings whereas they found that micronutrients affected the sugar cane yield among different varieties.

Table (12). Cane yield (tons/fed) as affected by sugarcane varieties, micronutrients, and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane varieties	first season 2021/2022				second season 2022/2023			
	Cane yield (tons/fed)							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	57.9	61.5	64.0	61.1	56.7	64.4	67.2	62.8
G.99-103	68.4	71.3	71.8	70.5	65.1	71.4	79.4	72.0
G.2004-27	61.1	65.5	67.1	64.6	52.5	72.3	74.7	66.5
G.2003-44	38.9	40.7	52.2	43.9	40.6	42.0	50.4	44.3
G. 84-47	46.5	53.3	55.5	51.8	47.6	60.2	58.8	55.5
G.2007-61	45.2	52.1	55.1	50.8	33.6	48.0	68.6	50.1
G.2003-49	44.9	48.9	50.3	48.0	40.6	51.8	51.8	48.1
G.2003-47	44.7	46.2	52.7	47.9	43.4	46.3	51.8	47.2
Mean	51.0	54.9	58.6	**Mean**	47.5	57.0	62.8	
LSD at 0.05 level of significance								
Micronutrients (M)				0.91				2.54
Varieties (V)				2.48				1.56
M x V				4.29				2.71

Sugar yield (tons/fed.)

Data in Table (13) demonstrated the sugar yield (tons/fed) of the harvested sugar cane crop at the two investigated seasons under the treatments of micronutrients spraying. The significant differences in sugar yield (tons/fed) were observed among the sugar cane varieties, micronutrients' levels and the interaction between the varieties and micronutrients spraying at the two seasons. The obtained data revealed that the sugar yield at the first season has minimum and maximum mean values of control and 2g/L micronutrients spraying with the values of 5.9 and 7.5 tons/fed, respectively. Regarding the second season, the minimum mean value of sugar yield was 5.4 tons/fd for the control treatment and the maximum mean value was 7.7 tons/fed for the second level of micronutrients spraying. The sugar can verities were affected by micronutrients treatment during the two cultivated seasons. However, at the first season, the G.2003-44 variety has the minimum sugar yield with a value of 5.4 tons/fed, while the G.99-103 variety has the maximum mean value of 7.9 tons/fed. At the second season, the same trend of the minimum (5.4 tons/fed) and the maximum (7.9 tons/fed) was observed for the same sugar cane varieties, respectively.

These findings are like to the results of Vallejo-Torres and López-Hernández (2001) and Sohu et al. (2015) whereas they found that sugar yield was affected by spraying micronutrients during cultivating seasons and observed the similar effect on sugar yield.

Table (13). Sugar yield (tons/fed) as affected by sugarcane varieties, micronutrients, and their interaction in 2021/20222 and 2022/2023 seasons

Sugar cane Varieties	first season 2021/2022				second season 2022/2023			
	Sugar yield (tons/fed)							
	Micronutrients levels				Micronutrients levels			
	Control	1g/L	2g/L	Mean	Control	1g/L	2g/L	Mean
G.T.54-9	7.0	7.4	8.3	7.5	6.7	7.8	8.4	7.6
G.99-103	7.1	8.3	8.3	7.9	7.0	7.8	8.8	7.9
G.2004-27	6.9	7.4	8.6	7.7	5.8	8.1	8.8	7.6
G.2003-44	4.2	4.8	7.1	5.4	4.7	5.1	6.4	5.4
G. 84-47	5.6	7.0	7.5	6.7	5.1	7.3	7.0	6.5
G.2007-61	5.1	6.0	6.5	5.9	3.8	5.5	8.1	5.8
G.2003-49	5.6	6.5	6.9	6.3	4.8	6.2	6.4	5.8
G.2003-47	5.5	5.7	6.8	6.0	5.3	6.7	7.4	6.5
Mean	5.9	6.6	7.5		5.4	6.8	7.7	
LSD at 0.05 level of significance								
Micronutrients (M)				0.46				0.30
Varieties (V)				0.45				0.33
M x V				0.77				0.57

CONCLUSION

The study revealed significant findings that contribute to the understanding of micronutrient management practices in sugar cane farming, with specific implications for optimizing agricultural productivity and crop quality in this region. The results showed that the application of level-2 micronutrients (2g/L) significantly impacted the yield and quality of the cultivated sugar cane varieties over the two investigated seasons in the alluvial soils (high suitable. By shedding light on the effects of micronutrient spraying on both yield and quality, the study paves the way for refined agricultural practices that can drive enhanced productivity and improved crop quality in the region.

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تأثير الرش بالعناصر الصغرى على انتاجية وجودة قصب السكر في التربة الثقيلة بصعيد مصر

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الملخص العربي

تهدف هذه الدراسة للكشف عن تأثير الرش بالعناصر الصغرى على انتاجية وجودة محصول قصب السكر (*Saccharum officinarum* L.) في التربة الثقيلة تحت الظروف المناخية الزراعية في صعيد مصر. أجريت تجربة حقلية خلال الموسمين 2022/2021 و2023/2022 على ثمانية أصناف من قصب السكر. تم تطبيق ثلاث معاملات رش بالمغذيات الصغرى وهي صفر (الكنترول)، 1جم/لتر، 2جم/لتر من خليط الحديد والزنك والمنجنيز وذلك في الموسمين. تم تحديد معايير الإنتاجية مثل طول القصب، القطر، إنتاجية القصب والسكر. تم اختبار مؤشرات جودة البركس والسكروز والسكريات المختزلة ونقاء العصير ونسب استخلاص السكر لتقييم جودة قصب السكر. تم أخذ عينات من قطاعين تربة ممثلين للحقول المزروعة وتم تحليلهما باستخدام الطرق القياسية لتحليل التربة لتوصيفها وكذلك تحديد حالة المغذيات الدقيقة. أظهرت النتائج البارزة لهذه الدراسة أن المستوى الثاني من المغذيات الصغرى (2 جرام / لتر) أثر بشكل كبير على إنتاجية وجودة الأصناف المزروعة في الموسمين المدروسين. وقد تساهم هذه النتائج في فهم ممارسات إدارة المغذيات الصغرى في زراعة قصب السكر، والتي تم تصميمها خصيصًا لتلبية احتياجات هذه المنطقة، مع ما يترتب على ذلك من آثار على تحسين الإنتاجية الزراعية وجودة المحاصيل.

الكلمات المفتاحية: قصب السكر، العناصر الصغرى، صعيد مصر، أصناف القصب.