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Influence of Foliar Application with Micronutrients on Productivity of Three Sugar Beet Cultivars under Drip Irrigation in Sandy Soils

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Abstract: Two field experiments were conducted at the Desert Experimental Station of the Fac. of Agric., Cairo Univ. in Wadi El-Natroon, during 2012/2013 and 2013/2014 seasons to study the response of sugar beet yield and some of its attributes in three multigerm seed cultivars, *viz.* Heba, Ninagri and Halawa under drip irrigation in a split plot design to foliar application with zinc (Zn) + Manganese (Mn) + Iron (Fe) + Boron (B). The mixture of micronutrients was applied at three different concentrations, *viz.* 50 Zn + 50 Mn + 50 Fe + 500 B (C_1), 100 Zn + 100 Mn + 100 Fe + 1000 B (C_2) and 150 Zn + 150 Mn + 150 Fe + 1500 B (C_3) in ppm/L, as well as, the control treatment of distilled water (C_0). The results revealed that increasing micronutrients mixture from C_0 level up to C_3 level significantly increased root weight by 21.54% and 23.81%, root yield by 28.00% and 24.40% and sugar yield by 76.50% and 60.61% in the first and second seasons, respectively. Quality traits, in terms of total soluble solids (TSS), sucrose%, purity% and extractable sucrose% were significantly increased by increasing levels of micronutrients in both seasons. The highest values of such traits resulted from C_3 level. The sugar beet cultivar Halawa recorded the highest and significant values of mean root weight (0.93 and 0.98 kg), root yield (23.52 and 24.34 ton/fed.), extractable sucrose% (14.04 and 13.59%) and sugar yield (3.34 and 3.35 ton/fed.) in the first and second seasons, respectively. The interaction between micronutrients and cultivars was significant for mean root weight, root yield, purity%, extractable sucrose% and sugar yield in both seasons. Spraying cultivar Halawa with C_2 and/or C_3 level was recommended for high root and sugar yields.

Key words: *Beta vulgaris* L. · Micro-nutrients · Cultivars · Quality traits · Sugar yield

INTRODUCTION

Sugar beet growers in Egypt are paid based on the tons of recoverable sucrose that is extracted from their crop. Sugar beet profitability therefore, depends on producing a high tonnage crop with high sucrose content. Nutrients management is an important key for accomplishing this goal. Most fertilizer programs in sugar beet production in Egypt focus on nitrogen and phosphorus and, in some cases, potassium. In recent years, sugar beet grown in sandy soils which is very poor in organic matter has shown a variety of visual symptoms that resemble micronutrients deficiency. Soil test and plant tissue analysis suggest deficiencies in one or more of the following micro-nutrients; B, Fe, Mn and Zn or a variety of other possibilities. Under typical sugar beet growing conditions there is little emphasis on these nutrients because their release from the soil organic matter and naturally occurring soil minerals is sufficient to meet the sugar beet needs. However, in sandy soils with low organic matter (< 2%) this may not always be the case and deficiencies may appear.

Draycott and Christenson [1] reported that sugar beet can become deficient in several micronutrients, but is most responsive to the application of B, Mn and Fe fertilizers when the soil availability of these nutrients is low. Boron and Mn deficiencies are probably most frequent and subsequently are the most studied of all the micronutrient important to sugar beet production.

Kobraee *et al*. [2] stated that Zinc deficiency appears to be the most widespread and frequent micronutrient deficiency problem in crop plants worldwide, resulting in severe losses in yield and nutritional quality. Zinc is an essential micro-nutrient and has particular physiological functions in all living systems, such as the maintenance of structural and functional integrity of biological

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membranes and facilitation of protein synthesis and gene expression and is considered as the most limiting factor for producing crops in different regions of the world.

Mousavi *et al*. [3] reported that crop yield significantly increases with the use of micronutrients such as Zn, Fe, B and Mn that have an important metabolic role in plant growth and development therefore called an essential trace elements or a micronutrients. Zinc uptake and transfer is in the form of Zn^{++} in plants enzymes structure, energy production and Krebs cycle. Also, Zn has a positive impact on crops yield; therefore crops quantitative and qualitative yield is strongly dependent on zinc.

Abd El-Gawad *et al.* [4], Yarnia *et al.* [5] and Nemeat-Alla *et al.* [6] reported that application of high rates of micronutrients produced the highest root yield of sugar beet plants, while it produced the lowest values of quality characters such as sucrose, TSS and purity percentages. Amin *et al.* [7] reported that fertilized sugar beet plants with foliar spray of mixture of micronutrients; iron sulphate, zinc sulphate and manganese sulphate at the rate of 1.09g/l for each significantly increased values of dry matter per plant and sugar yield, while significantly decreased TSS, sucrose and purity percentages. Neamatollahi *et al*. [8] studied the affect of different levels of zinc (0, 40, 80 kg $ZnSO_4$/ha) on yield and quality of five sugar beet varieties. Their results cleared that application of zinc and variety had a significant effect on yield and sugar content. The rate of 40 kg $ZnSO_4$/ha gave the highest yield and sugar percent, while the application of 80 kg $ZnSO_4$/ha significantly decreased sugar percent. Mekki [9] investigated the response of yield and quality of sugar beet plants to foliar application with Urea, Zn and Mn in newly reclaimed sandy soil. He found that, the highest and significant values of root, top, sugar yields and sucrose percentage (57.24, 32.51, 2.46 t/ha and 18.93%, respectively) were obtained with the application of 2% Urea + 400 ppm Zn + 400 ppm Mn. Purity % was increased up to 87.20 % with foliar spraying with 2% Urea+ 400 ppm Zn followed by (83.64 %) with 2% Urea+ 400 ppm Zn + 400 ppm Mn.

The objective of this study was to determine the effect of different micronutrients mixtures of zinc, manganese, iron and boron as foliar application on yield and quality of three sugar beet cultivars grown under drip irrigation system in newly reclaimed sandy soil conditions.

MATERIALS AND METHODS

Two field experiments were conducted at Wadi El-Natroon Desert Experimental Station, Fac. of Agric., Cairo Univ. (Figure, 1) during 2012/2013 and 2013/2014 seasons under drip irrigation to evaluate the effect of foliar application with zinc ($ZnSO_4$. $7H_2O$) + Manganese ($MnSO_4$. $7H_2O$) + Iron (Fe_2SO_4. $7H_2O$) + Boron (H_3BO_4) on sugar beet productivity of three multigerm seed cultivars, *viz*. Heba (Denmark), Ninagri (England) and Halawa (Germany).

The mixture of micronutrients was applied as a foliar application at three different concentrations, *viz.* 50 Zn + 50 Mn + 50 Fe + 500 B (C_1), 100 Zn + 100 Mn + 100 Fe + 1000 B (C_2) and 150 Zn + 150 Mn + 150 Fe + 1500 B (C_3) in ppm/L, as well as, the control treatment of distilled water (C_0). The micronutrients mixtures were applied three times at 60, 75 and 90 days after sowing in addition to the control treatment. Irrigation water was saline (4.1 dS/m).

Preceding crops and soil characteristics of sugar beet experimental fields during 2012/13 and 2013/14 seasons are presented in Table (1). Results in Table (1) indicated that soil of the experimental site was sandy, saline and poor in macro and micro nutrients, as well as, organic matter.

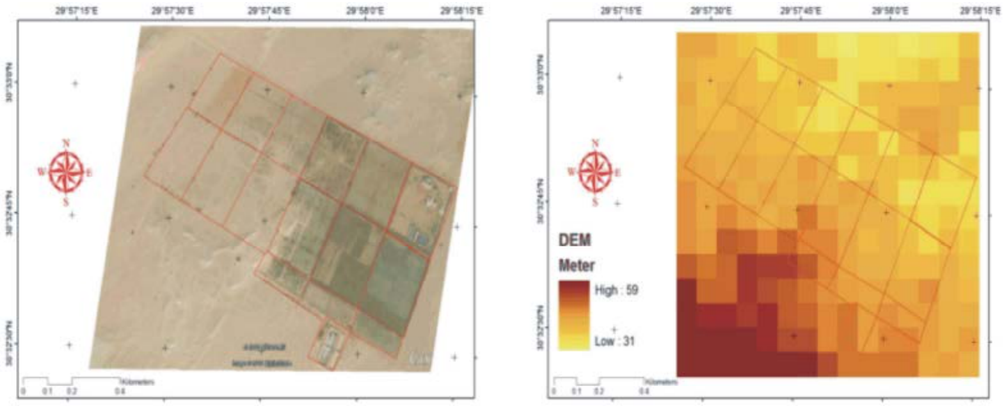

Fig 1: The experimental site located between 30°32'30" and 30° 33'0" N and between 29° 57'15" and 29°58'15" E with an altitude of 31 and 59 meters above sea level

Table 1: Preceding crops and soil properties of sugar beet experimental fields during 2012/13 and 2013/14 seasons.

	2012/ 2013	2013/ 2014
Preceding crop	Sesame	Sunflower
Physical properties		
Sand %	93.15	94.85
Silt %	3.85	3.00
Clay %	3.00	2.15
Soil texture	Sandy	Sandy
Chemical properties		
pH	7.80	7.95
EC (dS/m)	5.33	5.25
Na (mq/l)	36.23	34.24
Cl (mq/l)	32.44	32.24
Organic matter (%)	0.30	0.28
Total $CaCO_3$ %	3.10	2.55
N (mg kg^{-1})	9.63	8.78
P (mg kg^{-1})	4.5	3.6
K (mg kg^{-1})	80	70
B (mg kg^{-1})	0.25	0.20
Zn (mg kg^{-1})	0.26	0.25
Mn (mg kg^{-1})	0.35	0.30
Fe (mg kg^{-1})	0.90	0.82

The experimental design was a randomized complete block in a split-plot arrangement with three replications. Sugar beet cultivars were allocated to the main plots, while micronutrients mixtures were distributed at random in the subplots. Seeds of sugar beet cultivars were sown on ridges 60 cm apart and 17.5 cm between hills to ensure 40×10^3 plants $fed.^{-1}$. Each subplot included 5 ridges each was 4 m in length. Therefore, each subplot size was 12 m^2. Sugar beet seeds were sown on the first week of October of each season. Nitrogen was added at a rate of 100 kg N/fed. (feddan=4200 m^2) in the form of ammonium nitrates (33.5% N) in three equal splits, the first was applied after thinning at 4-leaf stage and other splits were added at one and two months later. Phosphorous in the form of super phosphate (15.5%) at the rate of 30 Kg P_2O_5 /fed. was added before sowing and during soil preparation. Potassium in the form of potassium sulfate (48%) was added at the rate of 48 Kg K_2O/fed. with the first dose of N. Thinning took place to one plant/hill at 4-leaf stage (4 weeks from planting). Other cultural practices were done as recommended.

Sugar beet was topped and harvested by hand on May 15th (210 days old). Harvested roots from the whole area of each sub-plot were weighed and adjusted to ton per feddan. Total soluble solids were determined by using digital refractometer model PR-1, ATAGO, Japan. Sucrose % was determined polarimetrically on a lead acetate extract of fresh macerated roots according to Carruthers and Oldfield [10]. Purity was calculated by dividing sucrose by TSS. Extractable sucrose % was calculated using the following equation from Dexter *et al.* [11]:

$$\text{Extractable sucrose \%} = [\text{sucrose \%} - 0.3][1\text{-}(1.667\frac{(100\text{-purity})}{\text{purity}})]$$

Sugar yield was calculated according the following equation:

Sugar yield ton $fed.^{-1}$ = root yield ton $fed.^{-1}$ × Extractable sucrose %.

Collected data were statistically analyzed using analysis of variance of the spilt plot design according to procedures outlined by Steel *et al.* [12] using MSTAT-C computer package [13]. Treatment mean comparisons were performed using least significant difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Effect of Micronutrients Mixture: Sugar beet yield and all of its attributes were significantly affected by micronutrients mixture levels in both seasons with the exception of number of harvested plants (Table 2).

A gradual increase in mean root weight as micronutrients mixture increased up to C_3 level was recorded. The increase reached to 4.53%, 13.10% and 21.54% in the first season and 5.25%, 14.90% and 23.81% in the second season as micronutrients mixture increased from C_0 to C_1, C_2 and C_3, respectively. This increase in root weight is mainly due to the role of micronutrients that have an important metabolic role in plant growth and development [5, 14, 3].

Spraying micronutrients mixture at the levels of C_1, C_2 and C_3 increased root yield by about 8.07%, 16.55% and 28.00% in the 1st season, corresponding to 5.31%, 15.92% and 24.40% in the 2nd season as compared to control treatment (C_0), respectively. The increase in root yield accompanying high levels of micronutrients mixture might have been due to the increase in individual root weight as mentioned before. The role of micronutrients in increasing dry matter and root yield in sugar beet was reported by Abd El-Gawad *et al.* [4], Yarnia *et al.* [5], Nemeat-Alla *et al.* [6], Amin *et al.* [7] and Mekki [9].

Root quality traits, in terms of TSS, sucrose %, purity % and extractable sucrose % were significantly affected by varying levels of micronutrients in both seasons (Table 2). Increasing micronutrients levels from C_0 to C_3 significantly increased TSS by 19.94 %, sucrose% by 24.30 %, purity % by 3.56% and extractable sucrose by

Table 2: Effect of spraying with micronutrients mixture on sugar beet yield and some of its attributes during 2012/2013 and 2013/2014 seasons.

Micronutrients mixture	Mean root weight (kg)	No. of harvested plants (10^3/fed.)	Root yield (ton/fed.)	TSS	Sucrose%	Purity%	Extractable sucrose%	Sugar yield (ton/fed.)
2012/2013 Season								
C_0	0.817	24.27	19.82	20.11	16.75	83.35	10.96	2.17
C_1	0.854	25.09	21.42	21.40	18.18	85.03	12.60	2.69
C_2	0.924	24.98	23.10	23.02	19.84	86.20	14.31	3.32
C_3	0.993	25.55	25.37	24.12	20.82	86.32	15.09	3.83
$LSD_{0.05}$	0.030	n.s	0.80	0.45	0.33	0.58	0.29	0.12
2013/2014 season								
C_0	0.819	24.63	20.16	20.86	17.41	83.48	11.45	2.31
C_1	0.862	24.62	21.23	22.27	18.96	85.18	13.23	2.81
C_2	0.941	24.87	23.37	23.34	19.91	85.33	14.00	3.28
C_3	1.014	24.74	25.08	24.15	20.72	85.79	14.78	3.71
$LSD_{0.05}$	0.038	n.s	1.19	0.50	0.23	1.10	0.44	0.16

n.s. = non significant

C_0 = control treatment (distilled water), C_1 = 50 Zn + 50 Mn + 50 Fe + 500 B in ppm,

C_2 = 100 Zn + 100 Mn + 100 Fe + 1000 B in ppm, C_3 = 150 Zn + 150 Mn + 150 Fe + 1500 B in ppm.

Table 3: Effect of sugar beet cultivars on sugar yield and some of its attributes during 2012/2013 and 2013/2014 seasons.

Cultivar	Mean root weight (kg)	No. of harvested plants (10^3/fed.)	Root yield (ton/fed.)	TSS	Sucrose%	Purity%	Extractable sucrose%	Sugar yield (ton/fed.)
2012/2013 Seasons								
Heba	0.863	24.77	21.41	22.22	18.85	84.77	13.04	2.83
Ninagri	0.896	24.94	22.34	22.21	18.70	84.17	12.65	2.85
Halawa	0.933	25.21	23.52	22.07	19.14	86.73	14.04	3.34
$LSD_{0.05}$	0.032	n.s.	0.66	n.s.	n.s.	0.75	0.36	0.11
2013/2014 season								
Heba	0.848	24.76	21.02	23.11	19.63	84.94	13.64	2.89
Ninagri	0.897	24.60	22.02	22.15	18.75	84.67	12.87	2.84
Halawa	0.983	24.78	24.34	22.71	19.37	85.23	13.59	3.35
$LSD_{0.05}$	0.029	n.s.	0.92	n.s.	n.s.	n.s.	0.26	0.16

n.s. = non significant.

37.68 % in the first season, corresponding to 15.77, 19.01, 2.77 and 29.08% in the second season, respectively. Similar trends were observed by Garib and El-Henawy [14].

Results in Table (2) cleared that sugar yield was significantly increased by increasing foliar application of micronutrients mixture from C_0 to C_3. These results were true in the two growing seasons. Such increase amounted to 76.50 % in the first season and 60.61 % in the second one. However, the increase in sugar yield accompanying high micronutrients level might have been due to the increase in root yield as well as extractable sucrose percentage as mentioned before. Such results are in accordance with those reported by Yarnia *et al.* [5], Amin *et al.* [7] and Mekki [9].

The previous results revealed strong improvement in sugar yield and most of its attributes under newly reclaimed sandy soils by applying micronutrients as a foliar application. However, chemical analysis of the soil experiment (Table 1) showed that zinc and boron availability under experimental soil conditions is limited due to high pH (>7.0), high free calcium carbonate and low organic matter content [15]. More boron appears to be required by plants growing in soils with high pH [16]. Therefore, under these conditions, foliar applications with micronutrients are recommended to improve the efficiency of Zn and B assimilation [17].

Effect of Sugar Beet Cultivars: Results in Table (3) revealed that sugar beet cultivars differed significantly in mean root weight, root yield, extractable sucrose% and sugar yield in both seasons except for purity% only in the first season.

The highest and significant mean root weight values were recorded by the cultivar Halawa in the first season (0.933 kg) and in the second one (0.983 kg). The same cultivar (Halawa) significantly surpassed the other two cultivars in root yield (23.52 and 24.34 ton/fed.), extractable sucrose% (14.04 and 13.59%) and sugar yield

(3.34 and 3.35 ton/fed.) in the first and second seasons, respectively. The superiority of cultivar Halawa in root yield might be due to its superiority in mean root weight and root number at harvest.

Moreover, high root yield and extractable sucrose% from Halawa cultivar lead to high sugar yield during the two seasons. These results are in agreement with those obtained by Masri [18] and Neamatollahi *et al*. [8] who reported significant differences among sugar beet cultivars in mean root weight, root yield, extractable sucrose% and sugar yield.

Effect of the Interaction Between Micronutrients Mixture and Sugar Beet Cultivars: Results in Table (4) indicated that mean root weight, root yield, purity %, extractable sucrose % and sugar yield were significantly affected by the interaction between application of micronutrients mixture and sugar beet cultivars in both seasons.

The heaviest roots (1.060 and 1.133 kg) resulted from spraying the cultivar Halawa with micronutrients mixture at C_3 level in the 1st and 2nd seasons, respectively. The highest and significant root yield values; 27.06 and 27.86 ton/fed. resulted from spraying the cultivar Halawa with micronutrients mixture at C_3 level in the 1st and 2nd seasons, respectively. Data averaged across seasons (Fig. 2) indicated that applying micronutrients at C_3 level to the cultivar Halawa recorded the highest root yield (27.47 ton/fed.).

The highest purity percentages (90.70 and 87.33%) were recorded by applying micronutrients to Halawa cultivar at C_2 level in the 1st and 2nd seasons, respectively (Table 4). The highest extractable sucrose percentages were obtained from the cultivar Halawa (16.75 and 15.13 %) sprayed with micronutrients at C_2 level and/or from the cultivar Heba (15.37 and 15.22%) sprayed with micronutrients at C_3 level in the 1st and 2nd seasons, respectively.

Table 4: Effect of the interaction between micronutrients and sugar beet cultivars on sugar yield and some of its attributes during 2012/2013 and 2013/2014 seasons.

		Mean root weight (kg)		No. of harvested plants (10^3/fed.)		Root yield (ton/fed.)		TSS	
Micronutrients mixture	Cultivar	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
C_0	Heba	0.793	0.757	24.50	24.85	19.44	18.83	20.03	21.27
	Ninagri	0.833	0.870	24.15	24.55	20.13	21.32	20.60	20.00
	Halawa	0.823	0.830	24.15	24.50	19.87	20.34	19.70	21.33
C_1	Heba	0.810	0.780	24.52	24.50	19.85	19.11	21.32	22.88
	Ninagri	0.877	0.887	25.20	23.80	22.04	21.09	20.95	21.56
	Halawa	0.877	0.920	25.55	25.55	22.36	23.50	21.93	22.36
C_2	Heba	0.887	0.897	24.15	24.85	21.45	22.28	23.30	23.87
	Ninagri	0.913	0.880	25.20	25.20	23.05	22.16	23.17	22.94
	Halawa	0.973	1.047	25.58	24.55	24.81	25.67	22.60	23.20
C_3	Heba	0.960	0.960	25.90	24.85	24.90	23.87	24.21	24.41
	Ninagri	0.960	0.950	25.20	24.85	24.15	23.51	24.13	24.10
	Halawa	1.060	1.133	25.55	24.53	27.06	27.87	24.03	23.95
	LSD$_{0.05}$	0.052	0.059	n.s.	n.s.	2.25	2.32	n.s.	n.s.

		Sucrose%		Purity%		Extractable sucrose%		Sugar yield (ton/fed.)	
Micronutrients mixture	Cultivar	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
C_0	Heba	16.42	17.83	81.96	83.86	10.20	11.91	1.99	2.24
	Ninagri	16.74	16.96	81.27	84.83	10.12	11.70	2.04	2.49
	Halawa	17.10	17.44	86.82	81.74	12.55	10.76	2.49	2.18
C_1	Heba	18.38	19.21	86.20	83.95	13.25	12.88	2.63	2.46
	Ninagri	18.03	18.53	86.15	85.94	12.95	13.25	2.85	2.79
	Halawa	18.14	19.15	82.74	85.65	11.62	13.57	2.60	3.19
C_2	Heba	19.64	20.45	84.27	85.71	13.32	14.54	2.86	3.24
	Ninagri	19.38	19.03	83.63	82.96	12.85	12.32	2.97	2.73
	Halawa	20.50	20.26	90.70	87.33	16.75	15.13	4.15	3.89
C_3	Heba	20.98	21.04	86.67	86.23	15.37	15.22	3.83	3.64
	Ninagri	20.66	20.48	85.63	84.96	14.66	14.22	3.54	3.34
	Halawa	20.82	20.64	86.64	86.18	15.24	14.90	4.11	4.15
	LSD$_{0.05}$	n.s.	n.s.	1.50	0.90	0.72	0.52	0.21	0.32

n.s. = non significant.

C_0 = control treatment (distilled water), C_1 = 50 Zn + 50 Mn + 50 Fe + 500 B in ppm,

C_2 = 100 Zn + 100 Mn + 100 Fe + 1000 B in ppm, C_3 = 150 Zn + 150 Mn + 150 Fe + 1500 B in ppm.

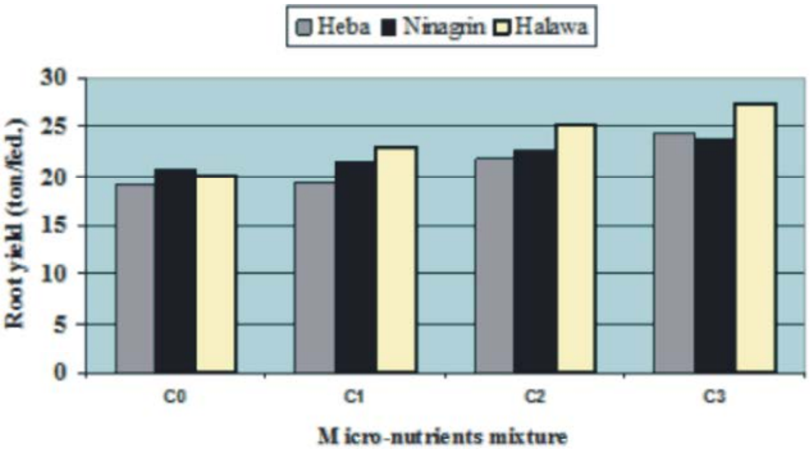

Fig 2: Root Yield of Sugar Beet as Affected by the Interation Between Micro-nutrients Mixture and Cultivars (Combined Across Seasons). C_0= control treatment (distilled water), C_1= 50 Zn + 50 Mn + 50 Fe + 500 B in ppm, C_2= 100 Zn + 100 Mn + 100 Fe + 1000 B in ppm, C_3= 150 Zn + 150 Mn + 150 Fe + 1500 B in ppm

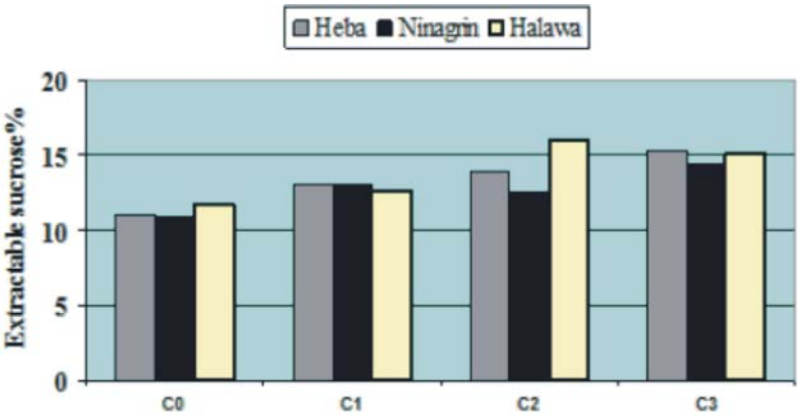

Fig 3: Extractable Sucrose % as Affected by the Interaction Between Micro-nutrients Mixture and Sugar Beet Cultivars (Combined Across Seasons). C_0= control treatment (distilled water), C_1= 50 Zn + 50 Mn + 50 Fe + 500 B in ppm, C_2= 100 Zn + 100 Mn + 100 Fe + 1000 B in ppm, C_3= 150 Zn + 150 Mn + 150 Fe + 1500 B in ppm

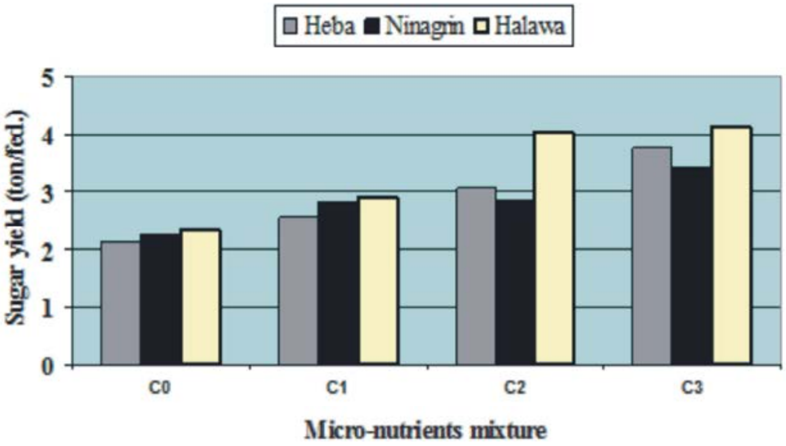

Fig 4: Sugar Beet Yield as Affected by the Intreaction Between Micro-nutrients Mixture and Sugar Beet Cultivars (Combined across seasons). C_0= Control Treatment (Distilled Water), C_1= 50 Zn + 50 Mn + 50 Fe + 500 B in ppm, C_2= 100 Zn + 100 Mn + 100 Fe + 1000 B in ppm, C_3= 150 Zn + 150 Mn + 150 Fe + 1500 B in ppm

Data averaged over seasons (Fig. 3) revealed that spraying cultivar Halawa with Micronutrients at C_2 level recorded the highest extractable sucrose percentage (15.94%).

The cultivar Halawa recorded the highest and significant values of sugar yield either under spraying with micronutrients at C_2 level (4.15 and 3.89 ton/fed.) or under spraying with micronutrients at C_3 level (4.11 and 4.15 ton/fed.) in the 1st and 2nd seasons, respectively.

Data averaged across seasons (Fig. 4) revealed that spraying cultivar Halawa with micronutrients at C_3 level recorded the highest sugar yield (4.13 ton/fed.).

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