http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2020.1416.1423

Research Article
Impact of Nano-Micronutrients as Foliar Fertilization on Yield and Quality of Sugar Beet Roots

[1]Mohamed Said Abbas, [1]Adel Saad El-Hassanin, [2]Mohamed Desouki Hassan Dewdar and [3]Hamdy Abd Elfattah Abd Elaleem

[1]Department of Natural Resources, Faculty of African Postgraduate Studies, Cairo University, Egypt
[2]Department of Agronomy, Faculty of Agriculture, Fayoum University, Egypt
[3]Fayoum Sugar Company, Etsa, Fayoum, Egypt

Abstract
Background and Objective: Nanotechnology is one of the new technologies that entered almost all sides of our lives and were used in agriculture production. Nowadays, nanotechnology has expanded horizons in all fields of science. The study was aimed to investigate the response of yield and quality of sugar beet cv. Farida to foliar application of nano-microelements mixtures (Fe, Mn, Zn and B) with/without urea. **Materials and Methods:** Two field experiments were carried out in the experimental farm of the Etsa region in Fayoum Governorate, Egypt, during the two successive seasons (2015/16 and 2016/17). Fourteen treatments of four microelements as nano form sole and in combination with urea were applied and twelve traits were studied, growth traits, Juice quality traits and yield. **Results:** showed that the best results were found when sugar beet plants were treated with nano-microelements 200 mg L^{-1}+ urea 1% and was ranked as the first favorable treatments for root length and diameter, dry matter per plant as root, top and sugar yields in both seasons, followed by the treatment of Nano-microelements 160 mg L^{-1}+urea 1% for most of the traits studied. From the obtained results, **Conclusion:** it could be concluded that the application of nano-microelements 200 mg L^{-1}+urea 1% treatment for significantly produced higher yields associated with improving the quality traits of sugar beet and saving the plants' needs from micronutrient and nitrogen fertilizers if this fertilizer rate has been added in the form of nanoparticles.

Key words: Nanotechnology, sugar beet, urea, foliar application, top yield, length and diameter

Citation: Abbas, M.S., A.S. El-Hassanin, M.D.H. Dewdar and H.A.E.A. Elaleem, 2020. Impact of nano-micronutrients as foliar fertilization on yield and quality of sugar beet roots. Pak. J. Biol. Sci., 23: 1416-1423.

Corresponding Author: Mohamed Said Abbas, Department of Natural Resources, Faculty of African Postgraduate Studies, Cairo University, Egypt
Tel: 00201116893637

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is a crop of major importance for sugar production in temperate zones. Sugar is produced in the world from sugar beet with productivity of 56.4 million tons. The sugar beet area is estimated at 10.6 million feddans, producing an estimated 254.4 million tons (roots).

Zinc and boron availabilities in calcareous soils are limited due to high pH (>7.0), high free calcium carbonate and low organic matter content[1]. Moreover, utilization of micronutrients like manganese, zinc and iron with balance can enhance and increase the productivity of yield sugar beet[2-5]. In the meantime adding micronutrient mixtures (Fe+Zn+Mn) has. improved yield and other attributes of sugar beet crop[6-8].

Nanotechnology is one of the new technologies that entered almost all fields of our life including; agriculture production. Nowadays, nanotechnology has expanded horizons in all fields of science. They are widely used in industrial products, pharmaceuticals, engineering fields, medicine and agriculture[9]. Nanotechnology can be used in crop production to improve growth and increase yield[10]. Substituting traditional methods of fertilizer application with nano fertilizers is a way to release nutrients into the plant gradually and in a controlled manner[11]. Hence, nano-fertilizers are either nano-materials, which can supply one or more nutrients to the plants resulting in enhanced growth and yield or that which lead to better performance of conventional fertilizers, without directly providing crops with nutrients.

The application of nanoparticles to plants can be beneficial for growth and development due to its ability for greater absorbance and high reactivity[12-13]. Nanomaterial could be applied in designing more soluble and diffusible sources of zinc fertilizers for increased plant productivity[14]. Therefore, the present study aimed to assess the effect of foliar spraying of nano-micronutrients mixtures, i.e, iron (Fe) manganese (Mn), zinc (Zn) and boron (B) using nanotechnologies, besides nitrogen in the form of urea (N) on growth, quality and yield traits of sugar beet (*Beta vulgaris* L.) plants.

MATERIALS and METHODS

Site selection and description: Two field experiments were carried out in the experimental farm of the Etsa region in Fayoum Governorate, Egypt, during the two successive winter seasons (2015/16 and 2016/17). Physical and chemical analyses of the soil were carried out before planting.

Experimental design and treatments: The fourteen treatments were T_1: spraying with tap water, T_2: nano-micronutrients 200 mg L^{-1}, T_3: nano-micronutrients 160 mg L^{-1}, T_4: nano-micronutrients 120 mg L^{-1}, T_5: nano-micronutrients 80 mg L^{-1}, T_6: nano-micronutrients 40 mg L^{-1}, T_7: nano-micronutrients 200 mg L^{-1}, T_8: nano-micronutrients 200 mg L^{-1} + urea 1%, T_9: nano-micronutrients 160 mg L^{-1} + urea 1%, T_{10}: nano-micronutrients 120 mg L^{-1} + urea 1%, T_{11}: nano-micronutrients 80 mg L^{-1} + urea 1%, T_{12}: nano-micronutrients 40 mg L^{-1} + urea 1%, T_{13}: nano-micronutrients 200 mg L^{-1} + urea 1% and T_{14}: urea 1%.

Characteristic features of NPs Nano-microelement: Manganese oxide, boric acid (H_3BO_4) and zinc and iron oxides were determined[15].

Experimental treatments and field procedures: Treatments were arranged in a randomized complete block design with four replications. Planting dates were on the second half of October of the two seasons. The plot area was 21 m^2 and each plot consisted of five ridges of 7 m in length and 0.6 m in width. All recommended agricultural operations were carried out in terms of weed control, hoeing, lightening, irrigation, fertilization, pest control and diseases in accordance with the recommendations.

Soil characterization and laboratory analyses: Before the trial establishment, soil samples were taken from each experimental field and analyzed for initial nutrient status. The soil samples were collected using auger from at least 5 points in a W-shape to have a representative sampling. The samples were taken from 0-30 cm from each plot and then bulked together and passed through a 2 mm sieve to form a composite sample. The composite samples were prepared using standard procedures and analyzed for physical and chemical properties. Total nitrogen (total N) was determined using the micro-Bremner digestion method[16]. Soil pH (S/W ratio of 1:1) in water was measured using the glass electrode pH meter, particle size distribution using the hydrometer method and electrical connectivity using EC-Meter[17]. Available phosphorus extracted by $NaHCO_3$ and solution (pH 8.5) by Olsen method with, exchangeable cations (K, Ca, Mg and Na) and micronutrients (B, Cu, Mn, Fe and Zn) were analyzed based on flame photometry (Na, K), titration with EDETA -2Na for (Ca , Mg) and reading with inductively coupled plasma optical emission spectroscopy (ICP-OES),. Exchangeable anions (CO_3, HCO_3, Cl, SO_4) was determined by shaking the soil with 1N KCl and titration with HCl for (CO_3

and HCO_3), with $AgNO_3$ for Cl, barium for SO_4 and the organic matter extracted by Walkley and Black method[18]. Effective cation exchange capacity (ECEC) was calculated as the summation of exchangeable cations (K, Ca, Mg and Na) and exchangeable anions (CO_3, HCO_3, Cl, SO_4). All the laboratory analyses were carried out at the Analytical Services Laboratory of the El-Fayuom University, Egypt.

Sugar yield and nutrient uptake: At harvest time, samples were collected and separated into tops and roots, four samples representing all ridges for each subplot were harvested, cleaned, topped, weighed and then was converted to estimate; root yield (ton/ha) and top yield (ton ha^{-1}):

$$\text{Apparent or gross sugar yield per ha} = (\text{root yield ton ha}^{-1} \times \text{sucrose \%})$$

The following criteria were studied for determining sugar yield:

Growth traits: Root length (cm), root diameter (cm), root fresh weight per plant (g) and top fresh weight per plant (g). Tops and roots were cut into small pieces, and a representative sample was taken for each treatment, weighed and quickly oven-dried at 105°C till constant weight for dry weight determination. The dry materials obtained were used for the estimation of root dry weight per plant (g) and top dry weight per plant (g).

Juice quality traits: The juice quality of fresh roots was extracted to determine the following characters: sucrose percentage by using Saccharometer on a lead acetate extract of fresh macerated root according to the procedure of Fayoum Sugar Company[19]. Sucrose percentage, quality percentage, sodium, potassium and alpha-amino nitrogen were determined by using Analyzer-HG in reception laboratory in Fayuom Company according to the method of AOAC.[20]. Recoverable sugar percentage (RS%, corrected sugar %) was determined by using the following formula:

$$\text{RS (\%)} = \text{Pol (\%)} - 0.029 - 0.343\ (\text{Na+K}) - 0.094\ (\text{alpha–amino-N})$$

where, Pol (%) is Sucrose (%), K, Na and amino–N in Milliequivalent /100 g in beet[21].

Statistical analysis: Regular analysis of variance of RCBD as outlined by Snedecor and Cochran[22] was applied on each season using MSTAT-C computer program. Bartlett's test of homogeneity indicated no statistical evidence for heterogeneity[23]. Thus, combined analysis of variance for the two seasons was done and the means were compared using the NEW LSD test at the 5% level.

RESULTS AND DISCUSSION

Variation in soil physical and chemical properties of the study area: Most soil physical and chemical properties showed calcareous soils and high pH (7.65), high free calcium carbonate (11.2%) and low organic matter content (0.76%). Mean total N, effective cation exchange capacity (ECEC) and organic carbon in the soils fell within low fertility status (Table 1).

Characteristics of nanoparticles: Nanoparticles used in this study ranged from 1 to 100 nm by Transmission Electron Microscopy (TEM) micrograph of synthesized nano Mn oxide, boric acid (H_3BO_4) nanoparticles, nano zinc oxide and iron oxide nanoparticles. Nanoparticles have great potential to

Table 1: Physical and chemical analysis of the experimental soil, Data presented as the average over two the study seasons

Soil characteristics	
Particle size distribution	
Sand (%)	11.35
Silt (%)	13.00
Clay (%)	75.2
Texture class	Clay
Chemical properties	
pH (in suspension)	7.65
EC dSm^{-1} (extract 1:5)	4.36
$CaCO_3$ (%)	11.2
OM (%)	0.76
Soil moisture content	
SP (saturation %)	65.60
FC	43.55
WP	20.85
AW	24.00
Soil soluble cations (meq L^{-1})	
Ca^{++}	8.31
Mg^{++}	7.57
K^{+}	0.75
Na^{+}	30.80
Soil soluble anions (meq L^{-1})	
CO_2^{--}	--
HCO_3^{--}	2.55
Cl^{-}	22.95
SO_4^{--}	23.2
Macronutrients available (ppm)	
N	6.25
P	31.00
K	276.50
Micronutrients available (ppm)	
B	0.61
Fe^{++}	15.55
Zn^{++}	0.77
Mn^{++}	6.65

deliver nutrients to specific target sites in living systems. The loading of nutrients on the nanoparticles is usually done by (a) absorption on nanoparticles, (b) attachment on nanoparticles mediated by ligands, (c) encapsulation in nanoparticulate polymeric shell, (d) entrapment of polymeric nanoparticles and (e) synthesis of Nanoparticles composed of the nutrient itself [24].

Sugar yield response to nano-micronutrient management strategies: The obtained values of mean squares from the combined analysis for traits; root length, root diameter, root fresh weight, top fresh weight, root dry weight and top dry weight, sugar yield, root yield, top yield, sucrose percentage, recoverable sugar and quality traits are presented in Table 2. Mean squares of nano-micronutrient treatments (T) were highly significant indicating different responses of mean performances of sugar beet plants under the different experimental fertilization treatments. There was no significant difference between seasons, and the interaction between seasons and treatments were not significant.

Growth traits: The results were significantly affected by the treatments of nano micronutrients. Data in Table 3 showed a significant and positive effect on root length, root diameter, root fresh weight, top fresh weight, root dry weight and top dry weight traits. Spraying nano micro-elements and nitrogen foliar applications significantly increased them, compared with the control (spraying with water). The highest values of root length (36.82 cm) and root diameter (16.20 cm), root fresh weight (1336.33 g), for the top fresh weight (612.30 g); root dry weight (211.30 g) and top dry weight (96.80 g) were associated by plants treated with T_8 (nano-microelements 200 mg L^{-1} + urea 1%) as compared to control (T_1) and T_{14} (urea 1%), followed by the treatment of nano-microelements 160 mg L^{-1} + urea 1% (T_9), as compared to control (T_1) and T_{14} (urea 1%).

The remainder treatments showed comparable values for the previous traits. The nano fertilizer used in the experiment is a formulated colloidal farming fertilization supplement that facilitates nutrient uptake, transportation and absorption. Eventually, it is evident that treatments significantly increased

Table 2: Analysis of variance showing mean squares for growth, quality and yield and its components traits in sugar beet (data are combined across two seasons)

S.O.V	D.F.	Root length (cm)	Root diameter (cm)	Root fresh weight (g)	Top fresh weight (g)	Root dry weight (g)	Top dry weight (g)	Sodium (%)	Potassium (%)	Alpha-amino (%)	Sucrose (%)
S	1	111.16	0.000	534368	85180	7983	1609.3	0.0093	1.7902	0.02611	49.5691
T	13	143.34**	27.666**	230601**	44081**	5157**	1177.0**	1.1070**	2.6996**	3.74771**	10.7631**
S x T	13	3.08	1.792	811	1289	426	42.1	0.1867	0.1774	0.01716	0.4277
Error	78	22.08	6.443	40156	8224	1028	202.9	0.1571	0.2493	0.04259	0.7378

S.O.V	D.F.	Quality (%)	Sugar loss to molasses (%)	Recoverable sugar (%)	Sugar yield (t ha^{-1})	Root yield (t ha^{-1})	Top yield (t ha^{-1})	Fe	Zn	Mn	B
S	1	77.223**	0.02201	52.9925**	133.97*	1740.38	322.56	299.9	201.08	125.76	5.806
T	13	61.079**	0.69566**	17.7092**	46.02**	915.78**	166.92**	2264.8**	619.41**	306.50**	35.829**
S x T	13	2.883	0.08685	0.6108	2.13	28.97	4.89	107.8	22.05	6.67	0.199
Error	78	2.421	0.04821	0.8948	4.14	146.70	31.16	176.3	59.70	42.46	1.785

S.O.V: Source of variation, D.F: Degree freedom, S: Seasons, T: Treatments and S×T: Interactions of seasons by treatments. *,**Refers to significance at 5 and 1 levels

Table 3: Growth traits as affected by nano-micronutrients in sugar beet (data are combined across two seasons)

Treatments	Root length (cm)	Root diameter (cm)	Root fresh weight (g)	Top fresh weight (g)	Root dry weight (g)	Top dry weight (g)
T_1	21.12	10.06	697.01	311.61	110.50	49.60
T_2	32.35	13.70	1086.12	474.23	175.22	77.91
T_3	29.58	13.07	1031.23	455.70	163.01	73.90
T_4	27.26	12.33	988.11	444.12	153.50	70.40
T_5	25.75	10.86	918.00	417.91	144.73	65.21
T_6	23.28	10.36	826.22	372.33	131.11	59.62
T_7	26.33	12.37	966.13	441.90	152.42	68.41
T_8	36.82	16.12	1336.33	612.30	211.30	96.83
T_9	33.93	15.28	1246.01	552.22	189.41	89.70
T_{10}	31.82	14.51	1182.20	508.91	179.00	82.60
T_{11}	28.99	12.40	1049.00	467.10	162.72	71.62
T_{12}	26.57	11.39	938.02	419.21	149.80	66.34
T_{13}	30.99	13.70	1165.32	509.00	182.00	81.40
T_{14}	27.06	10.88	931.21	425.61	150.71	68.60
NEW LSD 5%	4.68	2.53	199.50	90.27	31.91	14.18

T_1: Spraying with tap water, T_2: Nano-micronutrients 200 mg L^{-1}, T_3: Nano-micronutrients 160 mg L^{-1}, T_4: Nano-micronutrients 120 mg/Lm, T_5: Nano-micronutrients 80 mg L^{-1}, T_6: Nano-micronutrients 40 mg L^{-1}, T_7: Nano-micronutrients 200 mg L^{-1}, T_8: Nano-micronutrients 200 mg L^{-1} + urea 1%, T_9: Nano-micronutrients 160 mg L^{-1} + urea 1%, T_{10}: Nano-micronutrients 120 mg L^{-1} + urea 1%, T_{11}: Nano-micronutrients 80 mg L^{-1} + urea 1%, T_{12}: Nano-micronutrients 40 mg L^{-1} + urea 1%, T_{13}: Nano-micronutrients 200 mg L^{-1} + urea 1% and T_{14}: Urea 1%, NEW LSD: New least significance difference

Table 4: Mean performances of quality traits as affected by nano micronutrients in sugar beet (data are combined across two seasons)

Treatments	Sodium (%)	Potassium (%)	α-amino	Sucrose (%)	Quality (%)
T_1	2.61	5.89	0.69	15.30	78.92
T_2	1.68	4.00	0.13	19.69	88.06
T_3	1.73	4.17	0.21	19.11	87.49
T_4	2.03	4.34	0.26	17.97	86.20
T_5	2.13	4.50	0.31	17.71	85.34
T_6	2.51	4.80	0.46	17.33	83.78
T_7	2.04	4.54	0.24	17.87	86.19
T_8	1.34	4.41	1.38	18.29	87.37
T_9	1.64	4.71	1.52	17.97	85.78
T_{10}	1.95	5.19	1.61	17.53	83.84
T_{11}	2.20	5.32	1.68	16.82	82.53
T_{12}	2.33	5.43	1.73	16.50	81.49
T_{13}	2.17	5.19	1.63	17.07	83.04
T_{14}	2.53	5.64	1.78	15.97	80.69
NEW LSD 5%	0.39	0.49	0.21	0.86	1.55

T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14}: Denote difference of treatments of fertilization. Refer to Table 3 footnote, NEW LSD: New least significance difference

root length, root diameter, root fresh weight and top fresh weight traits over control. In addition, the traits were more enhanced when the nano fertilizer was combined with conventional ones, even at a lower application rate (Table 3). This behavior suggests that the nano fertilizer can either provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth. Some previous related studies revealed similar findings[11,13]. The increase in root dimensions and weight are attributed to the numbers of increasing cells due to the increasing concentration of the micronutrients especially iron, boron, zinc and manganese. These results are in agreement with those of Gobarah *et al.*[25].

Quality traits: The results in Table 4 illustrated that the effect of nano micronutrients and/or urea applications were significant on potassium (%), sodium (%) and alfa-amino nitrogen (%), where treatments T_2 and T_3 possessed the lowest values of impurity followed by the two treatments, T_8 and T_9, for potassium (%), sodium (%) and α-amino nitrogen percentage traits in the combined analysis as compared to control (T_1). The obtained values were 1.68 and1.73 for K, % 4.00 and 4.17 for Na (%) and 0.13 and 0.21 for N (%) for T_2 and T_3 treatments, 19.69 and 19.11 (%) for sucrose % and 88.06 and 87.49% quality (%) for T_2 and T_3 treatments. Meanwhile, the values obtained were 18.29 and 17.96 (%) and 87.37 and 85.78 (%) for T_8 and T_9 for the same trait in the combined data across two seasons, respectively. Nano-micronutrient concentrations and their interaction effect had significant effects on K, Na and amino- N contents. The highest amount of these compounds occurred in the control treatment. However, by applying the micronutrients spray, they were reduced and thus the content of molasses forming substances. These results are consistent with the results of another study that showed in the control treatment and twice spray of the micronutrients that the amount of K was reduced from 6.38 to 6.05 (%); the amount of Na was reduced from 2.14 to 1.86% and the amount of N was reduced 4.65 to 3.91%[25].

In this concern, it was revealed that spraying the mixture of micronutrients twice recorded the highest value in sugar yields[3]. The high content of sodium, potassium and nitrogen prevents sucrose crystallization and reduces the white sugar extraction[5]. Marsi and Hamza[26] exhibited that increasing the micronutrient mixture significantly increased quality traits, purity percentage, total soluble solids and sucrose percentage.

Yield and its contribution: The results in Table 5 demonstrated that treating sugar beet plants with nano micronutrients (T_8 and T_9) exerted higher values than other treatments of sugar loss to molasses%, recoverable sugar percentage, sugar yield, root yield and top yield traits in the two seasons compared to control (T_1). The highest value of recoverable sugar percentage was (16.21) and was associated with the highest values for sugar yield (15.18 t ha^{-1}), root yield (84.28 t ha^{-1}) and top yield (37.68 t ha^{-1}). The lowest values of sugar loss to molasses% (1.54)resulted from the plants treated with T_8 (nano-microelements 200 mg L^{-1}+urea 1%) as compared to control (T_1) and T_{14} (urea 1%), followed by the treatment of nano-microelements 160 mg L^{-1}+urea 1% (T_9), as compared to control (T_1) and T_{14} (urea 1%).

The remainder treatments showed comparable values for the previous traits. The rest of treatments recorded beneficial effect and comparable values for aforementioned traits agreed with Gobarah *et al.*[25] who investigated the foliar application of micronutrients on sugar beet; the results concluded that treatment by a combination of (Fe+Zn+Mn+B) produced the maximum sucrose (%), purity (%), recoverable sugar (%) and white sugar yield. Amin *et al.*[3] revealed that spraying the

Table 5. Mean performances of yield and its components as affected by nano micronutrients in sugar beet (data are combined across the two seasons)

Treatments	Sugar loss to molasses (%)	Recoverable sugar (%)	Sugar yield (t ha^{-1})	Root yield (t ha^{-1})	Top yield (t ha^{-1})
T_1	2.53	12.29	06.42	41.78	19.17
T_2	1.65	17.37	13.74	70.46	29.18
T_3	1.73	16.99	12.16	63.64	28.03
T_4	1.84	15.74	11.13	61.80	27.33
T_5	1.93	15.39	10.19	57.55	25.72
T_6	2.19	14.72	08.87	51.36	22.92
T_7	1.86	15.63	11.09	62.04	27.19
T_8	1.55	16.21	15.18	84.28	37.68
T_9	1.72	15.37	14.47	74.72	33.98
T_{10}	1.99	14.97	12.43	70.80	31.32
T_{11}	2.10	14.06	10.61	62.90	28.75
T_{12}	2.30	13.59	09.31	56.20	25.80
T_{13}	2.06	14.37	12.17	71.08	31.32
T_{14}	2.43	12.93	08.90	55.80	26.18
NEW LSD 5%	0.22	0.94	2.02	12.06	5.57

T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14}: Denote difference of treatments of fertilization, Refer to Table 3 footnote, NEW LSD: New least significance difference

Table 6: Micronutrients traits as affected by nano micronutrients and bulk of nitrogen in sugar beet (data are combined across the two seasons)

Treatments	Iron (Fe) mg kg^{-1}	Zinc (Zn) mg kg^{-1}	Manganese (Mn) mg kg^{-1}	Boron (B) mg kg^{-1}
T_1	115.20	23.72	15.97	0.61
T_2	169.51	52.46	34.16	7.70
T_3	155.72	39.81	33.30	7.25
T_4	139.70	39.26	29.34	6.47
T_5	136.30	33.86	26.39	5.76
T_6	130.73	31.20	23.72	5.24
T_7	144.82	38.86	35.05	6.66
T_8	178.80	56.00	38.91	8.38
T_9	162.41	49.50	36.61	7.90
T_{10}	156.60	45.92	33.40	7.61
T_{11}	150.11	38.75	28.05	6.59
T_{12}	138.92	35.47	24.36	6.16
T_{13}	158.40	43.57	33.34	7.58
T_{14}	136.00	32.71	26.34	2.95
NEW LSD 5%	13.22	7.69	6.48	1.33

T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14}: Denote difference of treatments of fertilization, Refer to Table 3 Footnote, NEW LSD: New least significance difference

mixture of micronutrients twice recorded the highest values in sugar yields. In addition, Rassam *et al*.[5] found that the highest root and sugar yields were obtained with spraying 2 L ha^{-1} of the micronutrients. The effect of micronutrients on the performance of the sugar beet root yield was confirmed by many studies [27-28].

These pronounced increments may be due to the fact that the nano fertilizer may have a synergistic effect on the conventional fertilizer for better nutrient absorption by plant cells resulting to optimal growth. Furthermore, the ability of a sink to mobilize photosynthetic toward itself is often known as sink strength, which depends on two factors namely: sink size and sink activity. Sink size is the total biomass of the sink tissue while sink activity is the rate of photosynthates uptake per unit biomass of sink tissue[29].

Content of micronutrients (Fe, Zn, Mn and B): Conspicuously, the results presented in Table 6 demonstrated that treating sugar beet plants with nano micronutrients (T_8 and T_9) exerted higher values than the other treatments for iron (Fe), zinc (Zn), manganese (Mn) and boron (B) traits in the two seasons compared to control (T_1). The highest value of micronutrient elements were: Fe (178.8 mg kg^{-1}), Zn (56.0 mg kg^{-1}) , Mn (38.91 mg kg^{-1}) and B (8.38 mg kg^{-1}) for the plants treated with T_8 (nano-micronutrients 200 mg L^{-1} + urea 1%) as compared to control (T_1) and T_{14} (urea 1%) followed by the treatment of nano- micronutrients, 160 mg L^{-1} + urea 1% (T_9), as compared to control (T_1) and T_{14} (urea 1%).

The other treatments showed comparable values for the previous traits. Previous studies focused on the characteristics of NPs and revealed that NPs can enter plant cells and transport DNA and chemicals inside the cell[30-32]. DeRosa *et al*.[33] reported that in nano fertilizers, nutrients can be encapsulated by NMs, coated with a thin protective film or delivered as emulsions or NPs. Nano and sub Nanocomposites control the release of nutrients from the fertilizer capsule[34]. Kurepa *et al*.[35] added that nanoparticles can also be transported into the plant by forming complexes with membrane transporters or root exudates. Lin and Xing[36] examined the cell internalization and upward translocation of ZnO nanoparticles in *Lolium perenne* (ryegrass). They showed that these nanoparticles could enter the ryegrass root cells and move up to the vascular tissues. As mentioned earlier, the nano fertilizer may have influenced these processes through its efficient nutrient transportation capability in terms of penetration and movement of a wide range of nutrients, from roots uptake to foliage penetration and movements within the plant. Many studies have proved the significance of nano fertilizers.

The application of nanotechnology in agriculture is still in its budding stage. However, it has the potential to revolutionize agricultural systems, particularly where the issues on fertilizer applications are concerned. This study demonstrated that the Nano fertilizer application promoted the growth, development and antioxidant activity in sugar beet plants and has the potential to improve crop production and plant nutrition. Moreover, Nano-fertilizers have a great impact on the soil, can reduce the toxicity of the soil and decrease the frequency of fertilizer application. This study recommended that further researches on different crops using nano fertilizers.

CONCLUSION

The findings of the current study exhibited that the best results were: sugar beet plants treated with nano-microelements 200 mg L^{-1}+urea 1% could be ranked as the first favorable treatment, this treatment significantly produced the highest yields with improved quality traits of sugar beet and results in saving the plants' needs from micronutrient and nitrogen fertilizer.

SIGNIFICANCE STATEMENT

This study discovered that the application of nano-microelements 200 mg L^{-1}+urea 1% treatment for significantly produced higher yields associated with improving the quality traits of sugar beet. This study will help the researcher to uncover beneficial role involving the application of nanotechnology in the field of agriculture. In the future, this study needs to complete economically the cost of adding fertilizer to nanotechnology, whether it is suitable for farmers or not.

ACKNOWLEDGMENT

Authors express appreciation to all staff. We also thank farmers for helping us in cultivation.

REFERENCES

1. Welch, R.M., W.H. Allaway, W.A. House and J. Kudata, 1991. Geographic Distribution of Trace Element Problems. In: Micronutrient in Agriculture, Mortvet, J.J., F.R. Cox, L.M. Shuman and R.M Welch (Eds.). SSSA, Madison, WI., USA., pp: 31-57.
2. Mamyandi, M.M., A. Pirzad and M.R. Zardoshti, 2012. Effect of nano-iron spraying at varying growth stage of sugar beet (*Beta vulgaris* L.) on the size of different plant. Int. J. Agric. Crop Sci., 4-12: 740-745.
3. Amin G. A., E.A. Badr, and M.H.M. Afifi, 2013. Root yield and quality of sugar beet (*Beta vulgaris* L.) in response to biofertilizer and foliar application with micronutrients. World Appl. Sci. J., 27: 1385-1389.
4. Barłóg, P., A. Nowacka and R. Błaszyk, 2016. Effect of zinc band application on sugar beet yield, quality and nutrient uptake. Plant Soil Environ., 62: 30-35.
5. Rassam, G., M. Dashti, A. Dadkhah and A.K. Yazdi, 2015. Root yield and quality of sugar beet in relation to foliar application of micronutrients. Ann. West Univ. Timisoara: Series Biol., 18: 87-94.
6. Asadzade, N., S.G. Moosavi and M.J. Seghatoleslami, 2015. Effect of low irrigation and Zn and SiO_2 nano-fertilizers and conventional fertilizers on morph physiological traits and seed yield of sunflower. Biol. Forum–An Int. J., 7: 357-364.
7. Najafivafa, Z., N. Falahi, M. Zare, S.N. Bohloli and A.R. Sirousmehr, 2015. The effects of different levels of using zinc nano chelated fertilizers and humic acid on growth parameters and on some quality and quantity characteristics of medicinal plants of savory. Bull. Environ. Pharmacol. Life Sci., 4: 56-67.
8. Mekdad. A.A.A. and M.M. Rady, 2016. Response of *Beta vulgaris* L. to nitrogen and micronutrients in dry environment. Plant Soil Environ., 62: 23-29.
9. Biswas, P. and C.Y. Wu, 2005. Nanoparticles and the environment. J. Air Waste Manage. Assoc., 55: 708-746.
10. Reynolds, G.H., 2002. Forward to the future nanotechnology and regulatory policy. Pac. Res. Inst., 24: 1-23.
11. Naderi, M.R. and A. Abedi, 2012. Application of nanotechnology in agriculture and refinement of environmental pollutants. J. Nanotechnol., 11: 18-26.
12. Naderi, M.R. and A. Danesh-Shahraki, 2013. Nanofertilizers and their roles in sustainable agriculture. Int. J. Agric. Crop Sci., 5: 2229-2232.
13. Liu, R. and R. Lal, 2015. Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Sci. Total Environ., 514: 131-139.
14. Aktas, H., K. Abak, L. Ozturk and T. Cakmak, 2006. The effect of zinc on growth and shoot concentrations of sodium and potassium in pepper plants under salinity stress. Turk. J. Agric. For., 30: 407-412.

15. Khedr, M.H. and A.A. Farghali, 2005. Physicochemical properties of nanocrystallite copper ferrite prepared by a novel self flash combustion of acetate precursors. J. Mater. Sci. Technol.,
16. Bremner, J.M., 1996. Nitrogen-Total. In: Methods of Soils Analysis, Part 3: Chemical Methods, Sparks, D.L. (Ed.). Soil Science Society of America, Madison, WI., USA., pp: 1085-1121.
17. Gee, G.W. and Dani Or, 2013. Particle-size analysis. In: Methods of Soil Analysis, Part 4: Physical Methods, Dane, J. and G.C. Topp, Soil Science Society of America, USA, pp: 255-293 .
18. Walkley, A. and I.A. Black, 1934. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.
19. Le Docte, A., 1927. Commercial determination of sugar in sugar beet using socks. Inst. Sug. J., 29: 488-492.
20. A.O.A.C., 1990. Official methods of analysis. 15th ed. Association of Official Analytical Chemists, Washington, USA.
21. Cooke, D.A. and J.E. Scott, 1974. The Sugar Beet Crop. 1st Edn., Springer, Netherlands, Pages: 704.
22. Snedecor, G.W. and W.G. Cochran, 1982. Statistical Methods. 7th Edn., Iowa State University Press, Ames, Iowa, USA.
23. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons Inc., New York, USA., pp: 13-175.
24. Solanki, P., A. Bhargava, H. Chhipa, N. Jain and J. Panwar, 2015. Nano-fertilizers and Their Smart Delivery System. In: Nanotechnologies in Food and Agriculture. Rai, M. *et al*., (Eds.). Springer International Publishing, Switzerland, pp: 81-101.
25. Gobarah, M.E., M.M. Tawfik, S.M. Zaghloul and G.A. Amin, 2014. Effect of combined application of different micronutrients on productivity and quality of sugar beet plants (*Beta vulgaris* L.). Int. J. Plant Soil Sci., 3: 589-598.
26. Masri, M.I. and M. Hamza, 2015. Influence of foliar application with micronutrients on productivity of three sugar beet cultivars under drip irrigation in sandy soils. World J. Agric. Sci., 11: 55-61.
27. Hellal, F.A., A.S. Taalab and A.M. Safaa, 2009. Influence of nitrogen and boron nutrition on nutrient balance and sugar Bz\Eet yield grown in calcareous soil. Ozean J. Appl. Sci.,
28. Ghareib, H.S. and A.S. El-Henawy, 2011. Response of sugar beet (*Beta vulgaris*, L) to irrigation regime, nitrogen rate and micronutrients application. Alexandria Sci. Exch., 32: 140-156.
29. Taiz, L. and E. Zeiger, 2006. Plant Physiology. 4th Edn., Sinauer Associates Inc., New York, USA.
30. Ambrogio, M.W., M. Frasconi, M.D. Yilmaz and X. Chen, 2013. New methods for improved characterization of silica nanoparticle-based drug delivery systems. Langmuir, 29: 15386-15393.
31. Ghafariyan, M.H., M.J. Malakouti, M.R. Dadpour, P. Stroeve and M. Mahmoud, 2013. Effects of magnetite nanoparticles on soybean chlorophyll. Environ. Sci. Technol., 47: 10645-10652.
32. Torney, F., B.G. Trewyn, V.S.Y. Lin and K. Wang, 2007. Mesoporous silica nanoparticles deliver DNA and chemicals into plants. Nature Nanotech., 2: 295-300.
33. DeRosa, M.C., C. Monreal, M. Schnitzer, R. Walsh and Y. Sultan, 2010. Nanotechnology in fertilizers. Nat. Nanotechnol., Vol. 5. 10.1038/nnano.2010.2
34. Liu, X.M., Z.B. Feng, F.D. Zhang, S.Q. Zhang and X.S. He, 2006. Preparation and testing of cementing and coating nano-subnanocomposites of slow/controlled-release fertilizer. Agric. Sci. Chin., 5: 700-706.
35. Kurepa, J., T. Paunesku, S. Vogt, H. Arora and B.M. Rabatic *et al*., 2010. Uptake and distribution of ultrasmall anatase Tio_2 alizarin red S nanoconjugates in *Arabidopsis thaliana*. Nano Lett., 10: 2296-2302.
36. Lin, D. and B. Xing, 2007. Phytotoxicity of nanoparticles: Inhibition of seed germination and root growth. Environ. Pollut., 150: 243-250.