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Impact of bulk and nanoparticles zinc oxide foliar application on sugar beet yield and quality under different irrigation fertilization levels

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Abstract

Afield experiment was conducted at Abou El Ghar village, Kafr El Zayyat district, Gharbiya Governorate, Egypt during 2016- 2017 and 2017-2018 seasons. The aim of this study to evaluate the influence of bulk and nanoparticles zinc oxide on growth and some biochemical characteristics of sugar beet *(Beta vulgaris L.)*. The experiment was laid aut using strip-plot design with three replications . zinc oxide concentrations(control, 100, 200, 300 ppm) were arranged horizontally while nitrogen fertilizer (60, 80 and 100 Kg N/fed). Was allocated vertically .

The main results could be summarized as follows:-

1. foliar spray of nanoparticles zinc oxide had a significant effect on root fresh weight/plant, root yield, gross sugar yield, sucrose %, and recoverable sugar % in both seasons. As well as, had a significant effect on root/top ratio, in the second season only and had a significant effect on recoverable sugar yield in the first season only.
2. The best concentration of nanoparticles zinc oxide for sugar beet was 300 ppm with the highest root and sugar yields.
3. Increasing nitrogen rates from 60 to 100 kg N/fed. significantly increased the most studied characters under study such as, root fresh weight/plant, top fresh weight/plant in the second season also, sugar beet yields (root and top) as well as sugar losses in molasses. On the other direction, quality parameters such as sucrose %, purity, quality index significantly decreased by increasing nitrogen levels as nitrogen level increased. Moreover, root/ top ratio and harvest index decreased as nitrogen level increased.
4. It could be concluded that nitrogen fertilizer level at 100 Kg N/fed. and foliar sprayed zinc oxide nanoparticles at a concentration of 300 ppm is a recommended treatment for maximizing sugar beet yield. Otherwise, fertilization sugar beet plants

by 60 kg N/fed. with 200 ppm produced the highest mean values of studied quality traits.

Keywords: Sugar beet, Foliar application, Nitrogen fertilization, Zinc nanoparticles

Introduction

Zinc is a micronutrient that is essential for a number of different aspects of plant physiology and biochemistry. In sugar beet Zinc concentration in healthy leaves is about 20 mg Zn/ kg and in roots 10 mg Zn/ kg. ***Draycott (1972).*** According to the European Committee for Standardization, nanomaterials are defined as the materials with any external dimension at the nanoscale, or that possess nanoscale internal or surface structures. Nanoscale describes the size range from approximately 1–100 nm (usually <100 nm, though sometimes <50 nm). ***Lövestam et al. (2010)*** nanomaterials could to be applied in designing more soluble and diffusible sources of zinc fertilizer for increasing plant productivity. The smaller size, higher specific surface area and reactivity of Nano particulate zinc oxide compared to bulk zinc oxide may affect zinc solubility, diffusion and hence availability to plants. So decreased particle size increases the specific surface area of a fertilizer, which should increase the dissolution rate of fertilizers with low solubility in water such as zinc oxide ***Mortvedt (1992).***

Sugar beet crop is considered to be the second source for sugar production in Egypt. Commercial farming of sugar beet has been introduced in Egypt since the 1981/82 season, it is still new to Egyptian agriculture (***Abo-Elwafa et al. 2006; Abou-Elwafa 2010; Abo-Elwafa et al. 2013***). Also it is the second important sugar crop after sugarcane, the total Egypt production of sugar beet was 8.83 million tons from an area of 479.7 feddan it produced about 57.7 % of sugar in 2018 season compared with 2.5 % in 1982 ***(sugar crops council, Egypt, 2018)*** season and total world production of sugar beet is 301.02 million tons from an area of 4.9 million hectare ***(FAO, 2017).***

Nitrogen fertilization is the main determinant of sugar beet productivity. It is found in plant parts at different concentrations according to plant age and nitrogen available in the soil. ***Christenson et al. (1993)*** decidedly the amount and method of nitrogen application required to produce the maximum root and sugar yields**.** ***Marlander et al. (2003)*** reported that sugar beet crop needs about 200–250 kg N/ ha) in order to maximize sugar yield. Leaf color changes from pale green or yellow to dark green also increasing nitrogen fertilizer levels led to significantly improved all growth characters such as root, foliage fresh and weights ***(Kandil et al. 2004)***. Whereas, in the literature there is little evidence on the effect of zinc oxide on crop plants, The objective of this study, therefore, is to evaluate the response of sugar beet plant to bulk and nanoparticles zinc oxide and different levels of nitrogen fertilization.

Materials and Methods

Experiment and treatments:

A field experiment was carried out during the two successive seasons of 2016/2017 and 2017/2018 at Abou El Ghar village, Kafr El Zayyat district, Gharbiya Governorate, Egypt to study the influence of bulk and nanoparticles zinc oxide foliar application on sugar beet yield and quality under different levels of nitrogen fertilization.

The nitrogen and zinc oxide (bulk and nanoparticles) treatments studied were as follows:

Nitrogen fertilizer levels (Main plots):

Three nitrogen fertilizer levels used were 60, 80 and 100 kg N/fed.

Nitrogen was applied in the form of ammonium nitrate (33.3% N) which added at two equal doses the first dose after hoeing before the second irrigation and the second dose after one month later.

Bulk and nanoparticles zinc oxide (preparations):

Commercially obtained micro-sized pure ZnO powder 99.5% purity was used as the starting material. The powder was milled in a FRITSCH PULVERISETTE 2 ball mill for 1 hour. Grain size decreased with increased milling time. The crystalline phases were studied using a high-resolution X-ray diffract meter (PW 1700 X-ray diffract meter, with Cu_{α} K radiation (λ= 1.5406A°). the crystal structure of all samples were characterized by powder X-ray diffraction (XRD) using (PW 1700 X-ray diffract meter) where the patterns were recorded in the diffraction angle (20) range from 20° to 80° with step 0.06°/min. Fig. (1) represents X-ray diffraction pattern of the as purchased powder. The line broadening of the XRD peaks indicates that the prepared material consist of particles in the non-size range. By using the XRD pattern, we determined peak positions and the corresponding full-width at half-maximum (FWHM) for all diffraction peaks which are indexed as hexagonal wurtzite phase of ZnO (28, 29, 30).

Synthesized XnO nanoparticles size was calculated from Debye-Scherrerion equation (1-5):

$D = 0.89\ \lambda / \beta \cos \theta$ ….. (1) (k= 0.89 is Scherrer's constant, λ is the wavelength of X-rays, θ is the Bragg diffraction angle, and β is the full width at half-maximum (FWHM) of the diffraction peak. The average particle size of the starting material was found to be 34.8 nm (Fig. 1) meanwhile the ball mill treated sample was found to be 28.7 nm (Fig. 2). ***(Hauawa et al., 2015 and Othman et al., 2017).***

Spraying sugar beet plants by three nanoparticles zinc oxide concentrations i.e. 100, 200 and 300 ppm and sprayed plants by one concentration from bulk zinc oxide 300 ppm as well as sprayed plants with distilled water (control).

Plants sprayed thrice with zinc oxide (bulk and nanoparticles) at 60, 75 and 90 days from sowing.

The experiment were conducted on the basis of strip plot layout with randomized complete block design (RCBD) with four replications. Nitrogen fertilizer rates were assigned to main plot and different doses of zinc oxide (control, 100, 200, 300 ppm zinc oxide nanoparticle and bulk zinc oxide) were allocated sub-plots.

Zinc oxide nanoparticles were sprayed on plants using a backpack sprayer (capacity 20 L). In order to prepare zinc oxide nanoparticles concentration 100 ppm, 2 g zinc oxide was dissolved into water and then the solution was filled up to 20 L (concentration ppm = weight mg / volume L). Thus different concentrations of zinc oxide (100, 200 and 300 ppm) were prepared (2, 4 and 6 g/ 20 L water, respectively).

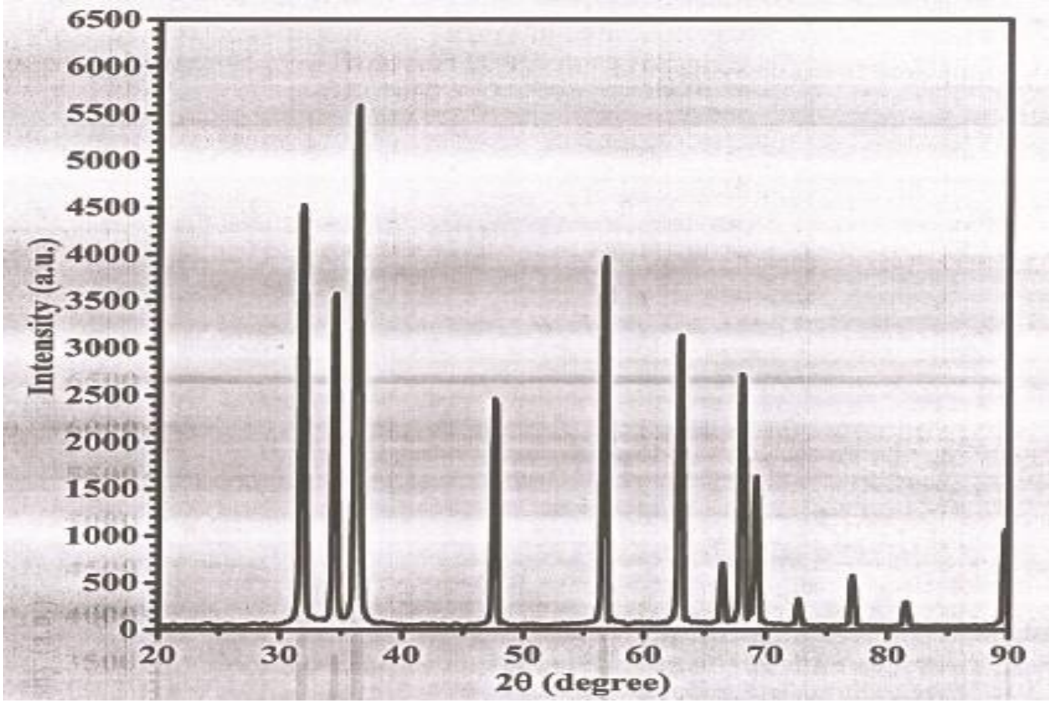

Fig. 1 : X-ray diffraction of as purchased ZnO powder. Average particle size <D> = 34.8 nm.

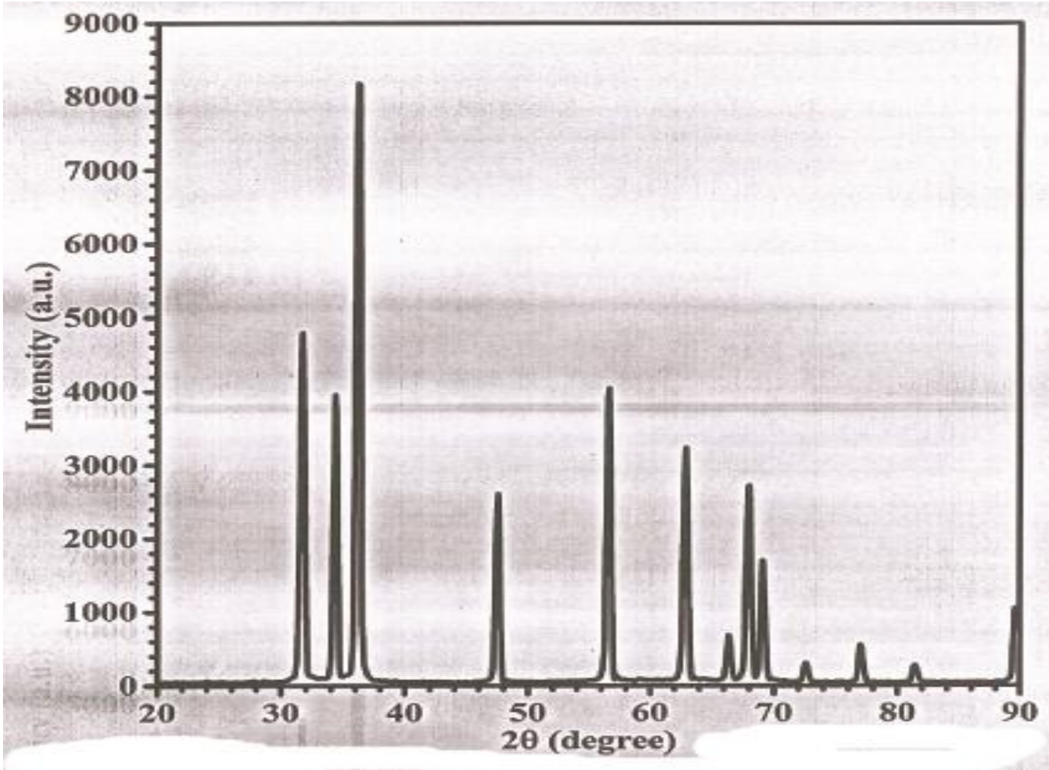

Fig. 2 : X-ray diffraction of ball milled treated ZnO powder. <D> = 28.7 nm average.

Soil samples were randomly taken from the experimental sites at depth of 0 to 30 cm from soil surface and were prepared for physical and chemical properties before sowing and the description was given in Table 1.

Table 1: Some Physical and chemical properties of soil in 2016/2017and 2017/2018 seasons.

Properties Seasons	Sand %	Silt %	Clay %	Texture	(pH)	Ec (ds/m)	Available (mg/kg)		
							N	P	K
2016/2017	22.20	39.30	38.50	Clay loan	9.95	1.33	167.0	0.34	292.0
2017/2018	22.00	40.10	37.90	Clay loan	7.75	1.30	171.1	0.35	3.3.0

Sowing took place at 11th and 5th November in the first and second seasons, respectively. Other agricultural practices for growing sugar beet according to the recommendations of Ministry of Agriculture were followed, except the factors under study.

The studied traits.

Harvesting dates were carried out after 180 days from sowing, a sample of ten plants were taken at random from the inner ridges of each experimental unit to estimate yield components traits as follows:

1- Root fresh weight (g/plant)

2- Top fresh weight (g/ plant)

3- Root / top ratio

At harvest all plants of the experimental unit were collected and cleaned. Thereafter, roots and tops were separated and weighted in Kilograms and converted to metric tons per fed. to estimate as follows :-

4- Root yield (ton/fed.)

5- Top yield (ton/fed.)

All parameters were determined in Dakahlia sugar company Laboratories at Belkas, Dakahlia Governorate

6- Gross sugar yield (ton/fed.). It was calculated by multiplying root yield by root sucrose percentage.

GSY= root yield x sucrose %

7- Recoverable sugar yield (ton/fed.) (**R.S.Y**) was calculated using the following equation:

RSY= root yield x sugar recovery percentage %.

8- Juice purity percentage was calculated according to the following formulas:

Purity % = 99.36 – [14.27 (Na% + K% + α–amino N %) / sucrose %] according to ***Deviller (1988).***

Statistical analysis and interpretation of data

The data obtained were statistically analyzed according to the method of analysis variance (ANOVA) using SPSS (statistical package for the social science version 19). Differences among treatment means were compared using the least significant differences test (LSD) at 5 % level probability level ***(Gomez and Gomez 1984).***

Results and Discussion

1- Yield attributes traits:-

Data illustrated in Table 2 revealed that nitrogen fertilizer levels exerted a significant effect on root fresh weight (g/plant)and had a highly significant effect on top fresh weight (g/plant) and root/top ratio in the second season only. So, it can be notice a gradual increase in means root fresh weight per plant1333 to 1400 g/plant in second season. with increasing nitrogen fertilizer levels from 60 to 100 kg/fed. The highest mean value of top fresh weight (823 g/plant) (g/plant) was recorded from 100 kg N/fed. in the second season. Nitrogen fertilization at level of 60 kg /fed. produced the highest mean value of root/top ratio (1.86) in the second season. But the differences between the studied nitrogen fertilizer levels with respect to their effect on root fresh weight, top fresh weight and root/top ratio didn't reach the significant level at 5% probability level in the first season. These findings are in agreement with those obtained by ***Abdelaal and Tawfik (2015), Ismail et al. (2016), Kandil et al. (2016) and Nemeat Alla (2016).***

Moreover, foliar spray by bulk and nanoparticles zinc oxide had a significant and highly significant effect on root fresh weight per plant in the first and second seasons, respectively. Thus, the maximum mean values root fresh weight per plant (1235 and 1451 g/plant) were recorded when sugar beet plants sprayed by 300 ppm zinc oxide nanoparticles concentration compared to control (1143 and 1240 g/plant in the first and second seasons respectively). Root/top ratio was significantly affected by bulk and nanoparticles zinc oxide foliar application in the second season only. Furthermore, increasing nanoparticles zinc oxide concentration lead to gradually increased root/top ratio in the second season. But it had insignificant effect on top fresh weight in both seasons.

The interaction had a significant and highly significant effect on root and top fresh weight in the first and second seasons, respectively .In addition, it had a highly significant on root/top ratio in the second season only. The highest mean values of root fresh weight (1342 and 1655 g/plant in the two respective seasons) were achieved from sugar beet plants which sprayed by 300 ppm zinc oxide nanoparticles under 60 Kg N/fed. in the first season and under 100 Kg N/fed. in the second season one. The highest mean values of top fresh weight (996 and 957 g/plant) were obtained from sugar beet plants sprayed by 200 and 300 ppm zinc oxide nanoparticles under 60 and 100 kg N/fed. in the first and second seasons, respectively. In the second season the highest mean value of root/top ratio (2.07) was recorded from 60 kg N/fed. with 300 ppm bulk zinc oxide concentration and the lowest mean value (1.59) was obtained from 80 kg N/fed. with 200 ppm zinc oxide nanoparticles concentration.

2- Root, top and sugar yields traits:-

Data exhibited in Table 3 show that nitrogen fertilizer levels exerted a significant influence on root yield in the second season only and highly significant influence on both top yield and purity in the same season. The maximum mean values of root yield (44.83 ton/fed.), top yield (26.35 ton/fed.) were recorded from sugar beet plants which were fertilized by 100 kg N/fed.in the second seasons. The highest mean value of purity % (88.86) for sugar beet plants which were received 60 kg N/fed. Similar results were reported by many investigators in other sugar beet production areas ***Shaban et al. (2014), Masri and Safina (2015), Bader (2016), Kandil et al. (2016) and Mekdad and Rady (2016).***

Bulk and nanoparticles zinc oxide had a significant and highly significant effect on root yield in the first and second seasons, respectively. In addition, it had a highly significant effect on gross sugar yield in both seasons and recoverable sugar yield in the first season only. The heaviest mean values of root yield (39.52 and 46.45 ton/fed.) and gross sugar yield (6.16 and 7.16 ton/fed.) were produced from the highest. concentration of nanoparticles zinc oxide (300 ppm) in both seasons. Also, the same concentration gave the highest mean value of recoverable sugar yield (4.88 ton/fed.) Furthermore, bulk and nanoparticles zinc oxide foliar application had insignificant effect on top yield and purity in both seasons and recoverable sugar yield in the second season only.

Table 2: Root fresh weight (g/plant), top fresh weight (g/plant) and root/top ratio of sugar beet as affected by nitrogen levels, bulk and nanoparticles zinc oxide foliar spray as well as their interaction in 2016/2017 and 2017/2018 seasons.

A Nitrogen levels	B ZnO ppm	Root fresh weight		Top fresh weight		Root/Top ratio	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
60 kg/fed.	control	1083	1151	775	691	1.46	1.69
	100	1237	1377	926	782	1.32	1.76
	200	1277	1368	996	711	1.28	1.93
	300	1342	1383	887	751	1.53	1.85
	Bulk	1042	1388	753	673	1.38	2.07
Mean		**1196**	**1333**	**867**	**772**	**1.40**	**1.86**
80 kg/fed.	Control	1093	1255	798	763	1.39	1.66
	100	996	1401	713	776	1.37	1.81
	200	1238	1255	848	786	1.46	1.59
	300	1198	1316	857	720	1.40	1.83
	Bulk	1062	1523	843	795	1.27	1.92
Mean		**1118**	**1350**	**812**	**768**	**1.38**	**1.76**
100 kg/fed.	Control	1252	1315	946	765	1.27	1.73
	100	1096	1341	810	815	1.35	1.65
	200	1095	1403	803	773	1.37	1.82
	300	1163	1655	798	957	1.47	1.73
	bulk	1136	1288	853	806	1.33	1.60
Mean		**1148**	**1400**	**842**	**823**	**1.36**	**1.71**
Means Of ZnO	Control	1143	1240	840	739	1.37	1.69
	100	1100	1373	816	791	1.35	1.74
	200	1203	1342	882	757	1.37	1.78
	300	1235	1451	847	809	1.46	1.80
	bulk	1080	1400	817	758	1.33	1.86
F-test at 5%							
A		NS	*	NS	**	NS	**
B		*	**	NS	NS	NS	*
A * B		*	**	*	**	NS	**

NS, * and ** means non-significant, significant at 5 and 1 % level of probability, respectively.

Table 3: Root yield (ton/fed.), top yield (ton/fed.), gross sugar yield, purity % and recoverable sugar yield of sugar beet as affected by nitrogen levels, bulk and nanoparticles zinc oxide foliar spray as well as their interactions in 2016/2017 and 2017/2018 seasons.

A Nitrogen levels	B ZnO ppm	Root yield		Top yield		Gross sugar yield		Purity %		Recoverable sugar yield	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2016/2017	2016/2017	2016/2017	2016/2017	2016/2017
60 kg/fed.	control	34.68	36.84	24.80	22.12	5.25	6.00	89.09	87.20	4.11	4.63
	100	39.60	44.08	29.64	25.04	5.97	6.94	88.88	88.92	4.65	5.32
	200	40.88	43.80	31.88	22.76	5.97	7.29	89.29	89.04	4.70	5.74
	300	42.96	44.28	28.40	24.04	6.64	7.00	89.38	89.74	5.24	5.44
	Bulk	33.36	44.42	24.12	21.55	5.11	7.00	89.64	89.42	4.07	5.44
	Mean	38.30	42.69	27.77	23.10	5.89	6.85	89.26	88.86	4.55	5.31
80 kg/fed.	Control	35.00	40.16	25.56	24.42	5.36	6.24	89.38	89.22	4.24	4.84
	100	31.88	44.86	22.84	24.85	4.89	7.00	88.58	87.28	3.83	5.30
	200	39.64	40.16	27.16	25.18	5.97	6.33	89.41	88.94	4.69	4.90
	300	38.36	42.12	27.44	23.04	6.10	6.69	90.01	87.51	4.91	5.15
	Bulk	34.00	48.74	27.00	25.44	5.31	7.37	89.75	88.77	4.22	5.59
	Mean	35.78	43.21	26.00	24.58	5.52	6.73	89.43	88.34	4.38	5.15
100 kg/fed.	Control	40.08	42.08	30.28	24.48	5.99	6.55	88.45	88.36	4.61	5.00
	100	35.08	42.94	25.92	26.08	5.30	6.31	89.67	87.79	4.21	4.72
	200	35.04	44.92	25.72	24.76	5.28	7.06	89.23	87.68	4.16	5.36
	300	37.24	52.96	25.56	30.62	5.73	7.78	89.39	84.11	4.50	5.44
	bulk	36.36	41.24	27.32	25.80	5.32	6.06	88.56	85.11	4.09	4.25
	Mean	36.76	44.83	26.96	26.35	5.52	6.75	89.06	86.61	4.31	4.95
Means of ZnO	Control	36.59	39.69	26.88	23.68	5.53	6.27	88.97	88.26	4.32	4.82
	100	35.52	43.96	26.13	25.32	5.39	6.75	89.04	87.99	4.23	5.11
	200	38.52	42.96	28.25	24.23	5.74	6.89	89.31	88.55	4.52	5.33
	300	39.52	46.45	27.13	25.90	6.16	7.16	89.59	87.12	4.88	5.32
	bulk	34.57	44.80	26.15	24.26	5.25	6.81	89.32	87.77	4.13	5.09
F- test at 5%											
A		NS	*	NS	**	NS	NS	NS	**	NS	NS
B		*	**	NS	NS	**	**	NS	NS	**	NS
A * B		*	**	*	**	NS	**	NS	*	NS	**

NS, * , * and ** means non-significant, significant at 5 and 1 % level of probability, respectively.

The interaction had significant and highly significant effects. in the first and second seasons, respectively on both root and top yields. In addition, it had a highly significant effect on gross sugar yield and recoverable sugar yield in the second season only. Furthermore, the interaction had a significant effect on purity in the second season. Thus, the heaviest mean values of root yield (42.96 and 52.96 ton/fed.) were produced from 300 ppm zinc oxide nanoparticles concentration with 60 and 100 kg N/fed. in the first and second seasons, respectively. Moreover The maximum mean values of top yield (31.88 and 30.62 ton/fed.) were obtained from sugar beet plants which were sprayed by 200 and 300 ppm zinc oxide nanoparticles under 60 and 100 kg N/fed. in the first and second seasons, respectively. Also the highest mean value of gross sugar yield (7.78 ton/fed.) and purity % (89.74 %) were recorded from sugar beet plants which were sprayed by nanoparticles zinc oxide at the concentration of 300 ppm under100 and 60kg N/fed. in the second season respectively. While, the highest mean value of recoverable sugar yield (5.59 ton/fed.) in the second season was obtained from sugar beet plants which were sprayed by bulk zinc oxide at the concentration of 300 ppm and fertilized with 80 kg N/fed.

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الملخص العربي

تأثير استخدام التسميد الورقي بأكسيد الزنك النانومتري وأكسيد الزنك العادي علي المحصول والجودة في بنجر السكر تحت مستويات مختلفة من التسميد الأزوتي

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[3]مجلس المحاصيل السكرية
[4] شركة الدقهلية للسكر

أجريت تجربة حقلية في قرية أبو الغر، مركز كفر الزيات، محافظة الغربية، مصر خلال موسمي 2017/2016 و2018/2017 لتقييم تأثير التسميد الورقي بأكسيد الزنك النانومتري وأكسيد الزنك العادي على النمو والمحصول والجودة تحت مستويات مختلفة من التسميد النيتروجيني. كانت المعاملات عبارة عن الرش الورقي بأكسيد الزنك النانومتري وأكسيد الزنك العادي عند تركيزات (كنترول،300،200،100 جزء في المليون من أكسيد الزنك النانومتري وتركيز واحد من أكسيد الزنك العادي300جزء في المليون) عند ثلاثة مستويات من التسميد الآزوتي (60 ، 80 ،100 كجم/فدان).

يمكن تلخيص النتائج الرئيسية على النحو التالي:

الرش الورقي بأكسيد الزنك النانومتري له تأثير معنوي على وزن الجذرالطازج/النبات ومحصول الجذور/فدان ومحصول السكر ومحصول السكر الكلي والسكروز ٪ ونسبة السكر القابل للاستخلاص في كلا الموسمين. كذلك كان له تأثير معنوي على نسبة الجذر/العرش والفقد في محصول السكر ومعامل الجودة ونسبة الاستخلاص في الموسم الثاني فقط وكان له تأثير معنوي على محصول السكر القابل للاستخلاص في الموسم الأول فقط.

إن أفضل تركيز لأكسيد الزنك النانومتري علي بنجر السكر كان300 جزء في المليون يعطي أعلى محصول للجذور والسكر.

زيادة معدلات النيتروجين من60 إلى100 كجم ن / ف تؤدي إلي زيادة معنوية في الصفات المدروسة مثل وزن الجذر الطازج/النبات و وزن العرش الطازج/نبات في الموسم الثاني وكذلك محصول الجذور والعرش والفقد في محصول السكر بينما حدث انخفاض في صفات الجودة بشكل ملحوظ عن طريق زيادة مستويات النيتروجين مثل السكروز والنقاوة ونسبة السكرالقابل للاستخلاص مع زيادة مستوى النيتروجين. وأيضا انخفاض نسبة الجذر/العرش مع زيادة مستوى النيتروجين.

يمكن استنتاج أن مستوى التسميد النيتروجيني عند100 كجم نيتروجين/فدان والرش الورقي بأكسيد الزنك النانومتري بتركيز300 جزء في المليون من المعاملات الموصي بها لتعظيم إنتاج محصول بنجر السكر. وكذلك تسميد نباتات بنجر السكر بمعدل 60كجم ن/ف مع 200 جزء في المليون تعظم صفات الجودة.