Yield and Quality of Three Sugar Beet Varieties as Affected by Titanium Dioxide Nanoparticles Foliar Application and Nitrogen Fertilization

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Abstract

A field experiment was conducted at Mallawi Agriculture Research Station Farm (latitude of 27.73 ° 28′ N and longitude of 30.83° 95′ E) El-Minia Governorate, Egypt in two successive seasons of 2016/2017 and 2017/2018 to find out the influence of nitrogen fertilization and Titanium dioxide nanoparticles TiO_2 on yield and quality of three sugar beet varieties. Varieties exhibited significant differences in root length and sugar recovery in the two growing seasons, whereas the differences in TSS% were not significant. The differences among varieties in pol% and sugar yield were significant only in the second and the first growing season, respectively. Nitrogen fertilization had significant effects on root length, pol%, sugar recovery and sugar yield in both seasons, meanwhile it has a significant effect on TSS% only in the first season. TiO_2NP concentrations had significant effects on root length, pol%, sugar recovery and sugar yield in the two growing seasons, meanwhile it has insignificant effect on TSS% in both seasons. The second order interaction had insignificant effect on root length, TSS% and sugar yield in both seasons, meanwhile it has significant effects on pol% and sugar yield in the two growing seasons. Under conditions of the present work, it is recommended to fertilization Hercule or Kawemira sugar beet varieties by 60 or 80 kg N/fed. and 300 or 200 ppm TiO_2NP to produce the best quality as well as the highest sugar yield/fed.

Keywords: Sugar beet; Nitrogen; Fertilization; Titanium dioxide; Varieties.

Introduction

Sugar beet is one of the two traditional sugar crops in the world as well as Egypt ***(Abo-Elwafa et al. 2006; Abou-Elwafa 2010)***.

Sugar beet contains from 13 to 22% sucrose. The increase in the population and the average per capita consumption of sugar may lead to an annual increase in sugar consumption of about 65 thousand tons ***(MALRS; Sugar Crops Council, 2018)***. Therefore, targeting the increase of the unit area production of sugar beet with superb quality is one of the most important solutions to meet the gap between production and consumption**.**

All sugar beet varieties cultivated in Egypt are imported from European countries. The variation among sugar beet varieties in gene structure led to wide differences in sugar beet yield and quality as found by (***Nemeat-Alla et al. 2002)*** cultivars exhibited significantly differences in juice quality, root and sugar yield, in favour Toro and Farida cultivars compared with the cultivar Lola (**Azzazy, *et al.* 2007).**

Adequate soil fertility is one of the requirements for profitable sugar beet production. Nitrogen (N) is the most yield-limiting nutrient, and N management is critical to obtain optimum sugar beet yield and quality. (**Ahmed et al. 2017**) reported that sugar beet varieties differed significantly in root length, root and sugar yields/fed. as well as sucrose, purity, impurities percentages.

Nitrogen element (N) is an important nutrient for sugar beet crop. To obtain a maximum yield and sucrose accumulation in the beet roots, the amount of Nitrogen supplied to the plants should be reduced just prior to harvest to avoid vigorous top growth. An over-abundant uptake of N at this stage would decrease the sugar percentage and increase the presence of "α-amino N" compounds, which make sugar extraction difficult within the storage roots (Pocock et al. 1990). Deficient soil N negatively affects the plant growth and N surplus can also negatively impact the environmental quality and human welfare (Sutton et al. 2011). Therefore, optimizing the use of N through a better understanding of the crop requirement is an important goal to obtain roots of high quality, to guarantee the highest net income for the farmers and to minimize the groundwater pollution due to nitrate leaching (Draycott and Christenson 2003). There is strong evidence that the role of N in the generation of the foliage canopy is a central mechanism governing the yield of healthy and disease-free sugar beet crops (Malnou et al. 2006). It is well documented that N is the most nutrient limiting of sugar beet productivity Hergert (2010). The application of too little N can results in reduced root yield. Contrary, high amount of applied N is the cause of imbalanced partitioning of assimilates among leaves and storage root, and lead to decrease of root sucrose concentration. Its oversupply, increases also concentrations of impurities, such as α-amino-N, K, Na, in turn decreasing storage root quality (Hoffmann 2005) and (Malnou et al. 2008).

Recently; nanotechnology provides different nano-devices and nano-material which having great roles in agriculture. The nano-fertilizers have higher surface area that is mainly due to very low size of particles which provide high reactivity with other compounds and high solubility in different solvents such as water. Particle size of nano-fertilizers is less than 100 nm which facilitates more penetration into the plant from applied surface such as soil or leaves. Here too, several studies in the past 10 years have reported the effect of TiO_2NP on seed germination, root efficiency, chlorophyll content, antioxidants, yield and quality properties of many plants such as onion (Haghighi and Silva 2014), oats (Andersen et al. 2016), chickpea (Mohammadi et al. 2013), barley (Mandeh et al. 2012). and soybean (Rezaei et al. 2015).

Nanoparticles are particles between 1 and 100 nanometres (nm) in size with a surrounding interfacial layer. The interfacial layer is an integral part of nanoscale matter, fundamentally affecting all of its properties.

According to (ISO Technical Specification 80004 2011), a nanoparticle is defined as a nano-object with all three external dimensions in the nanoscale, whose longest and shortest axes do not differ significantly, with a significant difference typically being a factor of at least 3.

The main purpose of the presented study was to evaluate the effect of nitrogen fertilization and Titanium dioxide nanoparticles on yield and juice quality of three sugar beet cultivars.

Materials and Methods

This experiment was conducted during 2016-2017 and 2017-2018 seasons at Mallawi Research Station, (latitude of 27.73 o 28′ N and longitude of 30.83o 95′ E) El-Minia Governorate, Egypt to evaluate the yield of three sugar beet varieties under three rates of nitrogen fertilizations with four concentrations of TiO2NP as a foliar application in a nanoparticles form. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications using split split plots arrangement. The total area of the experiment was 1825 m2, consists of 108 plots with plot area of 10.4 m2 which has four rows of four meters long.

The soil of experimental sites was salty clay loam. The mechanical and chemical analyses of experimental sites of the soil are presented in Table 1.

Treatments consist of:

1. **Three sugar beet varieties (V)**

- Kawemira (V1): a German variety
- Top (V2): a German variety
- Hercule (V3): a Belgium variety

2. **Three nitrogen fertilization levels**

- N1: 60 kg nitrogen (130 kg urea) per faddan.
- N2: 80 kg nitrogen (173 kg urea) per feddan.
- N3: 100 kg nitrogen (217 kg urea) per feddan.

3) Four concentrations of TiO2NP foliar application by

- T0: control
- T1: 100 ppm
- T2: 200 ppm
- T3: 300 ppm

Table 1. Physical and chemical analyses of the experimental soils at depth of 30 cm in 2016/2017 and 2017/2018 seasons

Properties	2016/17	2017/18
Texture analysis		
Clay %	36.90	37.13
Silt %	54.45	53.52
Sand %	8.65	9.35
Texture grade	Salty clay loam	Salty clay loam
Organic matter %	1.22	1.18
PH(1:1 suspension)	8.10	8.00
E.C. m.mohs (1:1)	1.8	1.6
Soluble cations		
Ca++ meq/L.	9.78	8.45
Mg++ meq/L.	2.72	2.75
K+ meq/L.	0.24	0.23
Na+ meq/L.	4.95	4.45
Soluble anions		
CO3-- meq/L.	--	--
HCO3- meq/L.	3.68	3.25
Cl- meq/L.	5.80	4.90
SO4-- meq/L.	8.36	7.78
Available N (mg/kg) soil	21.10	19.35
Available P (ppm)	8.50	7.85
Available K (mg/kg) soil	175	180
Available S (ppm)	7.50	7.25

Sowing took place on the 11th and 15th October in the 1st and 2nd seasons, respectively, by using 3-4 seeds per hill (20 cm hill-spacing) in one side of the ridge. After 25 days, from planting date the 1st hoeing process was carried out to get rid of weeds among sugar beet plants. Approximately at the middle of November, the thinning process was done to keep one sugar beet plant per hill.

A month later, the 1st dose of nitrogen fertilization were done from each subplot according to its studied nitrogen rate. 321, 428 and/or 537 g of urea were added to the plots under studied nitrogen rates of 60, 80 and/or 100 kg nitrogen per feddan respectively.

Approximately a month later, the second hoeing process was carried out (heaping soil around plants). Thereafter, in the fourth month of sowing date, processes of nitrogen fertilization and foliar spraying were repeated with the same rates used in the 1st dose. Irrigation practices for growing sugar beet were applied up according to the recommendations of the Egyptian Ministry of Agriculture and were prevented about a month before harvest.

After finishing the fertilization process, Three quarters of the experimental plots (81.0 plots) were subjected to foliar application with different concentrations of TiO_2NP (100, 200 and/or 300 ppm). A constant volume of 400 ml/plot was sprayed using a hand pump sprayer. The remaining 27.0 plots which served as control treatments were sprayed by 400 ml of distilled water.

Rates of TiO_2NP spraying solution were based upon 160 liters per feddan. The lab preparation of TiO2NP concentrations were performed by adding 6.48 g of TiO2NP (powder) drop by drop to 1400 ml of distilled water. The resultant mixture was stirred using a magnetic stirrer at room temperature until the complete solubility. The mixture volume was then supplemented to 1620 ml by distilled water. The prepared mixture was placed in a sealed glass vial and necessary dilutions were made in the field immediately before spraying.

The concentration of 100 ppm was prepared by taking 10 ml of the mixture into a flask and completing the volume by adding distilled water to 400 ml and then pouring it into the hand pump tank for spraying over the plants within the studied plot. Concentrations of 200 and / or 300 ppm were obtained by taking 20 and / or 30 ml of concentrated mixture and following the same previous dilution steps.

One week before harvest (after three weeks of water withholding), a sample of five plants were uprooted from each experimental unit and transferred to the laboratory. Plants were separated to roots and leaves to record the vegetative characters and the total soluble solids.

At harvest, plants of the two intermediate rows from each subplot were uprooted and separated to roots and leaves. The weight of each separate section was recorded to estimate the yield of roots and leaves per feddan.

After that, five roots were randomly taken from each sub plot and transferred to the quality control laboratory of Abu Kurqas sugar factory to record the quality parameters and then estimate the sugar yield as tons per feddan.

Measured and calculated data

a) Vegetative characters

1- Root length (cm)

b) Quality parameters

1- Total soluble solids (TSS%): was recorded by a stand rafractometer (Atago No. 5000, Japan).

2- Sucrose content (Pol %): was determined by the ICUMSA method (1994) at Abou-Korkas Sugar Company laboratory.

3- Sugar recovery: determined according to the procedure of Abou-Korkas Sugar Company described by (Saparonova et al. 1979). by the following equation:-

(Pol – 0.29) – 0.343 (K + Na) – alpha amino N (0.094)

c) Yield and its components

1- Sugar yield (tons fed-1)

All collected data were analyzed with analysis of variance (ANOVA) Procedures using M-State software program. Differences between means were compared by LSD at 5% level of significance (Gomez and Gomez, 1984).

Results and discussion

A. Vegetative characters

1) Root length (cm)

Results in Table 2 showed that sugar beet varieties had significant effects on root length. Hercule variety (V3) had the highest root length in both seasons.

Table 2 . Effect of varieties, nitrogen, TiO_2NP concentrations and theirinteraction on root length (cm) at harvest of sugar beet in 2016/2017 and2017/2018

		2016/2017					2017/2018				
		T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
V1	N1	28.94	30.44	33.15	34.95	31.87	29.45	30.41	32.49	33.87	31.55
	N2	30.03	29.92	32.24	33.82	31.50	30.10	30.01	31.79	33.00	31.23
	N3	30.60	31.17	33.64	35.25	32.67	30.53	30.97	32.87	34.10	32.12
Mean		29.85	30.51	33.01	34.67	32.01	30.03	30.46	32.38	33.66	31.63
V2	N1	28.61	29.39	30.93	32.27	30.30	29.01	29.61	30.79	31.82	30.31
	N2	28.93	31.58	32.05	33.93	31.62	29.26	31.28	31.65	33.09	31.32
	N3	29.83	31.55	35.17	40.16	34.18	29.95	31.26	34.04	37.86	33.28
Mean		29.13	30.84	32.72	35.45	32.03	29.40	30.72	32.16	34.26	31.63
V3	N1	31.34	31.39	33.70	37.46	33.47	31.10	31.14	32.91	35.79	32.73
	N2	30.14	33.99	34.58	37.18	33.97	30.19	33.13	33.59	35.58	33.12
	N3	33.46	34.39	36.86	37.22	35.48	32.73	33.44	35.33	35.61	34.28
Mean		31.65	33.25	35.04	37.28	34.31	31.34	32.57	33.94	35.66	33.38
Means for N	N1	29.63	30.41	32.59	34.89	31.88	29.85	30.39	32.06	33.83	31.53
	N2	29.70	31.83	32.95	34.97	32.36	29.85	31.48	32.34	33.89	31.89
	N3	31.30	32.37	35.22	37.54	34.11	31.07	31.89	34.08	35.86	33.22
Mean		30.21	31.54	33.59	35.80	32.78	30.26	31.25	32.83	34.53	32.22

	Ftest	LSD0.05	Ftest	LSD0.05
Varieties (V)	*	0.67	*	0.50
Nitrogen (N)	*	0.57	*	0.42
V x N	*	0.99	*	0.72
TiO2NP (T)	*	0.42	*	0.33
V x T	ns	--	ns	--
N x T	ns	--	ns	--
V x N xT	ns	--	ns	--

This may be due to the agree of genetic make up and environmental conditions which in agreement with those obtained by ***(Ismail et al. 2006)*** and ***(Hanan and Yasin 2013)*** and (***Ahmed et al. (2017)*** they reported that sugar beet varieties differed significantly in root length. who reported significant differences among varieties with respect to root length.

The effect of nitrogen levels on root length was significant. Data showed that, sugar beet root length did not responded to the increase in nitrogen level from 60 up to 80 kg. This result may be due to the role of nitrogen in improvement cell division which reflected on root elongation. However, the high rate of 100 kg caused a significant increase in root length. These findings were observed in the two growing seasons and showed harmony with those reported by ***(Nemeat-Alla and El-Geddawy 2001)*** and ***(Nemeat-Alla et al. 2014)*** who concluded that increasing the nitrogen level resulted in the highest root length.

The interaction between sugar beet varieties and nitrogen levels significantly affected root length. It could be noticed that, neither Kawemira (V1) nor Hercule (V3) presented any response toward raising the nitrogen rate from 60 to 80 kg. Meanwhile, root length of V2 significantly showed a gradual increase with increasing the nitrogen rate. Data also showed that, all of the tested varieties attained their greatest values of root length with the highest rate of nitrogen (100 kg). These findings were observed in both seasons.

Data in Table 2 demonstrated that sugar beet root length was significantly influenced by the tested TiO_2NP concentrations and showed a linear response in the two growing seasons. The highest TiO_2NP concentration (T3) gave a significant superiority over the control treatment (T0) by approximately 15.61 % and 12.36% for the first and the second growing seasons respectively. These results were in line with ***(Castiglione et al. 2011)*** who summarized that in Vicia narbonensis and Zea mays, TiO_2NP give rise in development of mitosis of root cells which reflected to root elongation. Moreover, ***(Servin et al. 2012)*** has also hypothesized that TiO_2NP promote plant root growth by stimulating nitrogen accumulation and thus protein formation.

All the other interactions between the studied factors had insignificant effects on root length in the two growing seasons.

b) Quality parameters

1) Total soluble solids (TSS%)

Data in Table 3 illustrate that tested sugar beet varieties exhibited insignificant differences in TSS% in the two growing seasons. (Shaban et al. 2014) also found similar results.

In addition, TSS of sugar beet roots was significantly affected by the evaluated nitrogen rates. This observation was observed in the first season only. In general increasing nitrogen fertilization decreases TSS%. Sugar beet fertilized with 60 kg nitrogen produced the highest TSS. The difference between the other two studied rates was insignificant. (Nemeat-Alla 2016) also detected a linear decrease on TSS of sugar beet roots with increasing nitrogen fertilization.

In both seasons, TSS was insignificantly affected by the different TiO_2NP concentrations (Table 3). On the other side the interaction between V and T was significant only in the first season. It was clear that, the variation in TSS values between T0 and T1 was insignificant in case of Hercule (V3). However T0 significantly surpassed T1 in the other two tested varieties. In addition, Kawamira (V1) showed a significant increase response to increase TiO2NP concentration and achieved the highest value at 300 ppm, while other varieties did not show this behavior.

Table 3 . Effect of varieties, nitrogen, TiO2NP concentrations and theirinteractions on total soluble solids (TSS%) at harvest of sugar beet in2016/2017 and 2017/2018

		2016/2017					2017/2018				
		T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
V1	N1	21.96	19.49	20.99	21.97	21.10	20.37	19.79	20.37	21.07	20.40
	N2	20.94	19.28	20.25	21.62	20.52	17.19	19.79	20.07	20.48	19.38
	N3	20.31	19.32	20.30	21.43	20.34	19.96	19.54	20.03	20.79	20.08
Mean		21.07	19.36	20.51	21.67	20.65	19.18	19.71	20.16	20.78	19.96
V2	N1	21.37	20.28	21.26	20.53	20.86	20.30	20.23	20.72	20.29	20.38
	N2	22.82	18.57	20.98	21.30	20.92	19.98	20.04	20.54	20.79	20.34
	N3	19.91	20.89	22.11	19.37	20.57	20.02	19.58	20.29	20.04	19.98
Mean		21.36	19.91	21.45	20.40	20.78	20.10	19.95	20.52	20.37	20.23
V3	N1	21.23	21.75	21.77	20.33	21.27	19.54	19.54	20.29	20.06	19.86
	N2	21.88	21.29	19.94	20.42	20.88	18.51	20.04	20.56	19.85	19.74
	N3	20.02	21.33	21.97	20.58	20.97	20.53	20.49	20.01	20.09	20.28
Mean		21.04	21.45	21.23	20.44	21.04	19.53	20.03	20.29	20.00	19.96
Means for N	N1	21.52	20.50	21.34	20.94	21.08	20.07	19.85	20.46	20.47	20.21
	N2	21.88	19.71	20.39	21.11	20.77	18.56	19.96	20.39	20.37	19.82
	N3	20.08	20.51	21.46	20.46	20.63	20.17	19.87	20.11	20.31	20.11
Mean		21.16	20.24	21.06	20.84	20.83	19.60	19.89	20.32	20.38	20.05

	2016/2017 Ftest	2016/2017 LSD0.05	2017/2018 Ftest	2017/2018 LSD0.05
Varieties (V)	ns	--	ns	--
Nitrogen (N)	*	0.27	ns	--
V x N	ns	--	ns	--
TiO_2NP (T)	ns	--	ns	--
V x T	*	0.75	ns	--
N x T	*	0.76	ns	--
V x N xT	ns	--	ns	--

Results revealed that TSS value were significantly affected by the interaction between nitrogen rates (N) and TiO2NP concentrations (T) only in the first season. It was clear that, TSS of N1 and N3 under T3 were increased with insignificant differences over those obtained under T1. However, this increment reached to significance level in case of T2.

2) Sucrose content (Pol %)

Data in Table 4 illustrated that, Pol % was significantly influenced by the tested varieties only in the second season the variety Kawemira (V1) was significantly surpassed over V2 and V3 by about 3.45 % and 6.09% respectively. These results are in agreement with those obtained by (Osman et al. 2003), (Safina and Abdel Fatah 2011) and (Hanan and Yasin 2013).

The main effect of the studied nitrogen rates was significant in the two growing seasons with respect to Pol %. Data showed that, the middle rate of nitrogen (N2) showed its individual superiority whereas, the heavy one (N3) presented the lowest sucrose content. These results may be due to the excessive of nitrogen element led to decrease of Pol concentration. These results were observed in both seasons. (Carter et al. 1976) also mentioned that, sucrose content of sugar beet roots were decreased when sugar beet exposed to insufficient nitrogen supply as a reflection of the low growth rate and were also decreased when nitrogen uptakes were larger than optimal because the excessive nitrogen led to a decrease in sugar concentration.

Here too, the interaction between V and N had a significant effect of Pol % only in the second season. It could be noticed that, sucrose content of Kawemira (V1) did not responded to nitrogen levels while the other two were greatly influenced. In addition, the difference between N1 and N3 was significant under V2 whereas those treatments did not differed significantly under V3.

Data in Table 4 shows that tested TiO_2NP concentrations have a direct effect on sucrose content of sugar beet roots in both seasons. In the first season, only the heavy rate of TiO2NP (300 ppm) caused a significant reduction in sucrose %.

Table 4 . Effect of varieties, nitrogen, TiO2NP concentrations and their interactionon sucrose percentage (POL) at harvest of sugar beet in 2016/2017 and 2017/2018

		2016/2017					2017/2018				
		T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
V1	N1	16.89	16.58	17.44	17.33	17.06	16.99	17.61	18.18	16.47	17.31
	N2	17.26	17.93	17.97	17.12	17.57	17.26	17.53	18.66	16.64	17.52
	N3	17.12	17.70	16.98	16.48	17.07	17.26	17.28	17.53	17.49	17.39
Mean		17.09	17.40	17.46	16.98	17.23	17.17	17.48	18.12	16.86	17.41
V2	N1	17.34	17.20	17.44	16.63	17.15	16.74	16.80	16.93	17.07	16.88
	N2	17.53	17.43	17.31	17.83	17.52	16.93	17.87	18.01	16.55	17.34
	N3	15.89	17.27	16.45	17.30	16.73	15.88	16.54	16.07	16.54	16.26
Mean		16.92	17.30	17.07	17.25	17.13	16.51	17.07	17.00	16.72	16.83
V3	N1	18.47	17.84	17.06	17.01	17.59	16.78	15.88	16.41	16.13	16.30
	N2	18.02	17.38	17.82	17.64	17.71	16.65	16.72	16.58	16.56	16.63
	N3	17.33	17.04	16.29	16.42	16.77	16.91	16.91	15.59	15.83	16.31
Mean		17.94	17.42	17.06	17.02	17.36	16.78	16.50	16.19	16.17	16.41
Means for N	N1	17.56	17.21	17.31	16.99	17.27	16.83	16.76	17.17	16.55	16.83
	N2	17.60	17.58	17.70	17.53	17.60	16.94	17.38	17.75	16.58	17.16
	N3	16.78	17.33	16.57	16.73	16.85	16.68	16.91	16.39	16.62	16.65
Mean		17.31	17.37	17.19	17.08	17.24	16.82	17.02	17.10	16.58	16.88

		Ftest	LSD0.05	Ftest	LSD0.05
Varieties (V)		ns	--	*	0.15
Nitrogen (N)		*	0.28	*	0.16
V x N		ns	--	*	0.28
TiO2NP (T)		*	0.22	*	0.11
V x T		*	0.38	*	0.17
N x T		*	0.38	*	0.18
V x N xT		*	0.66	*	0.32

In the meantime, differences among other tested concentrations were insignificant. In the second season, raising the TiO_2NP level from 0.0 up to 100 and/or 200 ppm was accompanied by a significant increment of sucrose % but raising the concentration up to 300 ppm caused a drastically decrease in sucrose%. This may be due to the role of titanium in improve crop performance through stimulating the activity of cretin enzyme, enhancing chlorophyll content, photosynthesis, prorating nutrient uptake and improving yield and quality. This result in agree with these finding by ***(Shiheng et al. 2017).***

It is known that the maturity of sugar beet is to increase the storage rate of sucrose in roots, which is accompanied by a slow activity in vegetative growth due to the low efficiency of the photosynthesis processes. Data showed that concentrations of 100 and/or 200 ppm TiO_2NP led to some what improvements in the sucrose content. This was in harmony with ***(Rutskaya 1976)*** who mentioned that, the development of sugar beet was favorably influenced by the addition of titanium and the sugar content of the beet roots became higher.

Raising the TiO_2NP concentration up to 300 ppm led to an increase in the plant's ability to maintain the efficiency of photosynthesis processes, thus sustaining vegetative growth activity and slowing sucrose storage processes. ***(Ghooshchi 2017)***. also reported that TiO_2NP prevent chlorophyll degradation and stimulate its biosynthesis. Moreover; ***(Choi et al. 2015)***. illustrated that, spraying TiO_2NP solution to strawberry plants when insufficient solar radiation happens during the winter season, could promote the growth and increase photosynthesis activity.

Results revealed that sucrose % was markedly affected by the interaction between varieties (V) and TiO2NP concentrations (T), in the two growing seasons. Data showed that, in the first season T0 was significantly surpassed over the other concentrations under V3. In cases of V1 and V2, T0 did not differed significantly among the other concentrations. In the second season, Pol % of V1 significantly increased by raising TiO_2NP concentration from 100 up to 200 ppm, whereas the difference between those two concentrations was disappeared under V2.

The results pointed out that the interaction between the studied nitrogen rates and TiO_2NP concentrations had a substantial effect on sugar beet POL, in the two growing seasons. In the first season data showed a clear reduction on sucrose contents when accrued by raising TiO_2NP from 200 up to 300 ppm under N1. However, the same increment of TiO_2NP concentration did not exhibit any affects under conditions of N2 and N3. In the second season, differences between T0 and T1 were significant under N2 and N3 while the difference between those two treatments was insignificant under N1.

The second order interaction was significant in both seasons. In the 1st season there are five combinations gave the highest POL. The V1N2T2 combination was emerged among those first season superior combinations and was unique in the highest value in the second season. Moreover, the heavy rate of nitrogen (N3) showed a negative response with raising TiO2NPconcentration up to 300 ppm. This response appeared in cases of V1 and V3 while, a positive response was found by V2 under the same conditions. These findings were observed in both seasons.

3) Sugar recovery

Sugar recovery is an estimated indicator that describes the recovery of crystalline sugar, and the efficiency of sugar processing which affected greatly by the quality of the roots. Sugar recovery percentage can considered as an indicator of the chemical composition of the roots ***(Oltmann et al. 1984).*** Therefore, the sugar recovery percentage can also be considered as the result of the final interaction between all of the quality measurements.

Means listed in Table 5 showed that sugar recovery was significantly affected by sugar beet varieties in the two growing seasons. It could be noticed that the variety Top (V2) gave the greatest percentage of sugar recovery where the other two varieties differed insignificantly between each other. These findings are in line with those reported by (Ismail et al. 2006) and (Mekdad and Rady 2016).

Table 5 . Effect of varieties, nitrogen, TiO2NP concentrations and thei interactions on sugar recovery % at harvest of sugar beet in 2016/2017 and 2017/2018

		2016/2017					2017/2018				
		T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
V1	N1	14.42	13.58	14.83	14.78	14.40	14.53	14.84	15.66	13.96	14.75
	N2	15.26	15.61	15.54	14.45	15.21	14.67	15.14	15.91	14.01	14.93
	N3	14.62	15.27	14.60	14.14	14.66	15.01	14.78	14.84	15.18	14.95
Mean		14.77	14.82	14.99	14.46	14.76	14.74	14.92	15.47	14.38	14.88
V2	N1	14.90	14.75	14.86	14.24	14.69	14.39	14.13	14.26	14.28	14.27
	N2	15.04	15.00	14.92	15.68	15.16	14.28	15.57	15.58	14.15	14.89
	N3	12.78	14.43	13.72	15.00	13.98	13.55	13.96	13.84	14.15	13.88
Mean		14.24	14.73	14.50	14.97	14.61	14.07	14.55	14.56	14.19	14.35
V3	N1	16.26	15.17	14.73	14.86	15.26	14.72	13.47	13.96	13.69	13.96
	N2	15.98	15.07	15.67	15.50	15.56	14.26	14.20	13.78	14.14	14.10
	N3	14.73	14.76	14.07	13.85	14.35	14.41	14.68	13.20	13.05	13.84
Mean		15.66	15.00	14.82	14.74	15.05	14.47	14.12	13.65	13.63	13.96
Means for N	N1	15.19	14.50	14.80	14.63	14.78	14.55	14.15	14.63	13.98	14.32
	N2	15.43	15.22	15.38	15.21	15.31	14.40	14.97	15.09	14.10	14.64
	N3	14.04	14.82	14.13	14.33	14.33	14.32	14.47	13.96	14.13	14.22
Mean		14.89	14.85	14.77	14.72	14.81	14.43	14.53	14.56	14.07	14.40

		Ftest	LSD0.05	Ftest	LSD0.05
Varieties V)		*	0.60	*	0.17
Nitrogen (N)		*	0.47	*	0.25
V x N		*	0.45	*	0.28
TiO2NP (T)		*	0.23	*	0.11
V x T		*	0.40	*	0.18
N x T		*	0.40	*	0.19
V x N xT		ns	--	ns	--

The main effect of nitrogen rates was significant in the two growing seasons. Data showed that, the percentage of sugar recovery reached the highest values when sugar beet was fertilized by the middle rate of nitrogen (80 kg). The increase in the nitrogen rate up to 100 kg has led to a slight reduction in sugar recovery compared to that produced with the lowest rate (60 kg). These results were observed in both seasons.

The increase in the sugar recovery values of beet roots which recorded in case of fertilization by 80 kg nitrogen is considered a direct reflected to the high percentages of sucrose and the low percentages of potassium, ***(Ghaemi and Bahrami 2013)*** also detected that, the lack and/or the oversupply of nitrogen showed the same negative effect on sugar recovery % of beet roots. In addition ***(Abdel-Motagally and Attia 2009)*** mentioned that, increasing nitrogen fertilization over the optimal rate led to a increase rise in root contents of soluble non-sugar which negatively interfere with sugar extraction.

The results manifested that sugar recovery was markedly influenced by the evaluated TiO_2NP concentrations, in the two growing seasons. Clearly, the heaviest concentration (300 ppm) led to an appreciable reduction on sugar recovery as a direct reflection of its low sucrose content (Table 5). In the first season, although there was a significant reduction in the sucrose % under T3 level, but the decrease in the sodium % led to higher value of sugar recovery with this treatment and statistically equal with the values of the other tested concentrations. ***(Oltmann et al. 1984)***. also mentioned that above all, a high concentration of sugar is required, whereas a high concentration of soluble non-sugar compounds impairs sugar recovery.

Results revealed that, each variety had a different behavior toward the different tested nitrogen rates. V3N2 and V1N3 gave the highest interaction values among the others (15.56 and 14.95) in the first and second growing seasons, respectively.

It could be noticed that, the variance between T0 and T1 conducted under V1 was insignificant. However, the difference between those two concentrations reached the level of significance under V2 and V3. Moreover, increasing TiO_2NP concentration from 200 up to 300 ppm caused a significant reduction on sugar recovery of kawemira (V1) whereas; the same raise did not exhibit any variance with Hercule (V3). These findings were observed in the two growing seasons.

Here too, sugar recovery was markedly influenced by the interaction between nitrogen rates (N) and TiO_2NP concentrations

(T). Data revealed that, increasing the TiO_2NP concentration from 200 up to 300 ppm caused a significant reduction on sugar recovery of sugar beet which received 60 kg nitrogen. However the difference between those two concentrations disappeared when the nitrogen rate reached 100 kg. These findings were observed in the two growing seasons.

c) Yield and its components

1) Sugar yield (ton fed^{-}1)

Data in Table 6 illustrated that, sugar yield was significantly responded by the tested sugar beet varieties only in the first season. Hercule (V3) scored the highest sugar yield as a direct reflection to its high sugar recovery. Meanwhile, V2 attained the lowest value according to its low roots yield. These results were in line with those obtained by (**Safina and Abdel Fatah 2011**), (**Ahmad et al. 2012**) and **(Ahmad et al. 2016).**

Nitrogen fertilization rates markedly affected sugar yield in the two growing seasons. Sugar yield is the product of multiplying root yield and extractable sugar. No significance differences between 80 and 100kg nitrogen fertilization were observed in the first season, whereas in the second season sugar yield presented a linear enhancement with increasing nitrogen rates. This is likely to be one of the reasons for the increase in sucrose storage and the qualitative decrease in roots impurities under the rate of 80 kg nitrogen in first season. The heavy rate of nitrogen fertilization (100 kg) produced high yields of sugar as a direct reflection to its high roots yield in both seasons. These findings clearly reflect the balanced relationship between the effect of the amount of nitrogen on root weight and their impact on quality parameters. (**Ghaemi and Bahrami 2013**) also concluded that the effect of root yield is higher than the effect of sugar recovery on sugar yield.

Table 6 . Effect of varieties, nitrogen, TiO_2NP concentrations and their interactions on sugar yield (ton.fed.$^{-1}$) at harvest of sugar beet in 2016/2017 and 2017/2018

		2016/2017					2017/2018				
		T0	T1	T2	T3	Mean	T0	T1	T2	T3	Mean
V1	N1	4.36	4.18	4.83	4.93	4.58	3.83	3.95	5.10	4.51	4.35
	N2	5.02	4.94	5.46	4.98	5.10	4.07	4.53	5.05	4.47	4.53
	N3	5.11	5.53	5.25	5.42	5.33	4.64	4.69	4.94	5.07	4.83
Mean		4.83	4.88	5.18	5.11	5.00	4.18	4.39	5.03	4.68	4.57
V2	N1	4.61	4.47	4.80	4.67	4.64	3.99	3.89	4.03	4.14	4.01
	N2	4.75	4.88	4.97	5.29	4.97	3.85	4.20	4.54	4.37	4.24
	N3	4.12	5.03	5.01	5.70	4.96	3.94	4.41	4.55	4.66	4.39
Mean		4.49	4.79	4.93	5.22	4.86	3.93	4.17	4.37	4.39	4.21
V3	N1	5.02	4.84	4.83	4.97	4.92	4.19	3.97	4.24	4.35	4.19
	N2	5.21	5.26	5.73	5.85	5.51	4.25	4.24	4.81	4.92	4.55
	N3	5.37	5.39	5.64	5.64	5.51	4.31	4.79	4.57	4.58	4.56
Mean		5.20	5.16	5.40	5.49	5.31	4.25	4.33	4.54	4.62	4.43
Means for N	N1	4.67	4.50	4.82	4.86	4.71	4.00	3.94	4.46	4.33	4.18
	N2	4.99	5.03	5.39	5.37	5.20	4.06	4.32	4.80	4.59	4.44
	N3	4.87	5.32	5.30	5.59	5.27	4.30	4.63	4.68	4.77	4.59
Mean		4.84	4.95	5.17	5.27	5.06	4.12	4.30	4.65	4.56	4.41

		Ftest	LSD0.05	Ftest	LSD0.05
Varieties(V)		*	0.10	ns	--
Nitrogen N)		*	0.10	*	0.10
V x N		ns	--	ns	--
TiO2NP (T)		*	0.11	*	0.10
V x T		*	0.15	*	0.12
N x T		*	0.15	*	0.12
V x N xT		*	0.25	*	0.16

These findings are in line with those obtained by (El-Fadaly et al. 2011) and (Salim et al. 2012).

Sugar yield was significantly affected by the studied concentrations of TiO_2NP (Table 6). It is worthily noted that, sugar yield has positively responded to rise the TiO_2NP concentration from zero up to 200 ppm. This was in harmony with (Pais 1983) who reported that, sprayed sugar beet with titanium has a very favorable effect on sugar yield which remarkably greater by about 32 % after the foliar application than the untreated fields, while application TiO2NPat rate of 300 ppm led to reducing sugar yield because the highest rate of TiO_2NP decline root gravity . On the other side, the heavy rate of TiO_2NP (300 ppm) added nothing to sugar yield because the decline rate in roots quality was greater than the increment rate of roots weight. These findings were observed in both seasons.

The interaction between varieties and TiO_2NP concentrations was significant in both seasons. In the first season raising the concentration of TiO2NP from 200 up to 300 ppm had no effect on sugar yield of Kawemira (V1) and Hercule (V3). Meanwhile Top variety (V2) sugar yield was statistically higher with 300 ppm than it was with 200 ppm. In addition, Top variety (V2)was the only variety that recorded an improvement in the sugar yield as a result of increasing the concentration of TiO_2NP from zero to 100 ppm, while these conditions did not affect the other two tested varieties.

In the second season, the difference between T2 and T3 was insignificant under V2 (Top) and V3 (Hercule) meanwhile, Kawemira (V1) recorded its highest sugar yield with 200 ppm (T2). Moreover, sugar yield of V1 and V2 increased when treated by 100 ppm of TiO_2NP compared to the control; however V3 did not exhibit any variance under this condition.

Each rate of the tested nitrogen fertilizations showed a different effect on the sugar yield depending on the TiO_2NP concentration interacted with it. Means listed in Table 6 indicated that, in the first season, there was a significant increase on sugar yield when raising the TiO_2NP concentration from 200 up to 300 ppm only under the heaviest rate of nitrogen (100 kg). However under the other two tested nitrogen fertilization rates, T2 and T3 gave approximately the same sugar yields.

In the second season, sugar beet which fertilized with 60 or 80 kg nitrogen presented their highest sugar yield with 200 ppm of TiO_2NP whereas T2 and T3 were statistically equal under the heavy nitrogen rate. Moreover; sugar yield was positively responded to increase TiO2NP from zero up to 100 ppm when nitrogen rates were

80 and/or 100 kg. However with the lowest rate of nitrogen (60 kg), T0 and T1 seemed to be statistically equal.

The second order interaction was significant in both seasons. It could be noticed from first season results that, Hercule (V3) presented the greatest values of sugar yield compared to the other two tested varieties. It was the only one that exceeded 5.60 tons of sugar per feddan when it received 80 and/or 100 kg nitrogen with 200 or 300 ppm of TiO_2NP with insignificant differences between each other. In the second season, Kawemira (V1) produced the greatest four values of sugar yield. The T2 treatment (200 ppm) appeared in three of these four superior combinations with N1, N2 and N3 while the fourth value was with N3T3.

On the other hand the lowest values of sugar yield in both seasons were almost appeared with N1T0, N1T1 and N3T0 with the three tested varieties, these findings provide an evidence of that, the medium rate of nitrogen (80 kg) is the best treatment to balance the yield and quality and that the increase in TiO2NP concentration reduces the inverse relationship between the amount of yield and its quality parameters.

Conclusion

Under conditions of the present work, it is recommended to fertilization Hercule or Kawemira sugar beet varieties by 60 or 80 kg N/fed. and 300 or 200 ppm TiO_2NP to produce the best quality as well as the highest sugar yield./fed.

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الملخص العربي

إنتاجية وجودة ثلاثة أصناف من بنجر السكر متأثرة بالرش الورقي لثاني أكسيد التيتانيوم

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تم إجراء تجربة حقلية في مزرعة محطة البحوث الزراعية بملوي (دائرة عرض 28º 27,73′شمال وخط طول′ 95 30,83 شرق) – محافظة المنيا، مصر في موسمين 2017/2016 و2018/2017 لمعرفة تأثير التسميد النيتروجيني والرش الورقي بثاني أكسيد التيتانيوم (فى صورة نانومترية) على المحصول والجودة لثلاثة أصناف من بنجر السكر اظهرت النتائج تأثر طول الجذر وناتج السكرمعنويا بالأصناف تحت التجربة في موسمي النمو ، في حين أن الأصناف لم يكن لها تأثير معنوى على المواد الصلبة الذائبة الكلية في كلا الموسمين. تأثرمحتوى السكروز ومحصول السكر بدرجة معنوية بالأصناف في موسم النمو الأول والثاني على التوالي. كان للتسميد النيتروجيني تأثير معنوي على طول الجذر ومحتوى السكروز وناتج السكر ومحصول السكرفي كلا الموسمين، بينما تأثيره المعنوى على المواد الصلبة الذائبة الكلية كان فقط في لموسم الأول. اظهرالرش الورقى بثانى أكسيد التيتانيوم(النانومترى) تأثير كبير على طول الجذر ومحتوى السكروز٪ وناتج ومحصول السكر في موسمي النمو، بينما كان تأثيره غير معنوي على النسبة المئوية للمواد الصلبة الذائبة الكلية في كلا الموسمين. اظهر التفاعل بين جميع عوامل الدراسة تأثير غير معنوي على طول الجذر و المواد الصلبة الذائبة الكلية وناتج السكر في كلا الموسمين، في حين كان تأثيرالتفاعل معنوى على محتوى السكروز ومحصول السكر في موسمي الزراعة .تشير نتائج هذه الدراسة الى إمكانية التوصية بزراعة الصنف كوميرا اوالصنف هرقل مع تسميدهما بمعدل 60 او 80 كجم نيتروجين للفدان و المعاملة ب200 او300 جزء بالمليون من التيتانيوم النانومترى للحصول على أفضل صفاتجوده و اعلى محصول السكر.