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Effect of Nano-micronutrients Fertilization on Yield and Quality of Some Sugar Beet Varieties under Early and Late Sowing Dates

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SUGAR beet (*Beta vulgaris* L.) is the second source of sugar around the world after sugar cane. The experiment was carried out in the Research Farm , Faculty of Agriculture, Sohag University, in two successive seasons of 2016/2017 and 2017/2018 to study the effect of Nano-micronutrients fertilizer on yield and quality of sugar beet varieties under normal and late sowing conditions. The results showed the early sowing at 21st October increased the root, quality, sugar and root yields comparing with the late sowing at 21st November in both seasons. The foliar application of Nano fertilizer treatments affected significantly all studied traits, the foliar application at 60 days after sowing exhibited the higher values of all studied traits comparing with both of foliar application at 105 days and non-fertilizer in both seasons. The four sugar beet varieties (Nabila, Karta, Kosmas and Tesla) differed significantly on all studied traits in the two seasons. Tesla variety was superior than the others of all studied traits. All interaction effects showed significant differences for root fresh weight, sucrose, TSS, purity, root and sugar yields. The highest sucrose % (18.32 and 18.42%) and sugar yield (5.20 and 5.83ton/fed) were obtained from Tesla variety with Nano-fertilized at 60 days from sowing of early sowing in 21st October in 2016/2017 and 2017/2018 seasons respectively. According to principal component analysis, the most appropriate sugar beet varieties for selecting of sugar yield was Tesla variety under the most treatments of foliar Nano- micronutrients in both environments (stable genotype and recommended for the test environments), especially under D1 (sowing at 21 October) and F2 (spraying time of 60 day after planting).

Keywords: Nano-fertilization, Principal component analysis, Sugar beet, Sugar quality.

Introduction

Sugar beet (*Beta vulgaris* L.) is the second source of sugar around the world after sugar cane, while it is considered the most important crop for extracting sugar in Egypt. Sugar beet can be grown widely in environmental conditions, furthermore it considered promising winter crop for reclaimed soil to reducing the increasing demand for sugar and reducing water consumption under its conditions. Therefore, the Egyptian government paid great attention to the cultivation of sugar beet especially in recently reclaimed soil, taking into consideration this plant is high salinity and save a large amount of water (Amr & Mohamed, 2010). In Egypt, the cultivated area (521.63 feddans in 2017/2018 season with an average root yield of 21.51ton/fed. (FAO, 2018). The production of sugar from sugar beet reached 1.27 million tons, whereas the extracted beet sugar represents 56.61% (Kandil et al., 2020). Recently the Egyptian government moved to expand the sugar beet area in the new reclaimed soil. Although, this area facing many problems such as heat stress and deficiency of fertility especially in micronutrients. Fertilizers have an important role in increasing food production. Despite of this, it is known that Sugar crop have yields begun to decrease due to the imbalance of fertilization and reduce organic matter in the soil. Moreover, the excessive applications of nitrogen and phosphorous fertilizers affect groundwater and owing to leaching (Veronica et al., 2015). Nanotechnology is the new

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generation technology that has a major place in Progress in many different fields, including agriculture and food industries. Considering global climate changes Nanotechnology is the way food security can be achieved increasing food productivity in a sustainable development (Panpatte & Jhala, 2019). In the last few years, Nano-fertilizers considered as one of sustainable development for increasing crop productivity in the developing countries (Veronica et al., 2015). Interesting approach in application of necessary elements, including Nano-micronutrients had a major impact on production both in quantity and quality. Foliar application of B, Fe, Zn and Mn at the concentration of 1.5 l/fed exhibted highest root diameter and root fresh weight/plant, as well as sucrose%, root and sugar yields/fed. (Abdelaal et al., 2015). Nano-fertilization of sugar beet has been studied by many authors such as, Dewdar et al. (2018) found the best results for root length and diameter, dry matter per plant as root, top and sugar yields in two seasons under nano-microelements fertilization using 200mg/L + urea 1%. Also, Osman (2011) found that foliar spray of micronutrients solution of 1/2L/fed. attained highest values for root diameter and fresh weight/plant, as well as, sucrose%, purity%, root and sugar yields/fed. Planting date plays an important role in increasing yield and quality traits of sugar beet under the environmental conditions of Egypt, there are many researchers have shown that earless sowing of sugar beet during September-October results in highest sucrose % as well as root and sugar yields per unit area (Nasr & Abd El-Razek, 2008). The principal components analysis (PCA) can transform several possibly correlated variables into as miller number of variables and explained the variation among genotypes. This approach is very helpful in deciding which agronomic traits of crop contributing most to yield, subsequently, these agronomic traits should be emphasized in the selection and breeding programs. There are substantial differences between the groups, but the individuals within a single group are similar (Einstein, 1996).

Therefore, this investigation was aimed on: i) Study the effect of foliar application of Nano-Micronutrients under normal and late sowing dates on yield and quality of some sugar beet varieties; and ii) Classify sugar beet varieties based on PCA to determine which traits are best suited for the test environments.

Materials and Methods

The experiment was conducted in 2016/2017 and 2017/2018 at Research Farm of Faculty of Agriculture, Sohag University, to investigate the response of four sugar beet varieties Nabila and Karta imported from France and Kosmas and Tesla imported from Germany for Nano- micronutrients fertilizers under early (21st October) and late (21st November) sowing dates. Three treatments of foliar Nano- micronutrients were used (without foliar application, after 60 and 105 from sowing days). Randomized complete block design (RCBD) was used in split- split plot arrangement with four replicates. Sowing dates, Nano- micronutrients fertilizers and sugar beet varieties were laid out in main, sub and small plot respectively. This experiment was included 96 experimental units, plots area was 15m^2, which consisted of 5- ridges of 5m in length and 60 cm in width 15 cm spacing between hills. The foliar application of Magrow Nanomix (Fe 6%, Zn 6%, MN 5%, Cu 1%,B 2%, Mo 0.1%, Citric acid 4%) was used as Nano-micronutrients at rat of 200 g/ 600 liter of water/fed. Ammonium nitrate (33.5% N) at the rate of 80kg N/fed., in two equal doses were used after 20 and 30 days from sowing. Phosphorus was added before sowing in the form of superphosphate (15.5% P_2O_5).

Soil of the experiment was sandy-loam; some properties of soil surface are shown in Table 1 and average of meteorological data of the growing seasons 2016/2017 and 2017/2018 are listed in Table 2.

TABLE 1. Some properties of soil surface in 2016/2017 and 2017/2018 seasons

Soil properties	2016/2017	2017/2018
Sand (%)	67.66	67.54
Silt (%)	21.64	21.40
Clay (%)	10.7	10.92
Soil texture	Sandy-loam	Sandy-loam
pH (1:2.5)	7.9	7.8
EC (ds/m) (1:2.5)	0.67	0.72
Organic matter (%)	1.83	1.81
Total N (%)	0.15	0.16
P_2O_5 (ppm)	17	17.4
K_2O (ppm)	280	284
Available Fe (ppm)	2.88	3.00
Available Zn (ppm)	0.79	0.81
Available Mn (ppm)	0.34	0.42
Available Cu (ppm)	0.58	0.60

TABLE 2. Average of meteorological data of the growing seasons 2016/2017 and 2017/2018

2016/2017							
Measurement	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Max. Temp. (C^o)	34.4	29.0	23.4	22.2	24.0	28.7	34.3
Min. Temp. (C^o)	14.7	9.9	4.9	4.7	6.2	11.5	16.5
Max. RH (%)	66.8	69.5	71.6	65.3	56.9	50.3	42.4
Min. RH (%)	15.5	15.4	15.9	15.5	14.1	15.2	14.7
2017/2018							
Measurement	**October**	**November**	**December**	**January**	**February**	**March**	**April**
Max. Temp. (C^o)	32.7	26.7	23.6	20.8	26.6	33.1	35.0
Min. Temp. (C^o)	15.4	13.2	10.0	7.7	11.7	15.6	17.70
Max. RH (%)	82.8	89	84	80	85	59	62
Min. RH (%)	12.5	12	20	24	12	6	5

- Source: Sohag Agricultural Meteorological Station, Egypt Temp. = Temperature (C^o). Rh% = Relative humidity %. Max.= Maximum. Min. = Minimum.
- All Other agriculture practices were carried out as recommended.

The recorded data

Ten plants were chosen randomly from each plot to recording the following traits:

1. Root measurements: Root length (cm), Root diameter (cm) and Root fresh weight (kg/plant).

2. Quality traits: Total soluble solids percentage (TSS %) was determined using Hand Refractmeter, sucrose (%) was determined using "Saccharometer" according to the procedure outlined by Le Docte (1927), and juice purity% was calculated using the following equation:

Purity%= ((Sucrose% x100))/(TSS%)

3. Root and sugar yields: Three guarded rows of each plot were harvested to record the root yield (ton/fed) and sugar yield (ton/fed.) was calculated using the following equation: Sugar yield (ton/fed.)= Root yield x sucrose%.

Statistical analysis

The collected data were subjected to analysis of variance in Proc GLM procedure (SAS Version 9.1SAS Institute 2003) to analyze Sowing dates impact on sugar beet parameters. Each season separately by described. Least significant differences (LSD) test among the means of factor levels and their Interactions at probability level of 5% were used according to Gomez & Gomez (1984). INDOSTAT software version 9.2. was used to perform the principal component analysis. Eigenvectors generated by PCA were used to rank tested genotypes for the test environments.

Results and Discussion

Analysis of variance and mean performance.

The obtained results were summarized as three parts as main effect, First-order interactions and second order interactions in Tables 3-5.

Main effect

Data in Table 3 revealed that the planting dates, spraying of Nano micronutrients foliar applications and sugar beet varieties had a significant effect on the all studied traits, i.e. root fresh weight/plant (kg), root length (cm), root diameter (cm), sucrose %, total soluble solids %, purity %, root yield/fed. (ton) and sugar yield/fed. (ton) in both seasons, reflection the effect of chosen factors on the studied traits of sugar beet.

Sowing dates

The root, quality and yield measurements were affected significantly or higly significantly by sowing dates in both seasons (Table 3).

The highest values of root fresh weight (1.37 and 1.54kg), root length (23.64 and 29.32cm), root diameter (9.85 and 12.54cm), sucrose% (14.26 and 14.56), total soluble solids % (18.99 and 19.18), purity % (75.98 and 75.56.), root yield (25.98 and 27.66ton/fed.) and sugar yield (3.73 and 4.07 56ton/fed.) were recorded when sugar beet sown in 21st October in the first and second seasons, respectively. These results indicating that, the early sowing at 21st October affected positively on root characters, quality and yield traits, that is may be due to appropriate temperature for root growth based on their dimension and dry matter accumulation in the storage roots of growth period. Gobarah et al. (2019) reported that planting of sugar beet during October produced the highest yields of root and sugar, in addition to quality traits in terms of sucrose, purity% and recoverable sugar. These finding are in line with those obtained by Aly (2012), El-Mansoub & Mohamed (2014), and Gobarah et al. (2019).

Nano- micronutrients application

Nano-fertilizers play an important role in increasing productivity crops in developing countries. Enrichment in fertility and the preservation increases the productivity, quality, and reliability of crop (Veronica et al., 2015).

Data in Table 3 and Fig. 1 (A and B) showed that the root fresh weight/plant (kg), root length (cm) ,root diameter (cm) ,sucrose%, total soluble solids %, purity %, root yield /fed. and sugar yield/fed were affected significantly by foliar application of nano-fertilizer in both seasons. The Nano-fertilizer at 60 and 105 days after sowing effected significantly on root traits comparing with control, whereas insignificant differences between the time of Nano treatments. The highest values of root length (23.66 and 29.70cm), root diameter (10.38 and 12.99cm) as well as root fresh weight (1.32 and 1.56kg) were obtained when the Nano- fertilizer was sprayed at 60 days after planting in the first and second seasons, respectively. Significant differences were found among the foliar applications in sucrose and purity percentage as well as comparing with control treatment in both seasons. On the other hand the foliar application after 60 days was differed significantly in TSS compared with both of control and foliar at 105 days in both seasons. The highest percentage of sucrose% (14.59 and 15.26), total soluble solids %(18.54 and 19.37), purity % (78.20 and 78.41), root yield (26.12 and 28.82ton) and sugar yield (3.84 and 4.44ton/fed.) were found in sugar beet fertilized at 60 days. This increment improvement may be attributed to the important roles played by micronutrients as co-enzymes in plant metabolism, positively reflecting in growth and sugar yield (Mekdad & Rady, 2016). An application of nano fertilizer can be increased on plants Growth due to its high absorption and high reactivity (Liu & Lal, 2015). The highest sugar yield and the best technological quality of sugar beet were obtaining by using 100 ppm boron concentration and spraying after 70days after planting under newly reclaimed soil conditions (Abdel-Motagally, 2015). These finding, were in accordance with those reported by Abdel-Motagally (2015), Abd El-Hady (2017), Dewdar et al. (2018), Kopittke et al. (2019) and Kandil et al. (2020). The foliar micronutrients fertilizers such as Zn, Mn, Fe, Mo and Bo during 60-75 days from sowing improved root growth, quality traits%, root and sugar yields/ fed. (Shafika & El-Masry, 2006, Amin et al., 2013)

Performance of sugar beet varieties

Data in Table 3 and Fig. 2 (A and B) showed that the significant differences among the examined varieties (Nabila, Karta, Kosmas and Tesla) for all studied traits in both seasons. Tesla variety (V4) ranked the first one and produced the highest values of root length (24.67 and 34.40cm), root diameter (10.04 and 14.97cm), root fresh weight/ plant (1.30 and 1.77kg), root yield /fed. (27.15 and 28.96 ton), sugar yield/fed. (3.89 and 4.52ton), sucrose % (14.28 and 15.49), purity % (77.35 and 77.94) and T.S.S % (18.38 and 19.80), while, Karta variety came last in the 1st and 2nd seasons, respectively. The highly differences among sugar beet varieties could be due to the genetic make-up and their response to the environmental condition. Mohamed & Yasin (2013) studied the effect of micronutrients (control, B, Zn and their combinations) on four sugar beet varieties (Panther, Des-9003, LP15 and Sibel) and they found that Sugar beet variety Sibel produced the highest values of sugar extraction, purity and extractability percentages. The differences among sugar beet varieties were reported by Enan et al. (2009), Aly (2012), Mohamed & Yasin (2013), Hozayn et al. (2013), El-Emary (2017), Gadallah & Tawfik (2017), Nagib et al. (2018).

TABLE 3.The main effects of planting dates, foliar and varieties on sugar beet growth and quality traits in 2016/2017and 2017/2018 seasons

		Root fresh weight/plant (kg)		Root length (cm)		Root diameter (cm)		Sucrose %		Total soluble solids % (TSS)		Purity %		Root yield (ton/fed.)		Sugar yield (ton/fed).	
		2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018
Sowing Dates	D1	1.37	1.54	23.64	29.32	9.85	12.54	14.26	14.56	18.99	19.18	75.98	75.56	25.99	27.66	3.73	4.07
	D2	1.25	1.34	21.06	26.73	8.77	11.3	11.33	12.49	14.88	17.15	74.74	72.27	24.89	26.59	2.85	3.36
F test		*	**	**	**	**	**	**	**	**	**	*	**	**	**	**	**
Foliar	F1	1.17	1.33	21.63	26.18	8.44	10.9	11.25	12.07	15.63	17.14	72.25	69.98	24.5	25.88	2.77	3.16
	F2	1.32	1.56	23.66	29.7	10.38	12.99	14.59	15.26	18.54	19.37	78.2	78.41	26.12	28.82	3.84	4.44
	F3	1.3	1.42	21.78	28.2	9.13	11.88	12.55	13.23	16.62	17.98	75.65	73.36	25.7	26.67	3.25	3.56
LSD 5%		0.11	0.17	1.68	1.73	0.82	1.21	0.71	0.77	1.67	1.65	2.37	2.86	0.31	0.71	0.63	0.80
Varieties	V1	1.28	1.32	23.96	24.76	9.42	10.5	12.22	12.97	16.52	17.83	73.99	72.39	26.38	26.6	3.24	3.48
	V2	0.9	1.2	19.25	21.52	8.71	9.85	11.43	11.47	15.5	16.25	73.73	70.1	22.09	25.3	2.54	2.92
	V3	1.24	1.47	21.54	31.43	9.08	12.36	13.25	14.17	17.32	18.76	76.38	75.24	26.14	27.64	3.49	3.94
	V4	1.3	1.77	24.67	34.4	10.04	14.97	14.28	15.49	18.38	19.8	77.35	77.94	27.15	28.96	3.89	4.52
LSD 5%		0.16	0.18	1.67	1.93	0.83	0.59	0.91	1.12	1.41	1.38	1.79	1.02	1.25	1.38	0.42	0.37

- D1: Sowing date at 21 October, D2: Sowing date at 21st November, V1: Nabila, V2: Karta , V3: Kosmas, V4: Tesla, F1: Without foliar application (control), F2: Foliar at 60 days from sowing, F3: Foliar at 105 days from sowing.
- LSD :Least significant difference at 5%.

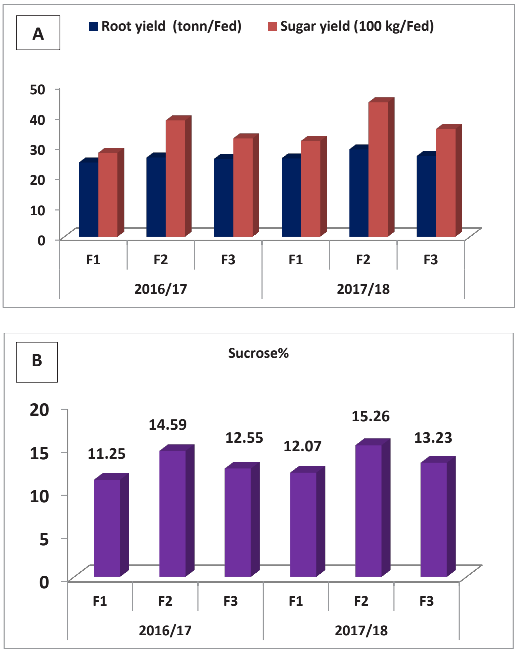

Fig. 1. Effect of foliar application of Nano-micronutrients on: A) Root yield and Sugar yield, B) Sucrose %

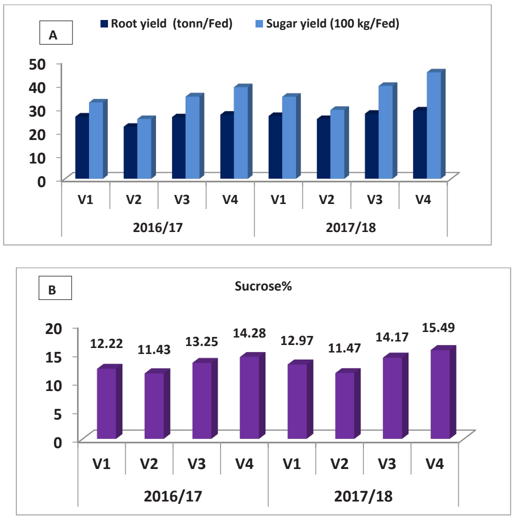

Fig. 2. A: Root yield and Sugar yield, B: Sucrose percentage of four sugar beet varieties

First-order interactions

Planting dates x varieties (D x V) interaction

Data in Table 4 showed that all studied traits had a significantly affected by DxV interaction in the both seasons, except root length and root diameter in the 1st and 2nd seasons, respectively, and purity % and T.S.S % in the 2nd season only. It is clear the Tesla sugar beet variety gave the highest values of root fresh weight (1.49 and 1.89kg/plant), root yield (27.57and 29.49ton/fed.), sugar yield (4.40 and 4.91ton/fed.) and sucrose (15.93 and 16.54%) when It was sown at 21st Oct. in both seasons. While, the lowest values were recorded when Karia variety sowing in late date at 21st November in both seasons. Hence, the results may be due to the genetic make-up differences of varieties and their interaction when sowing at different planting dates, which reflect the climatic conditions. Importance of suitable planting date and select the most stable varieties in agricultural practices in case of early or delayed sowing to maximize root and white sugar yields and improve its quality (Gobarah et al., 2019). These results are in harmony with those obtained by several researches Kaloi et al. (2014), Aly & Khalil (2017) and Gobarah et al. (2019).

Planting dates x foliar application time (D x F)

Data in Table 4 indicated that the effect of the interaction between sowing dates and foliar applications by Nano micro-nutrients was insignificant for all of studied traits except root yield (ton/fed.) and sugar yield (ton/fed.) in the 1st and 2nd seasons, respectively. Foliar applications by Nano micro-nutrients at 60 days after planting and early planting in 21st October produced the highest root yield (26.58 and 29.34ton/fed.), otherwise the lowest root yield (23.74 and 25.32ton/fed.) obtained with the latest date of planting and non-foliar application. It is remarkable result that the highest sugar yield (4.35 and 4.82ton/fed.) correlate with highest root yield in the 1st and 2nd seasons, respectively. This result might be due to the better plant establishment and growth in 21st October date which permitted the plants to fully benefit from foliar applications by Nano micro-nutrients at 60 days after planting. El -Sherief et al. (2016) studied the response of sugar beet during 2012/13 and 2013/14 years and concluded that the effect of application time (after 50 and 75 day after sowing) of the mixture of three levels B, Zn and Mn (zero), 0.5kg B+ 1.5kg Zn + 1kg Mn $fed.^{-1}$) and (1kg B + 3kg Zn + 2kg Mn $fed.^{-1}$) showed insignificant effect on purity %, total soluble solids percentage (TSS%), sucrose percentage. The later application at 75 days insignificantly surpassed the earlier application at planting in effecting purity %, total soluble solids percentage (TSS %) and sucrose percentage. In contrast, El-Gawad et al. (2004) showed that boron application at 105 days after planting had greater effect on qualitative yield of sugar beet than that of the boron application at 90 days after planting, though there was insignificant difference among the treatments.

TABLE 4. The first order of interaction effects between D, F and V on Sugar Beet growth and Quality Traits in two seasons.

		Root fresh weight/plant (kg)		Root length (cm)		Root diameter (cm)		Sucrose %		Total soluble solids % (TSS)		Purity %		Root yield (ton/fed.)		Sugar yield (ton/fed.)	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2016/2017	2016/2017	2017/2018
DV	D1V1	1.46	1.41	25.33	26.39	10	11.03	13.76	14.05	18.81	18.9	73	74.13	26.89	27.13	3.7	3.83
	D1V2	1.11	1.27	20.42	22.53	9.5	10.43	12.56	12.45	17.18	17.13	72.93	72.39	22.77	25.88	2.87	3.24
	D1V3	1.45	1.57	23.17	32.64	9.33	13.08	14.8	15.2	19.5	19.83	75.64	76.48	26.72	28.14	3.96	4.3
	D1V4	1.49	1.89	25.67	35.72	10.58	15.61	15.93	16.54	20.47	20.83	77.41	79.23	27.57	29.49	4.4	4.91
	D2V1	1.37	1.22	22.58	23.13	8.83	9.98	10.68	11.88	14.23	16.77	74.99	70.64	25.88	26.06	2.78	3.12
	D2V2	0.95	1.13	18.08	20.51	8.67	9.27	10.3	10.48	13.83	15.37	74.53	67.81	21.4	24.72	2.21	2.61
	D2V3	1.22	1.37	19.92	30.22	8.08	11.65	11.71	13.13	15.14	17.69	77.13	73.99	25.55	27.15	3.02	3.59
	D2V4	1.31	1.65	23.67	33.08	9.5	14.33	12.63	14.44	16.3	18.77	77.29	76.64	26.72	28.43	3.39	4.14
LSD 5%		0.27	0.42	n.s	n.s	n.s	n.s	0.58	0.63	0.53	n.s	1.12	n.s	0.61	1.23	0.33	0.49
DF	D1F1	1.35	1.41	23.38	27.32	8.75	11.49	12.51	13.1	17.96	18.24	69.35	71.5	25.26	26.43	3.16	3.49
	D1F2	1.41	1.67	24.81	30.93	11.06	13.7	16.24	16.33	20.12	20.29	80.57	80.28	26.58	29.34	4.35	4.82
	D1F3	1.37	1.52	22.75	29.72	9.75	12.42	14.04	14.26	18.88	18.99	74.31	74.9	26.12	27.21	3.69	3.9
	D2F1	1.18	1.26	20.19	25.05	8.13	10.3	10	11.04	13.29	16.04	75.14	68.46	23.74	25.32	2.38	2.83
	D2F2	1.15	1.46	22.5	28.48	9.69	12.28	12.93	14.2	16.97	18.45	75.83	76.53	25.65	28.31	3.34	4.05
	D2F3	1.17	1.31	20.5	26.68	8.5	11.34	11.07	12.21	14.36	16.96	76.99	71.82	25.27	26.14	2.82	3.21
LSD 5%		n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	0.73	1.27	0.48	0.42
FV	F1V1	1.26	1.27	25.38	23.69	9	9.51	10.8	11.75	15.27	16.73	71.22	69.98	25.64	25.6	2.77	3.03
	F1V2	0.87	1.19	18.5	19.83	7.63	9.1	10.43	9.61	14.69	14.83	71.33	64.53	21.04	24.25	2.2	2.34
	F1V3	1.22	1.39	19.13	29.33	8	11.49	11.5	12.89	15.88	17.96	72.77	71.58	25.19	26.4	2.91	3.42
	F1V4	1.34	1.49	24.13	31.9	9.13	13.48	12.28	14.04	16.66	19.04	73.67	73.83	26.14	27.25	3.2	3.84
	F2V1	1.14	1.37	23.38	25.23	10.5	11.63	13.86	14.68	18.22	19.35	75.71	75.7	26.93	28.08	3.74	4.13
	F2V2	1.05	1.2	20.63	23.3	10.75	10.1	12.43	13.18	16.46	17.69	75.22	74.38	23.02	26.61	2.87	3.51
	F2V3	1.41	1.58	23.75	32.63	9.38	13.19	15.47	15.88	19.36	19.9	79.78	79.69	26.68	29.49	4.13	4.69
	F2V4	1.45	2.11	26.88	37.65	10.88	17.04	16.59	17.33	20.15	20.54	82.08	83.86	27.85	31.12	4.63	5.4
	F3V1	1.44	1.32	23.13	25.36	8.75	10.36	12	12.48	16.07	17.43	75.05	71.48	26.59	26.12	3.2	3.27
	F3V2	1.04	1.2	18.63	21.44	8.88	10.35	11.44	11.61	15.36	16.24	74.66	71.4	22.2	25.04	2.55	2.92
	F3V3	1.36	1.45	21.75	32.34	8.75	12.41	12.79	13.74	16.72	18.43	76.6	74.45	26.54	27.03	3.43	3.72
	F3V4	1.39	1.71	23	33.65	10.13	14.39	13.98	15.11	18.34	19.83	76.3	76.12	27.45	28.5	3.84	4.32
LSD 5%		n.s	0.15	2.91	1.63	n.s	1.03	0.7	0.74	0.72	0.66	0.93	1.75	0.45	0.67	0.53	0.65

D1: Sowing date at 21 October, D2: Sowing date at 21 November, V1; Nabila, V2: Karta, V3: Kosmas, V4: Tesla, F1: Without foliar application (control), F2: Foliar at 60 days from sowing, F3: Foliar at 105 days from sowing, LSD: Least significant difference at 5%, n.s: Not significant

The Increase of root yield and sugar yield/ fed caused by foliar applications by Nano micro-nutrients could be attributed to the stimulating effect of Nano micro-nutrients on photosynthesis process in plant such as translocation of sugar and carbohydrates of assimilates from the top to root, which lead to increasing in root and sugar yield.

Varieties x foliar application (V x F)

Data in Table 4 and Fig. 3 (A and B) indicated that all studied traits were significantly affected by interaction between sugar beet varieties and foliar application by Nano micro-nutrients in both seasons, except root fresh weight (kg/plant), root diameter (cm) in the 1st season only. It is clear that Tesla variety treated with foliar application by Nano micro-nutrients at 60 day after planting gave the highest yields of root (27.85 and 31.12ton/fed.) and sugar (4.63 and 5.40 ton/fed) in the 1st and 2nd seasons, respectively. Also, the highest sucrose percentage (16.59 and 17.33%) was recorded in both seasons for Tesla sugar beet variety treated with foliar application by Nano micro-nutrients at 60 day after planting. Tesla sugar beet variety performed growth and yield much better than other varieties in nano- micronutrients treatment (spraying at 60 day after sowing) in the same soil conditions. The superiority of Tesla variety in root yield might be due to its high records of mean root dimensions and weights (Table 2), reflecting high sugar yield over both seasons. The differences of varietal response to foliar by Nano micro-nutrients may be mainly attributed to genetic make-up influences. Use of micronutrients like manganese, Zinc and iron with balance can enhance and Increase the yield of sugar beet crop (Rassam et al., 2015). Mohamed & Yasin (2013) found that Sibel variety treated with foliar application of B and Zn gave the highest root yield (tons/fed.), sugar yield (tons/ fed), sugar extraction % (13.78 and 12.00) and extractability percentage (86.90 and 84.53) were recorded in both seasons. Ehsan et al. (2013) showed that all varieties (Latitia, Florez, Rhizophort, Zarghan and 7112) and zinc treatments (0, 40 and 80kg/ha $ZnSO_4$) had significant effect on yield and sugar yield. Masri & Hamza (2015) explain that the growth, white sugar yield and purity significantly affected by the interaction application of micronutrients and sugar beet cultivars .These results are in line with those obtained in many previous studies Ehsan et al. (2013), Mohamed & Yasin (2013), Rassam et al. (2015), Masri & Hamza (2015), Mekdad & Rady (2016) and Abd El-Hady (2017).

Second order of interaction

Planting dates x foliar application x varieties (D x F x V)

The third interaction effects between the sowing dates, foliar application and sugar beet varieties in Table 5 had insignificant differences for all studied traits. except the sucrose percentage and sugar yield (ton/fed.) in both seasons. The best results of sucrose percentage (18.32 and 18.42) and sugar yield (5.20 and 5.83ton/fed.) were obtained by the second-order interaction application of D1 (sowing at 21 October), F2 (spraying time of 60 day after planting) and V4 (Tesla variety).

Principle component analysis (PCA)

Principal component analysis simplifies the complex data by transforming the number of correlated variables into a smaller number of variables called principal components. To assess the relationship between studied traits and four varieties (Fig. 4 and Table 6) and the relationship between combined treatments (two sowing dates and foliar application of Nano-micronutrients)for sugar yield trait (Fig. 5 and Table 6), principal component analysis was utilized that condensed them to two components (PCA1 and PCA2).

The analysis displayed that the Eigen value of PCA1 was higher than PCA2, highly related to all studied traits in Table 4. Whereas, the PCA1 had the eigen value 7.79 and contributed in 97.33% of the total variation with V3(Kosmas) and V4 (Tesla). Meanwhile, the PCA2 had the eigen value of 0.17 and explained 2.16% of the total variability with V2 (Karta) and V4 (Tesla). Using the biplot diagram (Fig. 4) showed that V3-Kosmas was located among all studied traits.

The relationships (similarities and dissimilarities) between four varieties and studied traits in early and late sowing dates are graphically displayed in abiplot of the two PCs (Fig. 4). According to biplot analysis, the correlation coefficients between each of root length, root fresh weight, T.S.S and root yield traits were positive and highly significant with sugar yield in four varieties (smallest acute angles). This means that selection based on these traits would result in an increasing sugar yield in both environments and these traits were located near V3-Kosmas. While, root diameter, purity % and sucrose % traits were negatively associated with sugar yield, where the angles between them were slightly less than 90 degrees or obtuse and these traits were located near V4 (Tesla) and V2 (Karta). On the other hand, the V1 (Nabila) was located away from all studied traits.

In the Table 6, the Eigen value of PCA1 also was higher than PCA2, highly related to all treatments. Whereas, the PCA1 had the eigen value 5.96 and contributed in 99.35% of the total variation with V3 and V4. Meanwhile, the PCA2 had the eigen value of 0.03 and explained 0.56% of the total variability with V2 and V4. The relationship between combined treatments (two sowing dates and foliar application of Nano-micronutrients) and four varieties for sugar yield trait (Fig. 5 and Table 7), three treatments of foliar Nano- micronutrients (without foliar application, after 60 and 105 from sowing days, respectively).

According to biplot analysis, the correlation coefficients between D1-F2, D1-F3, D2-F2 and D2-F3 treatments were positive and highly significant with four varieties for sugar yield and these treatments were located near V4. Therefore, V4 was the best of sugar yield under these treatments. Meanwhile, V3 were located near D1-F1 and D2-F1 treatments and suitable for them. Kaya et al. (2002), Abdolshahi et al. (2010), Dadbakhsh et al. (2011), Shivramakrishnan et al. (2018) were able to reveal that the genotypes with larger PCA1 and lower PCA2 scores gave high yields (stable genotypes). Moreover, Chahal & Gosal (2002) cleared that characters with largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero.

Conclusion

From this study, it was concluded that significant differences among four sugar beet varieties for all studied traits under the foliar application of Nano fertilizer treatments were found in early and late sowing dates. The mean performances and principal component analysis showed that the most appropriate sugar beet variety for selecting of sugar yield was V4 (Tesla variety) under the most treatments of foliar Nano- micronutrients in two environments (stable and recommended across the test environments), especially under D1 (sowing at 21 October), F2 (spraying time of 60 day after planting). A good hybridization breeding program can be initiated by the selection of genotypes from the PC1 as it contributed maximum toward diversity with maximum eigen value. Under these conditions, we concluded that the Sugar beet plants (Tesla variety) were exhibited the highest sugar yield and quality at sowing of 21st October and fertilized by nano-fertilizer after 60 days from sowing.

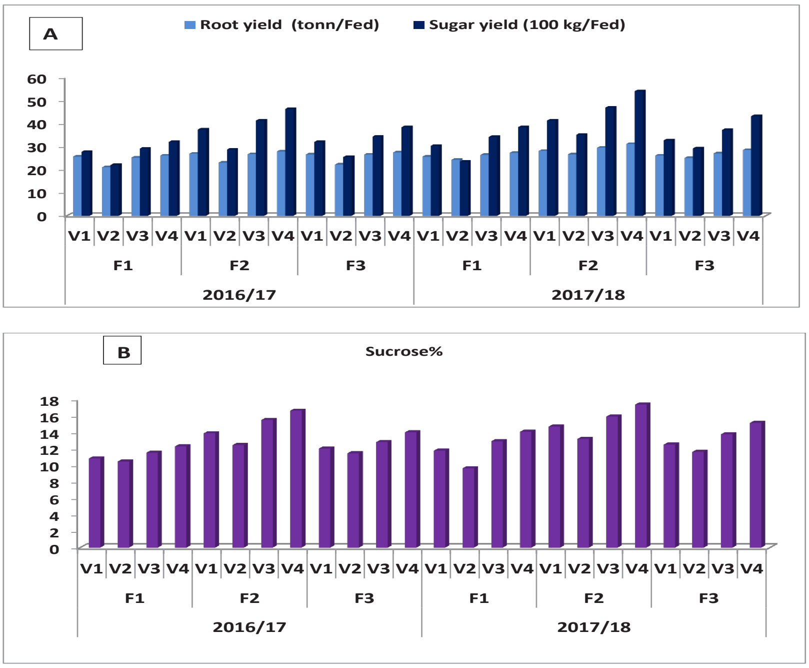

Fig. 3. Effect of foliar application of nano-micronutrients on: A) Root yield and Sugar yield, B) Scurose % of four sugar beet varieties

TABLE 5. The second order of interaction effects between D, F and V on Sugar Beet growth and Quality Traits in two seasons.

			Root fresh weight/plant (kg)		Root length (cm)		Root diameter (cm)		Sucrose %		Total soluble solids % (TSS)		Purity %		Root yield/fed. (ton)		Sugar yield/fed (ton)	
			2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
D1	F1	V1	1.46	1.34	27.00	24.75	9.50	10.03	12.02	12.73	17.70	17.77	67.95	71.45	26.36	26.19	3.15	3.34
		V2	1.06	1.19	20.00	20.88	7.75	9.73	11.07	10.65	16.32	16.00	67.82	66.51	21.96	24.88	2.43	2.65
		V3	1.42	1.48	21.00	30.65	8.50	12.05	12.95	13.98	18.45	19.10	70.09	73.12	26.12	26.87	3.38	3.76
		V4	1.45	1.63	25.50	33.00	9.25	14.15	13.97	15.05	19.37	20.07	71.54	74.91	26.59	27.80	3.68	4.19
	F2	V1	1.49	1.48	25.00	26.58	11.50	12.13	15.67	15.83	20.17	20.50	77.66	77.16	27.37	28.58	4.28	4.54
		V2	1.13	1.30	21.50	24.30	11.25	10.73	14.10	14.18	18.05	18.15	78.12	78.09	23.45	27.11	3.30	3.84
		V3	1.48	1.68	25.50	33.73	9.75	14.23	16.87	16.88	20.77	20.95	81.19	80.51	27.15	30.02	4.58	5.08
		V4	1.54	2.22	27.25	39.10	11.75	17.73	18.32	18.42	21.47	21.57	85.28	85.36	28.35	31.63	5.20	5.83
	F3	V1	1.40	1.42	24.00	27.85	9.00	10.93	13.57	13.60	18.55	18.42	73.36	73.78	26.93	26.65	3.65	3.63
		V2	1.13	1.30	19.75	22.43	9.50	10.85	12.50	12.53	17.15	17.25	72.84	72.57	22.89	25.66	2.86	3.22
		V3	1.45	1.55	23.00	33.55	9.75	12.95	14.57	14.75	19.27	19.45	75.63	75.80	26.88	27.52	3.92	4.06
		V4	1.48	1.82	24.25	35.05	10.75	14.95	15.50	16.15	20.55	20.85	75.41	77.42	27.78	29.03	4.30	4.70
D2	F1	V1	1.33	1.20	23.75	22.63	8.50	9.00	9.57	10.78	12.84	15.68	74.48	68.51	24.90	25.01	2.38	2.72
		V2	0.93	1.19	17.00	18.78	7.50	8.48	9.77	8.58	13.05	13.65	74.82	62.54	20.10	23.63	1.96	2.03
		V3	1.30	1.29	17.25	28.00	7.50	10.92	10.05	11.80	13.31	16.82	75.45	70.03	24.25	25.94	2.43	3.08
		V4	1.50	1.34	22.75	30.80	9.00	12.80	10.57	13.02	13.94	18.00	75.80	72.76	25.69	26.71	2.71	3.49
	F2	V1	1.30	1.26	21.75	23.88	9.50	11.12	12.05	13.53	16.26	18.20	73.75	74.24	26.48	27.58	3.19	3.74
		V2	0.96	1.09	19.75	22.30	10.25	9.48	10.75	12.18	14.86	17.22	72.30	70.66	22.59	26.12	2.43	3.18
		V3	1.32	1.48	22.00	31.53	9.00	12.15	14.06	14.87	17.93	18.85	78.36	78.87	26.20	28.95	3.68	4.31
		V4	1.36	2.00	26.50	36.20	10.00	16.35	14.85	16.22	18.81	19.51	78.87	82.36	27.34	30.62	4.06	4.98
	F3	V1	1.47	1.22	22.25	22.88	8.50	9.80	10.42	11.35	13.58	16.42	76.72	69.17	26.25	25.60	2.74	2.91
		V2	0.96	1.10	17.50	20.45	8.25	9.85	10.37	10.70	13.57	15.22	76.47	70.23	21.51	24.42	2.23	2.62
		V3	1.28	1.34	20.50	31.13	7.75	11.88	11.00	12.72	14.16	17.40	77.57	73.08	26.20	26.55	2.93	3.38
		V4	1.31	1.61	21.75	32.25	9.50	13.83	12.46	14.08	16.12	18.80	77.18	74.80	27.11	27.97	3.38	3.95
LSD 5%			n.s	n.s	n.s	n.s	n.s	n.s	1.05	0.99	n.s	n.s	n.s	n.s	n.s	n.s	0.32	0.43

D1: Sowing date at 21 October, D2: Sowing date at 21 November, V1; Nabila, V2: Karta, V3: Kosmas, V4: Tesla, F1: Without foliar application (control), F2: Foliar at 60 days from sowing, F3: Foliar at 105 days from sowing, LSD: Least significant difference at 5%, n.s: Not significant

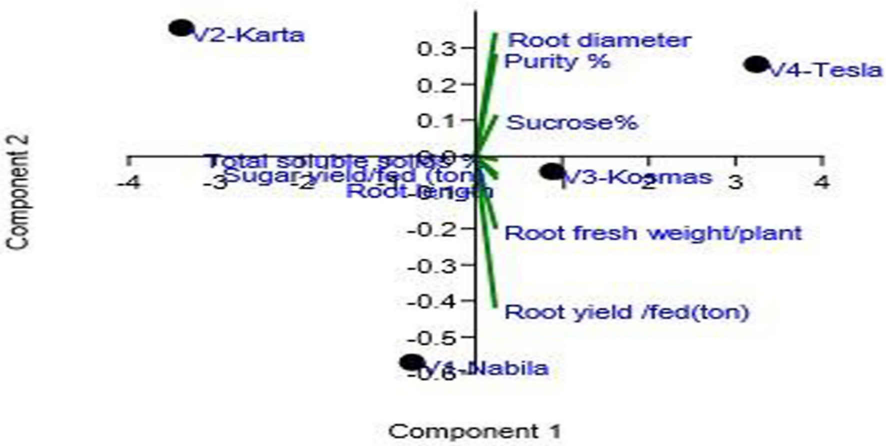

Fig. 4. Biplot diagram based on first two principal component axes of 4 sugar beet varieties according to mean measured of studied traits in two environments

TABLE 6. Contribution of principal component Axis (PCA) to the variation of the morphological traits in sugar beet varieties

Traits	PC 1	PC 2
Root fresh weight/plant	0.35467	-0.30193
Root length	0.35809	-0.091855
Root diameter	0.34605	0.52159
Sucrose %	0.35712	0.17069
Total soluble solids %	0.35819	-0.014316
Purity %	0.35037	0.42995
Root yield /fed(ton)	0.34548	-0.6394
Sugar yield/fed (ton)	0.35817	-0.072827
Eigenvalue	7.78633	0.172741
% variance	97.33	2.16
Cumulative variance	97.33	99.49

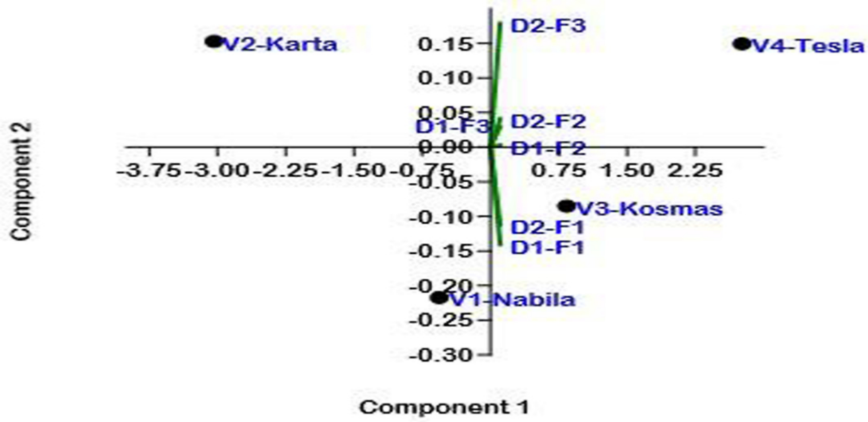

Fig. 5. A biplot of sugar yield (ton/fed.) for 4 sugar beet varieties in the eight environments

TABLE 7. Contribution of Principal Component Axis (PCA) to the variation of 4 sugar beet varieties in the eight environments for sugar yield

Traits	PC 1	PC 2
D1-F1	0.40746	-0.54371
D1-F2	0.40944	0.01268
D1-F3	0.40948	0.11481
D2-F1	0.4081	-0.43303
D2-F2	0.40874	0.15936
D2-F3	0.40626	0.69146
Eigenvalue	5.96	0.033
% variance	99.35	0.56
Cumulative variance	99.35	99.91

D1: First sowing date, D2: Second sowing date, F1, F2 and F3: three treatments of foliar Nano- micronutrients (without foliar application, after 60 and 105 from sowing days, respectively).

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تأثير تسميد النانو بالعناصر الصغرى على المحصول والجودة لبعض أصناف بنجر السكر تحت مواعيد الزراعة المبكرة والمتأخرة

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أقيمت التجربة الحقلية بمزرعة كلية الزراعة جامعة سوهاج فى الموسم الشتوى لعامى 2016/2017 و2017/2018 لدراسة تأثيرسماد النانو بالعناصر الصغرى على المحصول والجودة لبعض أصناف بنجر السكر تحت ظروف الزراعة المبكرة (21 اكتوبر) والمتأخرة (21 نوفمبر).

أظهرت النتائج أن:

- ميعاد الزراعة المبكر في 21 أكتوبر أدى إلى زيادة فى وزن الجذور و صفات الجودة ونسبة السكر ومحصول الجذور مقارنة بميعاد الزراعة المتأخر في 21 نوفمبر في كلا الموسمين.

- أثر تطبيق الرش الورقى لمعاملات تسميد النانو بالعناصر الصغرى معنويا على جميع الصفات المدروسة. حيث ان الرش الورقي بعد 60 يوما من الزراعة اعطى أعلى القيم لجميع الصفات المدروسة مقارنة مع كل من الرش الورقى بعد 105 يوم وبدون رش في كلا الموسمين.

- وجود اختلافات معنوية بين أصناف بنجر السكر الأربعة (Nabila, Karta, Kosmas and Tesla) في جميع الصفات المدروسة في كلا الموسمين.

- تفوق الصنف Teslaعن باقى الأصناف فى جميع الصفات المدروسة. أظهرت جميع تأثيرات التفاعل فروق معنوية في الوزن الرطب للجذر، السكروز، المواد الصلبة الكلية، النقاوة، محصول الجذور ومحصول السكر. تم الحصول على أعلى نسبة سكروز (18.32 و 18.42٪) ومحصول سكر (5.20 و5.83 طن / فدان) عند راعة صنفTesla مبكرا فى 21 اكتوبر والرش بعد 60 يومًا من الزراعة في موسمين 2016/2017 و 2017/2018 على التوالى.