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IMPACT OF PLANTING DENSITY, NITROGEN AND POTASSIUM FERTILIZER LEVELS ON YIELD AND QUALITY OF SUGAR BEET

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ABSTRACT: Two field experiments were carried out at the experimental farm (Ghazala Village), Faculty of Agriculture, Zagazig University, Sharkia Governorate, during 2016/2017 and 2017/2018 seasons to study the influence of three planting densities, (28000, 35000 and 46666 plants/fad.) three levels of N fertilizer (80,100 and 120 kg/fad.) and two levels of potassium fertilizer (24 and 48 kg k_2O/fad.) on yield and its attributes as well as quality of sugar beet grown in clay soil. Results of combined analysis illustrated that, decreasing planting density from 46666 to 35000 or 28000 plants/ fad., significantly increased root length, root diameter and fresh root weight g/plant; on the other hand the highest planting density (46666 plants/fad.) produced higher sucrose, extractable sugar percentages, sugar and recoverable sugar yields/fad., than low or medium densities. Raising N fertilizer levels significantly affected yield and its attributes as well as quality of sugar beet. Where, the results of the combined analysis indicated that, each increment of nitrogen fertilizer level from 80 up to 120 kg N/fad., cm was accompanied with a significant increase in root length, root diameter, fresh root weight/plant, root and recoverable sugar yields/fad., but significantly decreased sucrose (%). Data of combined analysis also revealed that application of 48 kg K_2O/fad., significantly increased root yield attributes *i.e.,* root length root diameter (cm), fresh root weight g/plant, sucrose, extractable sugar percentages, as well as, root and recoverable sugar yields ton/fad., compared with supply of 24 kg K_2O/fad. Interactions between the studied factors (according to the combined analysis) indicated that the highest root yield (ton/fad.) was achieved when sugar beet was sown with the highest plant density of 46666 plants/fad., and fertilized with 120 kg N/fad. As well as, the highest value of root diameter (cm) was achieved under the application of 120 kg N/fad., and addition of 48 kg K_2O/fad., while, the interaction between planting densities and potassium fertilizer levels had no significant effects on all studied traits.

Key words: Sugar beet, planting density, nitrogen, potassium levels.

INTRODUCTION

In Egypt, sugar beet (*Beta vulgaris* L.) considered as one of the most important sugar crops where it is the second crop for sugar production after sugar cane. Particularly, as it is good adapted to various Egyptian environmental conditions especially in newly reclaimed soils at North of Egypt due to its salinity tolerance. Sugar beet productivity in Egypt reached about 12.11 million ton from approximately 584978 fad. **(FAOSTAT, 2019).**

Maximizing productivity and quality of sugar beet could be achieved by using appropriate planting density which deem as a very important factor affecting yield and quality of sugar beet. In this respect, **Nafei *et al.* (2010), El-Ghareib *et al*. (2012)** and **El-Hity *et al.* (2014)** stated that, the planting densities of 48000, 46666, 42000, 56000 and 52000 plants/fad., respectively gave the highest root, top and sugar yields/fad., root length and diameter, fresh weight/plant, sucrose (%) and purity (%). Otherwise, **Sarhan *et al.* (2012)** revealed that, planting sugar beet with density of 28000 plants/fad., produced the

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highest values of root length and diameter as well as root fresh weight/plant. On the other hand, they added that high planting density of 35000 plants/fad., produced the highest yields of roots and sugar, while, the highest density of 46000 plants/fad., gave the superior averages of sucrose and purity percentage. Moreover, **Varga *et al.* (2015)** found that narrower intra-row spacing (13 and 15 cm) reduced the average of root weight in comparison to wider intra-row spacing (17 and 19 cm). In addition, **Yasin (2017)** concluded that decreasing planting density from 42000 to 33600 and 28000 plants/fad., increased root yield attributes, and sugar lost in molasses (SLM%), otherwise, the highest root yield/ fad., were achieved by dense planting of 42000 plants/fad.

Substantially nitrogen nutrition pronounced affects sugar beet productivity and quality, where lack of nitrogen will lead to a significant decrease in root yield, likewise excess nitrogen will cuse significant reduction in sucrose content of root and excessive leaf growth (**Blumentbal, 1996**). In this manner, **Amin *et al.* (2013)** and **Mahmoud *et al.* (2014)** revealed that, increasing nitrogen fertilizer level up to 100 kg N/fad., significantly increased root and sugar yields/ fad., also produced the highest sugar beet growth traits, but decreased sucrose percentage. In addition, many researchers reported that increasing nitrogen fertilizer levels up to 150 kg N/fad., gave a significant increase in sugar beet yield and its components **(Abou-Shady *et al.*, 2011; Osman, 2011; Abdou**, **2013; Awad *et al.*, 2013; El-Sayed, 2013)**, on the opposite, increasing nitrogen fertilizer level decreased significantly quality traits *i.e.* sucrose and purity (%). Moreover, **Omar and Mohamed (2013**) reported that increasing N fertilizer levels from 50 to 125 kg/fad., caused significant increase in root length, root diameter, fresh root weigh/ plant, sugar loss in molasses (%) and root yield/ fad. They added that, recoverable sugar yield was responded only to 100 kg N/fad., and the highest sugar (%), purity (%) and extractable sugar (%) were resulted from applying low nitrogen levels (either 50 or 75 kg N/fad.). Meanwhile, **Mekdad (2015)** indicated that there was a significant increase in root fresh weight, top fresh wight, root yield, gross sugar yield and lost sugar yield of sugar beet with increasing nitrogen up to 140 kg N/fad., compared to 100 kg N/fad., but nitrogen fertilizer level had no significant effect on purity (%). As well, **Ismail *et al.* (2016)** showed that increasing nitrogen fertilizer level up to 120 kg N/fad significantly increased root fresh weight, root length, root diameter, root and sugar yields/fad. **Ali and Yasin, (2016)** illustrated that the highest value for each of root diameter, root weight/plant, SLM%, root yield/fad., was achieved with applying 140 kg N/fad., while that level of nitrogen decreased sucrose (%), purity (%) and extractable sugar (%).

Potassium plays a main role in osmotic potential regulation, increasing water uptake ability of sugar beet plants (**Rengel and Damon, 2008; Zengin *et al.*, 2009).** There were many studies about the effect of K fertilizer levels on sugar beet grown in various soils. **Awad *et al.* (2013)** indicated that applying potassium fertilizer at the level of 48 kg K_2O/fad., produced the highest sugar loss (%) and sugar yield/fad., compared with the lowest rate of 12 kg K_2O/ fad., while 24 kg K_2O/fad., was statistically at par with 48 kg K_2O/fad. Similar results were reported by **Yasin (2017)** who reported that applying either 24 or 48 kg K_2O/fad., resulted in a significant increase in root length, sucrose (%), extractable sugar (%), SLM (%), root yield/fad. compared with control. The increment of potassium fertilizer level up to 36, 42 and 59 kg K_2O/fad., led to a significant increase in sugar beet root and top yields and impure sugar (%) as well as pure sugar yield **(Nafei *et al.*, 2010; Mehrandish *et al.*, 2012; El-Sarag and Moselhy, 2013**). Also, **Abdelaal *et al.* (2015)** showed that, K fertilizer level of 48 kg K_2O/fad., gave the highest average for each of root length and diameter as well as root and sugar yields/ fad. In the contrary, sucrose (%) was reduced with the increase of K level up to 36 kg K_2O/ fad., **Merwad (2016)** concluded that top, root and recoverable sugar yields/ha, sucrose (%) and purity (%) were significantly increased.

This investigation was carried out to study the effect of three planting densities, three levels of N fertilizer and two levels of potassium fertilizer on yield and its attributes as well as quality of sugar beet under clay soil conditions.

MATERIALS AND METHODS

Two field experiments were performed at the Experimental farm (Ghazala Village), Faculty of

Agriculture, Zagazig University, Sharkia Governorate, Egypt (30.11-N, 31.41-E) during the two successive winter seasons of 2016/ 2017 and 2017/ 2018 to find out the influence of planting density, nitrogen and potassium fertilizer levels on yield and quality of sugar beet. In both seasons, the preceding crop was corn (*Zea mays* L.). The soil samples were collected from the experimental sites at the depth of 0-30 cm before planting to determine soil mechanical and chemical properties. Mechanical and chemical analyses were carried out in Central Laboratory of Faculty of Agriculture, Zagazig University. The soil was clay in texture; it has a particle size distribution of 22.63, 30.67 and 46.70% for sand, silt and clay, respectively. It had an average pH value of 7.99, EC 1.88 dSm^{-1} (soil paste extract) and organic matter content of 1.04%. The available N, P and K contents were 58.91, 8.95 and 148.10 mg kg^{-1}, respectively. A split plot design with three replicates was used. In this experiment planting densities of 28000, 35000 and 46666 plants/fad., were assigned to main plots and the combination between nitrogen (80, 100 and 120 kg N/fad.) and potassium (24 and 48 kg K_2O/fad.) fertilizer levels were distributed in the sub-plots. Each experiment included 18 treatments which were the combinations of three planting densities, three levels of nitrogen fertilizer and two levels of potassium fertilizer. Each sub plot (10.8 m^2) contained 6 ridges, 3 m long 60 cm apart. Seeds of sugar beet were planted at distance of 25, 20 and 15 cm between hills to obtain 28000, 35000 and 46666 plants/ fad., respectively. Phosphorus fertilizer was added during seed bed preparation at level of 31 kg P_2O_5/fad., in the form of calcium superphosphate (15.5% P_2O_5). Nitrogen fertilizer applied in the form of urea (46.5% N) at three equal doses, the first was applied after thinning (*i.e.* 30 days after sowing) and the others were applied at 21 days intervals after the first application. Potassium fertilizer at the studied levels in the form of potassium sulphate (48% K_2O) was applied with the second dose of nitrogen (51 days after sowing). Planting was done on 16 and 28th of November in the first and the second seasons, respectively. Manual planting was applied in hills with approximately 3-4 seeds per hill and then plants were thinned after 30 days from sowing. Plants were kept free from weeds by hand hoeing for three times. The other regular agronomic practices, except the studied factors were done as recommended during growth seasons.

Studied Characters

Root yield and its attributes

At harvest (195 days after sowing) five plants were randomly taken from the second ridge of each plot to determine root length (cm), root diameter (cm), and fresh root weigh g/plant.

All plants of the third and fourth central ridges of each plot were harvested to estimate. root yield (ton/fad.), and recoverable sugar yield (ton/fad.) which calculated as follows:

Root yield × extractable sugar (%)

Quality parameters

Sucrose percentage (%) was determined using polarimeter on a lead acetate extract of fresh macerated root as well as, impurities (Na, K and alpha amino nitrogen) were determined according to **AOAC (2005)**. Purity percentage (%) was calculated according to **Devillers (1988**) following this equation: Purity=99.36– [14.27 (Na+K+α-amino nitrogen)/ sucrose (%)]. Sugar loss in molasses (SLM %) = 0.14 (Na + K)+0.25 (α-amino nitrogen)+0.50, was determined according to **Devillers (1988)**. Extractable sugar percentage (%) was determined according to **Dexter *et al.* (1967)** following this equation.

Extractable sugar percentage (%) = Sucrose (%) - SLM (%) - 0.60).

Purity percentage (%) was calculated according to the following equation (**Devillers, 1988**):

Purity = 99.36 – [14.27 (Na + K+ α-amino nitrogen)/ sucrose %].

Sugar lost in molasses (SLM%) = 0.14 (Na + K) + 0.25 (α- amino nitrogen) + 0.50 **(Devillers, 1988**).

Extractable sugar percentage (%) = Sucrose (%) - SLM (%) - 0.60 (**Dexter *et al*., 1967**).

Statistical Analysis

The obtained data of the two seasons as well as their combined were statistically analyzed as described by **Gomez and Gomez (1984)** using the computer MSTAT statistical analysis package **(MSTAT-C, 1991)**. Least significant differences (LSD) method was used to test the differences between treatment means at 5% level of probability as mentioned by **Steel *et al.* (1997)**. The error mean squares of split plot design were homogenous (Bartlett's test), the combined analysis was calculated for all the studied characters in both seasons. In interaction Tables, capital letters were used to compare the values in rows, while small letters were used to compare the values in columns.

RESULTS AND DISCUSSION

Effect of Planting Densities

Root yield attributes

Results presented in Table 1 indicate that, root length and diameter as well as fresh root weight/ plant were significantly affected by studied planting densities during both seasons and their combined analysis, except root length in the first season. It could be concluded that, decreasing planting density from 46666 plants/fad., to 35000 or 28000 plants/fad., significantly increased root length, root diameter and fresh root weight/ plant. These results may explain that low planting density of 28000 plants/fad., minimize the inter competition between plants which led to high light use efficiency of solar radiation utilized by plants. In turn high in the conversion of light energy to chemical energy and consequently high accumulation of dry mater and increase of yield and its attributes. In this connection, **Sarhan *et al.* (2012)** studied the effect of planting density (46000, 35000 and 28000 plants/fad.) on sugar beet and they found that sowing sugar beet plants with low density (28000 plants/fad.) recorded the highest values of root length and diameter as well as fresh root weight/plant. Also, the obtained results are in agreements with those noticed by **Shalaby *et al.* (2011), El-Ghareib *et al.* (2012), El-Hity *et al.* (2014) and Yasin (2017)**.

Juice quality

As shown in Tables 2 and 3, the results of the first season indicate that the tried densities were without significant effect on sucrose and extractable sugar percentages. Whereas, the results of the 2nd season and the combined of both seasons, revealed that the high planting density gave higher sucrose and extractable sugar percentages than low or medium densities. On the other hand, purity and sugar lost in molasses percentages showed insignificant response to the studied planting densities. The obtained results concerning sucrose and extractable sugar percentages are in concurrence with those recorded by **Hozayn *et al.* (2013), El-Hity *et al.* (2014) and Yasin (2017).** However **Refay (2000)** indicated that planting densities had no significant effect on sugar percentage of sugar beet. The obtained results regarding purity (%) and SLM (%) are in disagree with those reported by **Yasin (2017)** who recorded significant increment in purity and SLM percentages due to increasing planting density.

Root yield and recoverable sugar yield

The results of both seasons confirmed with those of the combined analysis and revealed highly significant differences among the tested planting densities in root and recoverable sugar yields/fad., (Table 3). Where root and recoverable sugar yields/fad., showed significant and gradual increment with each increase in planting density up to 46666 plants/fad. However, the differences between low and moderate planting densities did not reach the level of significant during the second season and the combined analysis regarding root yield as well as, during the second season respecting to recoverable sugar yield. The obtained results are in agreement with those reported by **Hozayn *et al.* (2013) and El-Hity *et al.* (2014)** regarding sugar yield/fad. Also, **Yasin (2017)** recorded significant increments in recoverable sugar yield/fad., due to increasing planting density up to 42000 plants/fad.

Effect of Nitrogen Fertilizer Levels

Root yield attributes

The results presented in Table 1 indicate that root length and diameter as well as fresh root weight/plant were highly significant affected by nitrogen fertilizer levels during both seasons and their combined analysis. Regarding the results of the combined analysis it could be concluded that, any increment of nitrogen fertilizer level from 80 up to 120 kg N/fad., was accompanied with a significant increase in each of root length,

Table 1. Root length, root diameter (cm) and fresh root weight/plant (g) of sugar beet as affected by planting density, nitrogen and potassium fertilizer levels during two successive winter seasons (2016/2017 and 2017/2018) as well as their combined analysis

Main effects and interactions	Root length (cm)			Root diameter (cm)			Fresh root weight/plant (g)		
	2016/ 2017 season	2017/ 2018 season	Comb. analysis	2016/ 2017 season	2017/ 2018 season	Comb. analysis	2016/ 2017 season	2017/ 2018 season	Comb. analysis
Planting density (D)									
28000 plants/fad.	19.84	20.80 a	20.32 a	11.85 a	12.05 a	11.95 a	1358 a	1470 a	1414 a
35000 plants/fad.	19.74	19.51 b	19.63 ab	12.03 a	12.31 a	12.17 a	1359 a	1270 b	1315 a
46666 plants/fad.	19.42	18.66 b	19.04 b	10.77 b	10.95 b	10.86 b	1173 b	1138 b	1156 b
F-test	NS	*	*	*	*	*	*	*	*
Nitrogen fertilizer level (N)									
80 Kg N/fad.	18.69 b	17.81 b	18.25 c	10.78 c	10.73 b	10.76 c	1109 b	1080 b	1095 c
100 Kg N/fad.	19.56 b	19.44 b	19.50 b	11.61 b	11.59 b	11.60 b	1254 b	1246 b	1250 b
120 Kg N/fad.	20.74 a	21.71 a	21.23 a	12.19 a	12.98 a	12.59 a	1527 a	1552 a	1540 a
F-test	**	**	**	**	**	**	**	**	**
Potassium fertilizer level (K)									
24 Kg K_2O/fad.	19.17	18.38	18.78	11.37	11.26	11.32	1273	1185	1229
48 Kg K_2O/fad.	20.16	20.93	20.55	11.69	12.27	11.98	1321	1400	1361
F-test	**	**	**	NS	**	**	*	**	**
Interactions									
D×N	*	*	NS	*	*	*	NS	*	NS
D×K	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×K	NS	NS	NS	NS	NS	NS	*	NS	NS

Where: NS, * and ** refers to not significant, significant at 5% and 1% level, respectively.

root diameter and fresh root weight/plant. These results supported by those recorded by **Abdo (2013), Omar and Mohamed (2013)** and **Abdou *et al.* (2014).** Also, **Ali and Yasin (2016)** revealed that raising N fertilizer level up to 105 kg/fad., significantly increased root length whereas, root diameter and fresh root weight/ plant were significantly increased due to increasing nitrogen fertilizer level up to 140 kg N/fad.

Juice quality

The presented results in Tables 2 and 3 reveal that all juice quality traits were affected significantly by the investigated nitrogen fertilizer level, with the exception of sucrose and extraetable sugar (%) in the first season as well as purity (%) during both seasons and their combined analysis. Regarding the combined analysis, it could be noticed that, increasing nitrogen fertilizer level from 80 to 100 or 120 kg N/fad., significantly decreased sucrose (%). Also, extractable sugar (%) exhibited significant reduction with each increment of nitrogen fertilizer levels up to 120 kg N/fad. Contrariwise, raising nitrogen fertilizer level rather than 100 kg N/fad., caused significant increase in sugar lost in molasses (%). Such decrease in sucrose and extractable sugar percentages with the increase in nitrogen fertilizer level may be due to the role of nitrogen through the increase of cell size and its water content and thus the root content of those quality parameters became little through the dilution effect. In other words, increasing nitrogen fertilizer level significantly increased non-sugar substances such as protein, amino acids and other substances which lead to decrease sucrose and extractable sugar percentages as explained by **Gobarah *et al.* (2010)**. The obtained results are in accordance with those mentioned by **Omar and Mohamed (2013), Abdou *et al.* (2014)** as well as **Ali and Yasin (2016).** On the other direction, **El-Sonbaty *et al.* (2012)** indicated that increasing nitrogen fertilizer level from 60 to 90 kg N/fad., significantly increased sucrose (%).

Root yield and recoverable sugar yield

Concerning the influence of nitrogen fertilizer levels on root and recoverable sugar yields/fad., (Table 3), the statistical analysis revealed significant differences throughout both seasons

Table 2. Sucrose (%), purity (%) and sugar lost in molasses (%) of sugar beet as affected by planting density, nitrogen and potassium fertilizer levels during two successive winter seasons (2016/2017 and 2017/2018) as well as their combined analysis

Main effects and interactions	Sucrose (%)			Purity (%)			Sugar lost in molasses (%)		
	2016/ 2017 season	2017/ 2018 season	Comb. analysis	2016/ 2017 season	2017/ 2018 season	Comb. analysis	2016/ 2017 season	2017/ 2018 season	Comb. analysis
Planting density(D)									
28000 plants/fad.	14.96	15.19 b	15.08 b	96.10	95.69	95.89	1.96	2.02	1.99
35000 plants/fad.	14.92	15.38 b	15.15 b	95.95	95.98	95.96	2.04	1.94	1.99
46666 plants/fad.	15.29	17.18 a	16.24 a	96.06	96.34	96.20	1.97	1.95	1.96
F-test	NS	**	**	NS	NS	NS	NS	NS	NS
Nitrogen fertilizer level (N)									
80 Kg N/fad.	15.09	16.52 a	15.81 a	95.98	96.34	96.16	1.96 b	1.91 b	1.93 b
100 Kg N/fad.	14.98	15.89 b	15.44 b	96.09	95.98	96.04	1.97 b	1.95 b	1.96 b
120 Kg N/fad.	15.08	15.35 c	15.22 b	96.04	95.69	95.86	2.05 a	2.06 a	2.06 a
F-test	NS	**	**	NS	NS	NS	**	**	**
Potassium fertilizer level (K)									
24 Kg K_2O/fad.	15.16	15.03	15.10	96.15	95.98	96.06	1.97	1.93	1.95
48 Kg K_2O/fad.	14.95	16.80	15.88	95.92	96.02	95.97	2.01	2.01	2.01
F-test	NS	**	**	NS	NS	NS	NS	**	**
Interactions									
D×N	NS	NS	NS	NS	NS	NS	**	NS	NS
D×K	NS	*	NS	NS	NS	NS	NS	NS	NS
N×K	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where: NS, * and ** refers to not significant, significant at 5% and 1% level, respectively.

Table 3. Extractable sugar (%), root yield (ton/fad.) and recoverable sugar yield (ton/fad.) of sugar beet as affected by planting density, nitrogen and potassium fertilizer levels during two successive winter seasons (2016/2017 and 2017/2018) as well as their combined analysis

Main effects and interactions	Extractable sugar (%)			Root yield (ton/fad)			Recoverable sugar yield (ton/fad)		
	2016/ 2017 season	2017/ 2018 season	Comb. analysis	2016/ 2017 season	2017/ 2018 season	Comb. analysis	2016/ 2017 season	2017/ 2018 season	Comb. analysis
Planting density (D)									
28000 plants/fad.	12.53	12.57 b	12.55 b	33.23 c	32.92 b	33.08 b	4.16 c	4.14 b	4.15 c
35000 plants/fad.	12.37	12.84 b	12.60 b	38.29 b	35.54 b	36.92 b	4.73 b	4.57 b	4.65 b
46666 plants/fad.	12.70	14.63 a	13.66 a	42.44 a	42.91 a	42.68 a	5.38 a	6.25 a	5.82 a
F-test	NS	**	**	**	*	*	**	**	**
Nitrogen fertilizer level (N)									
80 Kg N/fad.	12.66	14.01 a	13.34 a	35.92 b	31.58 c	33.75 c	4.53 b	4.48 c	4.51 c
100 Kg N/fad.	12.43	13.34 b	12.88 b	38.08 ab	36.76 b	37.42 b	4.73 ab	4.95 b	4.84 b
120 Kg N/fad.	12.52	12.69 c	12.60 c	39.96 a	43.03 a	41.50 a	5.00 a	5.53 a	5.26 a
F-test	NS	**	**	*	**	**	**	**	**
Potassium fertilizer level (K)									
24 Kg K_2O/fad.	12.66	12.50	12.58	38.94	34.25	36.60	4.68	4.28	4.48
48 Kg K_2O/fad.	12.41	14.19	13.30	37.03	40.00	38.52	4.83	5.69	5.26
F-test	NS	**	**	NS	**	**	NS	**	**
Interactions									
D×N	NS	NS	NS	NS	*	*	NS	NS	NS
D×K	**	NS	NS	NS	*	NS	NS	NS	NS
N×K	NS	NS	NS	NS	NS	NS	NS	NS	NS

Where: NS, * and ** refers to not significant, significant at 5% and 1% level, respectively.

and their combined analysis. Where increasing N-level from 80 to 100 and then to 120 kg/fad., tended to increase gradualy root and recoverable sugar yields/fad. Therefore, the highest value of each root and recoverable sugar yields/fad., was achieved by the highest N-level of 120 kg/fad., which followed by mid-level of 100 kg N/fad., while the lowest value for each of root and recoverable sugar yield was resulted by the low N-level of 80 kg/fad. In this connection, **Mekdad (2015)** reported that, each increase in nitrogen fertilizer level from 100 to 140 kg N/fad., caused a gradual increment in sugar yield. The obtained results are in harmony with those reported by **Abdou *et al.* (2014)** and **Ali and Yasin (2016).**

Effect of Potassium Fertilizer Levels

Root yield attributes

The results of the two seasons and their combined analysis detected that application of 48 kg K_2O/fad., significantly increased root yield attributes *i.e.* root length, root diameter and fresh root weight/plant, as compared to the application of 24 kg K_2O/fad. However, root diameter showed insignificant response to the studied potassium fertilizer levels in the first season. Many investigators reported significant increment in root yield attributes due to raising potassium fertilizer levels up to 48 kg K_2O/fad., such like, **Abdelaal *et al.* (2015)** and **Ferweez** and **Abd El-Monem (2018).**

Juice quality

In spite of the none significant differences between potassium fertilizer levels regarding sucrose, extractable sugar and sugar lost in molasses percentages in the 1st season, the results of the 2nd season confirmed by those of the combined analysis for the two seasons detected that the plants fertilized with 48 kg K_2O/fad., recorded higher means of the aforementioned traits compared with those fertilized with 24 kg K_2O/ fad. However, purity (%) exhibited no significant response to the studied potassium fertilizer rates. The increment of SLM% due to increasing potassium fertilizer rate may be attributed to the fact that high quantities of potassium in sugar beet roots increases impurities [Na (%), K (%) and alpha amino-N (%)] and decreased crystallization of sucrose in juice leading to loss of sucrose in molasses. The obtained results are in accordance with those mentioned by **Awad *et al.* (2013)** and **Yasin (2017)**. Also, **Ferweez and Abd El-Monem (2018)** investigated the effect of potassium fertilizer rates (0.0, 24.0 and 48.0 kg K_2O/fad.) on yield and quality of sugar beet and found that increasing K fertilizer rates up to 48.0 kg K_2O/fad., significantly increased sugar lost in molasses. They added that the highest values for each of sucrose and recoverable sugar percentages were obtained by the application of 24.0 kg K_2O/fad.

Root yield and recoverable sugar yield

In spite of the insignificant differences between potassium fertilizer levels on root and recoverable sugar yields/fad., in the 1st season, the results of the 2nd season confirmed by those of the combined analysis for the two seasons detected that, plants fertilized with 48 kg K_2O/fad., recorded higher root and recoverable sugar yields/fad., compared with those fertilized with 24 kg K_2O/fad. The increment in root and recoverable sugar yields may be ascribed to that potassium plays a vital role in photosynthesis due to carbohydrate metabolism, osmotic regulation, nitrogen absorption, protein synthesis and assimilates translocation **(Ulgen *et al.*, 2009; Nafei *et al.*, 2010).**

Impact of Interactions

Interaction between planting densities and nitrogen fertilizer levels

It could be noticed that the highest root yield was achieved when sugar beet was sown with the high planting density of 46666 plants/fad., and fertilized with 120 kg N/fad. On the other side, the lowest root yield was obtained when sugar beet was sown with the low planting density of 28000 plants/fad., and fertilized with 80 kg N/fad. (Table 4).

Interaction between planting densities and potassium fertilizer levels

The interaction between planting densities and potassium fertilizer levels had no significant effects on all studied traits during the combined analysis.

Interaction between nitrogen and potassium fertilizer levels

It could be concluded that, the highest value of root diameter was achieved under the application of 120 kg N/fad., and addition of 48 kg K_2O_5/fad. Contrariwise, the lowest value of root diameter was obtained under the application of 80 kg N/fad., regardless potassium fertilizer rate (Table 5).

Table 4. Root yield of sugar beet as affected by the interaction between planting densities and nitrogen fertilizer levels (combined analysis of the two seasons)

Nitrogen fertilizer level	Planting density		
	28000 plants/fad.	35000 plants/fad.	46666 plants/fad.
	C	B	A
80 kg N/fad.	29.51 b	34.06 b	37.69 c
	B	B	A
100 kg N/fad.	34.21 a	35.96 b	42.09 b
	C	B	A
120 kg N/fad.	35.51 a	40.72 a	48.26 a

Table 5. Root diameter of sugar beet as affected by the interaction between nitrogen and potassium fertilizer levels (combined analysis of the two seasons)

Potassium fertilizer level	Nitrogen fertilizer level		
	80 kg N/fad.	100 kg N/fad.	120 kg N/fad.
	B	B	A
24 kg K_2O/fad.	10.88 a	10.97 b	12.10 b
	C	B	A
48 kg K_2O/fad.	10.63 a	12.24 a	13.08 a

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تأثير الكثافة النباتية ومعدلات السماد النيتروجيني والبوتاسى على محصول وجودة بنجر السكر

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تم إجراء تجربتان حقليتان بالمزرعة التجريبية (بقرية غزالة) التابعة لكلية الزراعة، جامعة الزقازيق، محافظة الشرقية، مصر، خلال الموسمين الشتويين ٢٠١٧/٢٠١٦ و ٢٠١٨/٢٠١٧ لدراسة تأثير ثلاث كثافات زراعية، ثلاثة مستويات من السماد النيتروجيني ومستويين من السماد البوتاسي على محصول بنجر السكر ومساهماته وكذلك جودته تحت ظروف الأراضي الطينية، وقد أوضحت نتائج التحليل المشترك أن خفض الكثافة النباتية من ٤٦٦٦٦ إلى ٣٥٠٠٠ أو ٢٨٠٠٠ نبات/فدان أعطى زيادة معنوية في طول وقطر الجذر ووزن الجذر الغض/النبات؛ من ناحية أخرى، أعطت الكثافة النباتية العالية (٤٦٦٦٦ نبات/فدان) أعلى نسبة سكروز ونسبة السكر القابل للاستخراج ومحصول السكر وإنتاجية السكر القابل للاسترداد/فدان، مقارنة بالكثافات المنخفضة أو المتوسطة؛ زيادة مستويات السماد النيتروجيني كان له تأثيراً معنوياً على المحصول ومساهماته وكذلك على جودة بنجر السكر، حيث خلصت نتائج التحليل المشترك إلى أن كل زيادة في مستوى السماد النيتروجيني من ٨٠ إلى ١٢٠ كجم ن/فدان كانت مصحوبة بزيادة كبيرة في طول وقطر الجذر ووزن الجذر الغض/النبات ومحصول الجذور ومحصول السكر القابل للاسترداد/فدان، ولكن نسبة السكروز (%) انخفضت معنوياً، وكشفت نتائج التحليل المشترك أيضًا أن إضافة ٤٨ كجم K_2O/ فدان أدت لزيادة معنوية في مساهمات محصول الجذر (طول الجذر، وقطر الجذر، وزن الجذر الغض/النبات)، نسبة السكروز، والنسبة المئوية للسكر القابل للاستخراج، وكذلك محصول الجذور ومحصول السكر القابلة للاسترداد/فدان، مقارنة بالمستوى ٢٤ كجم K_2O/فدان، وقد أشارت التفاعلات بين عوامل الدراسة وفقًا للتحليل المشترك إلى أن أعلى محصول للجذور قد تحقق عندما تمت زراعة بنجر السكر بكثافة نباتية عالية تبلغ ٤٦٦٦٦ نباتًا/فدان وتسميده بـ ١٢٠ كجم ن/فدان، وكذلك فإن أعلى قيمة لقطر الجذر تم تحقيقه بإضافة ١٢٠ كجم N/فدان و٤٨ كجم K_2O/فدان، في حين أن التفاعل بين الكثافات النباتية ومستويات السماد البوتاسي لم يكن لها تأثيرا معنويا على جميع الصفات المدروسة.

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