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Response of Some Sugar Beet Varieties to Nitrogen and Zinc Application in Sandy Soil

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TWO field experiments were carried out in sandy soil at Wady El-Natron, Beheira Governorate, Egypt**,** at (30° 23' 09" N: 30° 25' 31" E. 23 m above sea level) in 2020/2021 and 2021/2022 seasons to evaluate the performance of three sugar beet varieties and their response to different levels of nitrogen and zinc fertilization, on growth, yield, and quality. The present work included twenty-seven treatments, which were the combinations of three multi-germ sugar beet varieties namely Aladdin, Lulu and Zoom; three nitrogen levels (70, 95 and 120 kg/fed) and three levels of zinc (zero, 2.25 and 4.50 g/L zinc sulphate). Randomized complete block design in a split-split plot arrangement was used. The results showed that the Zoom variety outperformed the other ones, producing the thickest and heaviest roots with the highest sucrose, extracted sugar percentages, root, top and sugar yields/fed, in both seasons. Fertilizing beets with 120 kg N/fed increased root diameter, fresh weight/plant, LAI, root, top and sugar yields/fed, in both seasons. Adding 95 kg N/fed produced the highest extracted sugar, sucrose percentages and quality index, in both seasons. Spraying beets with 4.50 g/L zinc gave the highest values of root diameter, sucrose and extracted sugar percentages, root, top, and sugar yields/fed, in both seasons. The highest values of root diameter, root and sugar yields/fed were obtained by fertilizing the Zoom variety with 120 kg N/fed and spraying 4.50 g/L zinc sulphate.

Keywords: Nitrogen fertilizer, Sandy soil, Sugar beet varieties, Zinc spraying.

1. Introduction

Sandy soils usually suffer deficiency retention of nutrients and subsequently low crop productivity. Therefore, several studies have been directed to elevate sugar beet yield by evaluating high-yielding cultivars and improving their nutrition approaches, which had a pivotal impact on sugar beet growth and yield. Concerning the differences between varieties, Aly et al. (2015) showed significant differences between sugar beet varieties in root diameter, fresh weight/plant, sucrose%, quality index, root and sugar yields/fed. Enan et al. (2016) reported that the Polate variety was superior to the other two cultivars tested, recording the highest values for root diameter, fresh weight/plant, foliage weight/plant, and top yield per fed in both seasons. while insignificant differences between Polat and Henrike varieties were found in fresh weight per plant and root diameter in the first season, leaf area index and root fresh weight per plant in the second season. but insignificant differences among varieties in their impact on gross and corrected sugar yields per fed in both grow seasons.

Aly et al. (2017) revealed that the sugar beet Karim variety had the highest values in leaf area index, root and foliage fresh weighs/plant, as well as root and extracted sugar yields/fed. At the same time, the Nancy variety had surpassed the Karim variety in sucrose, extracted sugar percentages and quality index% in both seasons. El-Mansuop et al. (2020) manifested that the Kawemira variety gave the tallest and heaviest roots, higher values of sucrose, extracted sugar percentages, and yields of root and sugar/fed, while sodium and alpha-amino N decreased. As for nitrogen, it plays an essential role in plant growth as

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it is a component of proteins that make up protoplasm, cells, and tissues. It is the most essential element for plant production. (Ivana *et al*. 2022). In this concern, Abd El-Kader (2011) showed that increasing nitrogen fertilizer by up to 110 kg N/fed significantly enhanced the sucrose content, K, and Na contents, as well as the top, root, and sugar yields/fed, in both seasons. El-Hassanin et al. (2016) found that decreasing nitrogen fertilization levels from 90 kg to 36 kg/fed significantly decreased root criteria, sucrose (%), sugar lost in molasses, extractability percentage and yields ton/fad in both seasons of sugar beet.

Wael et al. (2017) concluded that raising the nitrogen rate to 120 kg/fed resulted in a considerable increase in root dimension, root and sugar yields/fed, individual root weight, and impurities %. Additionally, they noted that an excessive amount of nitrogen application reduced the quality of the extracted sugars in terms of purity and sucrose percentages. Elwan and Helmy (2018) stated that raising the nitrogen rate to 120 kg nitrogen per fed, significant increases in fresh weight per plant, root diameter, sugar lost to molasses%, root and corrected sugar yields/fed in both seasons. However, the quality index decreased. the greatest sucrose and corrected sugar % were obtained by adding 100 kg N/fed. spraying has increased root yield and quality of beets sown in sandy soil. In parallel context with nitrogen, zinc plays a vital role as a structural constituent or regulatory co-factory of a wide range of different enzymes and proteins in many important biochemical pathways and these are mainly concerned with carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, Auxin metabolism, therefore the amount of Auxin decreases under zinc deficiency Alloway, (2008). Moustafa *et al*. (2011) found that foliar spray with Zn, Mn and Fe individually or in a mixture significantly increased sucrose %, root diameter, fresh and foliage weights/plant and sugar yield/fed and increased the uptake of N, Zn, Mn and Fe. Also, Enan (2014) stated that increasing foliar zinc up to 2000 ppm increased values of root dimension, fresh and leaf weights per plant, sucrose% and zinc concentration in root and leaves as well as, root, top and sugar yields per fed. Barlog et al. (2016). Spraying beet plant leaves with 2.0 Zn kg/ha resulted in the highest values of root and sugar yields/fed.

Therefore, the main aim of this study was to to evaluate the performance of three sugar beet varieties and their response to different levels of nitrogen and zinc fertilization, on growth, yield, and quality.

2. Materials and Methods

Two field experiments were carried out in sandy soil at Wady El-Natron, Beheira Governorate, Egypt (30° 23' 09" N: 30° 25' 31" E.) at an elevation of 23m above sea level) in 2020/2021 and 2021/2022 seasons to evaluate the performance of three sugar beet varieties and their response to adding different levels of nitrogen and zinc fertilization on growth, yield, and quality of sugar beet (*Beta vulgaris var.* saccharifera, L.).

The present work included twenty-seven treatments, which were the combinations of three multi-germ sugar beet varieties namely Aladdin, Lulu and Zoom; three nitrogen levels (70, 95 and 120 kg/fed) and three levels of zinc (zero, 2.25 and 4.50 g/L zinc sulphate) ($ZnSO_4 . 7H_2O$) containing 22% zinc. Randomized complete block design in a split-split plot arrangement was used, in both seasons. The tested sugar beet varieties were randomly sown in the main plots, while nitrogen fertilizer levels were added as soil application in the form of ammonium nitrate (33.5% N), which were distributed in the sub-plots, and zinc fertilizer levels were sprayed on tops of beets grown in assigned in the sub-sub plots. The sub-sub plot sized 21.60 m^2 included 6 ridges, 6-m long and 60 cm in width, with 20 cm between hills.

Nitrogen fertilizer levels were added after thinning (4-true leaf stage), followed by three doses at two-week intervals after the first one, while zinc levels were sprayed twice after 60 and 80 days from sowing. Phosphorus fertilizer was applied at 200 kg/fed as calcium superphosphate (15% P_2O_5) at seedbed preparation. Potassium fertilizer was added as potassium sulfate 48% K_2O/fed at the rate of 24 kg/fed in two equal doses: the first one was given after thinning, while the second dose was added with the third dose of nitrogen fertilizer. The three sugar beet varieties were sown on the second week of September and harvested after 210 days from cultivation in both seasons. The country of origin and types of the tested sugar beet varieties are manifested in Table 1.

The Sugar Crop Research Institute's recommendations for growing sugar beet were adopted. As shown in Table (2), soil samples (0–30 cm depth) from the experimental location were collected to evaluate its physical and chemical characteristics using the techniques outlined by **Cottenie *et al.* (1982)**.

Table 1. Origin country and source* of the three evaluated sugar beet varieties.

Sugar beet varieties	Type of seeds	Country of origin
Aladdin	Multigerm	Denmark
Lulu	Multigerm	Italy
Zoom	Multigerm	Denmark

*Source: Sugar Crop Research Institute, Agricultural Research Centre, Giza, Egypt.

The recorded data

At 110 days after seeding, five plants were randomly collected from the middle ridges of each sub-plot to determine the following:

1. Leaf area index (LAI): Leaf area was determined by the disk method using ten disks of 1.0 cm Watson (1958), the equation was used:

LAI = Leaf area per plant (cm^2)/plant ground area (cm^2).

Ten guarded plants were selected at random from each subplot's middle ridges at harvest, uprooted, topped, and weighed to determine the following traits:

1. Root diameter/plant (cm).
2. Root fresh weights/plant (g)
3. Quality analysis was done on fresh samples of sugar beet roots at the Laboratory at Alexandria Sugar Factory, Alexandria, Egypt.

Sucrose percentage (Pol %), was determined in fresh macerated root, according to the method of A.O.A.C. (2005). Na and K impurities in juice, measured as meq/100 g beet, were found in the lead acetate extract of freshly macerated root tissue using the "Flame photometry" method as described by Browen and Lilliand (1964), whereas alpha amino-nitrogen was found using the "ninhydrin hydrindantin" method as described by Cooke and Scott (1993). The Sugar Lost in Molasses (SLM%) was estimated using Devillers (1988) equation:

SLM = 0.14× (Na + K) + 0.25 × (α–amino N) + 0.50

Extracted sugar percentage (EX.%) was calculated using the equation provided by Dexter et al. (1967):

EX% = sucrose % - SLM % - 0.6

Quality index (QI) was determined using Cooke and Scott's (1993) equation by follows:

QI = (extracted sugar percentage ÷ sucrose percentage) x 100

Sugar beet yields

1. roots / plot were weight in kg and converted root yield/fed (ton).
2. Sugar yield/fed (ton), which was calculated according to the following equation.

Table 2. Physical and chemical properties of soil sample of the experimental site for 2020/2021 and 2021/2022 seasons.

2020/2021 season										
Particle size distribution				Soil texture	EC ($dS\ m^{-1}$)		Soil pH (1:2.5)	Organic matter, %		
Sand, %	Silt, %	Clay, %								
91.9	5.20	2.9		Sandy	1.21		7.94	0.61		
Cations (mmolc L^{-1})				Anions (mmolc L^{-1})				Available macro-nutrients (mg/kg soil)		
Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	$SO4^{2-}$	N	P	K
3.6	1.7	4.1	2.7	-	4.91	4.0	3.19	17.30	7.90	113.2
Available micro-nutrients (mg/kg)										
Zinc								0.19		
2021/2022 season										
Particle size distribution				Soil texture	EC ($dS\ m^{-1}$)		Soil pH (1:2.5)	Organic matter %		
Sand, %	Silt, %	Clay, %								
92.1	4.90	3.0		Sandy	1.23		8.01	0.54		
Cations (mmolc L^{-1})				Anions (mmolc L^{-1})				Available macro-nutrients (mg/kg soil)		
Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	$SO4^{2-}$	N	P	K
3.72	1.48	4.5	2.60	-	4.99	3.80	3.51	20.08	7.81	123.0
Available micro-nutrients (mg/kg)										
Zinc								0.22		

Sugar yield per fed (ton) = root yield/fed (ton) x Extracted sugar%. 3. Top yield per fed (ton).

Statistical analyses

The obtained data were subjected to analysis of variance according to Gomez and Gomez (1984). Treatment means were compared by Duncan's Multiple Range Test Duncan, (1955). All statistical analysis was performed using analysis of variance technique by means of "MSTAT-C" computer software package

3. Results and discussion

1. Root diameter, fresh weight/plant and leaf area index (LAI)

Root diameter, fresh weight/plant and leaf area index of three sugar beet varieties significantly differed in both seasons (Table 3). The Zoom variety had the highest values of root diameter and fresh weight/plant. Meanwhile, the highest LAI values were recorded from the Zoom variety without significant differences between it and the Lulu variety compared with the Aladdin variety ranked lowest in both seasons. These findings suggest that genetic structures or specific genetic structures of sugar beet varieties may affect these traits, this result is similar to those mentioned by Enan et al. (2016).

The three traits mentioned above tended to increase significantly due to raising nitrogen fertilizer levels from 70 to 95 and 120 kg N/fed in both seasons. Supplying beets with 120 kg N/fed significantly increased root diameter, fresh weight/plant and LAI by about (11.74%, 42.55% and 37.81%) in the 1st season. However, these increases were (21.43%, 39.80%, and 37.30%) compared to the application of 70 kg N/fed in the 2nd season, respectively. These findings are related to nitrogen's role as a crucial structural element in developing plant organs and promoting their growth. These results are in agreement with those stated by Elwan and Helmy (2018). As for the effect of zinc spray levels in the same Table, doubling the dose of sprayed zinc sulphate level (4.5 g/L) significantly increased root diameter, fresh weight/plant and LAI of sugar beet plants in both seasons. Sugar beet fertilized with 4.5 g/L zinc had heavier and thicker roots and leaf area index higher than those plants treated with 2.25 g/L and untreated with zinc. The positive influence of applied zinc levels may be due to its role in tryptophan biosynthesis as a precursor of Auxin, which improves plant growth and elongation as explained by Cakmak, (2008).

The interaction between varieties x nitrogen fertilizer rates significantly affected root diameter, fresh weight/plant and leaf area index, further between nitrogen and zinc fertilizer levels on root diameter and fresh weight/plant, whereas root diameter was affected significantly by the treble interaction between all studied factors in both seasons (Table 3).

Table 3. Root diameter, fresh weight/plant and leaf area index of three sugar beet varieties as affected by nitrogen and zinc fertilization levels in 2020/2021and 2021/2022.

Treatments	Root diameter (cm)		Root fresh weight/plant(g)		LAI	
	First season	Second season	First season	Second season	First season	Second season
(A) Sugar beet varieties						
Aladdin	10.66c	11.18c	320.73b	353.72b	2.38b	2.54b
Lulu	11.31b	11.47b	344.92b	385.85b	2.86a	2.99a
Zoom	12.35a	12.87a	426.88a	472.65a	3.32a	3.50a
F-Test at 0.5%	**	**	**	**	**	**
(B) Nitrogen fertilizer rates/fed						
70 kg N	10.73c	10.50c	293.62c	327.64c	2.38c	2.52c
95 kg N	11.61b	12.26b	380.36b	431.54b	2.91b	3.06b
120 kg N	11.99a	12.75a	418.55a	458.04a	3.28a	3.46a
F-Test at 0.5%	**	**	**	**	**	**
(C) Spraying zinc sulphate levels/fed						
Zero	10.69c	11.11c	317.35c	373.00c	2.73b	2.88b
2.25 g/L	11.51b	11.73b	358.89b	400.74b	2.83b	3.00b
4.50 g/L	12.12a	12.68a	416.29a	438.48a	3.01a	3.16a
F-Test at 0.5%	**	**	**	**	**	**
A×B	**	**	**	**	**	**
A×C	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
B×C	**	**	**	**	**NS**	**NS**
A×B×C	**	**	**NS**	**NS**	**NS**	**NS**

2. Sucrose% and impurities (K, Na and α-amino N contents)

Data in Table 4 shows notable significant variations in technological traits in terms of sucrose%, potassium, sodium and alpha-amino N contents among sugar beet varieties in both seasons. The Zoom variety gave the highest sucrose% values in sandy soil. The Aladdin variety had the lowest mean values of sodium and alpha-amino N contents compared to Zoom and Lulu varieties in both seasons. Nevertheless, the potassium content of the three types was insignificantly affected in both seasons. These differences may be attributed to the variations in growth traits and reactions to environmental conditions during the formation of soluble solids in plants. These results are consistent with those mentioned by Aly et al. (2017) who observed significant variations in technological traits among the evaluated sugar beet types.

Applying nitrogen fertilizer rates in both seasons significantly affected sucrose percentage and root impurities. Raising the N-fertilization level from 70 to 120 kg N/fed led to a substantial increase in sucrose %, while root potassium and sodium contents did not reach a significance level. A reduction significantly in sucrose % was observed when the nitrogen level increased to 120 kg N/fed. This reduction in sucrose % could be due to increased water retention in beetroot leading to a decrease in sucrose determined as a percentage of fresh weight or may show that applying 95 kg nitrogen/fed was required for the construction of an optimal foliage size able to play its functional role in photosynthesis and accumulation of sugars in roots. Therefore, adding 120 kg nitrogen/fed may result in more foliage than the beetroot's ability to transport and store sugar. (Elwan and Helmy 2018). At the same time, the alpha-amino N contents gradually increased by increasing the N-dose to 120 kg/fed in both seasons. This increase may be related to the fact that raising the amount of the applied nitrogen enhances to absorption of more solutes involved in the soil solution that is unfavorable to reflect sugar crystallization during processing. These results line with those mentioned by Abdelaal and Tawfik (2016) reported that there was a decrease in both sucrose% and quality index due to increasing mineral nitrogen levels, which led to the increase in amino compounds caused by the extreme nitrogen uptake.

Data in the same Table stated higher values of sucrose % by increasing the sprayed zinc level from zero to 4.5 g/L zinc in the 1st and 2nd seasons. These significant increments in sucrose % amounted to about 4.98 % and 5.31 % when spraying beet plants with 4.5 g/L zinc over those that received 2.25 g/L zinc in both seasons, respectively. On the other hand, root potassium and sodium contents were insignificantly affected by spraying zinc levels, while alpha-amino N content increased in both seasons. These results may refer to zinc influencing basic plant life processes, such as nitrogen metabolism, protein quality, photosynthesis and resistance to abiotic and biotic stress, as indicated by Alloway (2008).

The interactions between varieties x nitrogen fertilizer rates and in beteem nitrogen x zinc fertilization levels significantly affected sucrose% in both seasons (Table 4).

Table 4. Some technological traits of three sugar beet varieties as affected by nitrogen and zinc fertilization levels in 2020/2021and 2021/2022.

Treatments	Sucrose %		Impurities (meq/100 g beet)					
			Potassium		Sodium		Alpha-amino N	
	First season	Second season	First season	Second season	First Season	Second season	First season	Second season
(A) Sugar beet varieties								
Aladdin	16.18c	15.83c	3.75	3.71	1.07c	1.20c	1.44c	1.57c
Lulu	16.67b	16.52b	3.74	3.63	1.39b	1.42b	1.71b	1.80b
Zoom	17.28a	17.38a	3.01	3.16	1.58a	1.66a	1.81a	1.95a
F-Test at 0.5%	**	**	NS	NS	**	**	**	**
(B) Nitrogen fertilizer rates/fed								
70 kg N	15.68c	15.23c	3.56	3.58	1.28	1.25	1.47c	1.50c
95 kg N	17.50a	17.40a	3.49	3.52	1.34	1.44	1.69b	1.84b
120 kg N	16.96b	17.10b	3.45	3.44	1.42	1.56	1.82a	1.99a
F-Test at 0.5%	**	**	NS	NS	NS	NS	**	**
(C) Spraying zinc sulphate levels/fed								
Zero	15.97c	15.73c	3.52	3.62	1.31	1.38	1.42c	1.60c
2.25 g/L zinc	16.67b	16.56b	3.51	3.51	1.35	1.43	1.71b	1.82b
4.50 g/L zinc	17.50a	17.44a	3.47	3.42	1.38	1.48	1.82a	1.91a
F-Test at 0.5%	**	**	NS	NS	NS	NS	**	**
A×B	**	**	NS	NS	NS	NS	NS	NS
A×C	NS	NS	NS	NS	NS	NS	NS	NS
B×C	**	**	NS	NS	NS	NS	NS	NS
A×B×C	NS	NS	NS	NS	NS	NS	NS	NS

3. Sugar lost to molasses, extracted sugar percentages and quality index

The results in Table 5 confirmed that the three tested sugar beet varieties significantly differed in extracted sugar%, without significant variance among them in sugar lost to molasses% and quality index in both seasons. The Zoom variety outperformed the other two cultivars and was given the highest extracted sugar% values in both seasons. This increase in extracted sugar% amounted to (0.65 and 0.86), compared with those obtained from the Lulu variety in 1st and 2nd seasons, respectively. The variation among the evaluated cultivars in extracted sugar% may be due to genetic structure as mentioned by El-

Mansuop et al. (2020).

The applied N-fertilizer levels significantly influenced sugar loss to molasses, extracted sugar percentages and quality index in the same Table. It is turned out that the increase in the level of nitrogen up to 120 kg/fed was accompanied by a gradual increase in sugar loss to molasses%. Otherwise, the values of extracted sugar and quality index fluctuated where the addition of 95 led to an increase in the percentage of extracted sugar and the quality index compared to deficient supply and/or high doses of nitrogen in both seasons. These results referred that adding 95 kg N/fed may be preventing wasting a lot of sugar in molasses because of the extractability of sucrose from beets without higher impurities concentration (Wael et al. 2017).

Concerning the zinc sulphate effect, results showed that extracted sugar % and quality index were increased significantly as the applied zinc levels were raised from zero to 4.5 g/L zinc in both seasons. However, spraying zinc treatments had an insignificant influence on sugar loss to molasses% in both seasons. This result could be attributed to higher values of sucrose% and neutralization of root potassium and sodium values in Table (4). These results were parallel to what was reported by Barlog et al. (2016).

Among the studied traits only extracted sugar% affected significantly by the interaction between varieties x nitrogen fertilizer rates in the two growing seasons (Table5).

Table 5. Sugar lost to molasses, extracted sugar percentages and quality index of three sugar beet varieties as affected by nitrogen and zinc fertilization levels in 2020/2021 and 2021/2022.

Treatments	Sugar lost in molasses %		Extracted sugar %		Quality index	
	First Season	Second season	First season	Second season	First season	Second season
(A) Sugar beet varieties						
Aladdin	1.53	1.59	14.05c	13.65c	87.79	86.10
Lulu	1.65	1.66	14.43b	14.26b	86.48	86.25
Zoom	1.60	1.65	15.08a	15.12a	87.22	87.98
F-Test at 0.5%	**NS**	**NS**	**	**	**NS**	**NS**
(B)Nitrogen fertilizer rates/fed						
70 Kg N	1.54c	1.55c	13.53c	13.07c	86.30c	85.78c
95 Kg N	1.60b	1.65b	15.30a	15.15a	87.41a	87.01a
120 Kg N	1.64a	1.70a	14.72b	14.80b	86.78b	86.54b
F-Test at 0.5%	**	**	**	**	**	**
(C) Spraying zinc sulphate levels/fed						
Zero	1.53	1.60	13.84c	13.54b	86.62b	85.95c
2.25 g/L zinc	1.61	1.65	14.46b	14.32b	86.73b	86.41b
4.50 g/L zinc	1.64	1.66	15.25a	15.17a	87.14a	86.97a
F-Test at 0.5%	**NS**	**NS**	**	**	**	**
A×B	**NS**	**NS**	**	**	**NS**	**NS**
A×C	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
B×C	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
A×B×C	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4. Root, top and sugar yields/fed (ton)

Results in Table 6 revealed differences in the root, top and sugar yields/fed in sugar beet varieties in both seasons. Zoom cultivar showed superiority over the other evaluated cultivars in root, top and sugar yields by about (2.29 and 2.10 tons of root), (0.76 and 0.84 tons of foliage) and (0.47 and 0.48 tons of sugar) compared to the Lulu cultivar, which ranked second in the 1st and 2nd seasons respectively. These results may be attributed to the values obtained early from traits of root diameter, fresh weight/plant and sucrose%, as shown in Tables (3 and 4). Also, the difference among sugar beet cultivars may be due to the variation in the gene makeup and their response to environmental conditions, previously explained by Enan et al. (2016). Data in Table 6 manifested that an addition of 25 kg N/fed (the difference between adding 120 kg and 95 kg N/fed) was enough to produce the highest root, top sugar yields/fed, compared with plants that received 70 or 95 kg N/fed in both seasons. These results align with Elwan and Helmy (2018) who reported that raising nitrogen levels to 110 kg N/fed gave the highest root dimension, root, top and sugar yields per fed. However, sucrose content and quality index decreased.

Regarding the zinc effect, the results in the same

Table indicated that twice foliar spraying with 4.5 g/L zinc increased yields of root, top and sugar/fed by about (2.16, 0.56, and 0.39 tons/fed) in 1st season. Nevertheless, these increases were (2.43, 0.81 and 0.52 tons/fed) in the second season over those sprayed with half the dose of zinc (2.25 g/L), respectively. These results confirmed the effectiveness of N fertilization which is integrated by zinc foliar doses, which the experimental site is deficient because the soil is a sandy texture and has a high concentration of phosphorus and potassium content medium, as shown in (Table 2). Hence, zinc concentration decreased and declined photosynthesis, carbohydrates and protein synthesis. This result is in agreement with those decided by Mousavi (2011).

Except for top yield/fed, the treble interaction had a substantial effect on the aforementioned traits in both seasons (Table 6).

Table 6. Root, top and sugar yields/fed of three sugar beet varieties as affected by nitrogen and zinc fertilization levels in 2020/2021and 2021/2022.

Treatments	Root yield/fed (ton)		Top yield/fed (ton)		Sugar yield/fed (ton)	
	First season	Second season	First season	Second season	First season	Second season
(A) Sugar beet varieties						
Aladdin	16.77c	16.62c	5.43c	5.54c	2.30c	2.30c
Lulu	17.85b	18.40b	5.95b	6.13b	2.60b	2.65b
Zoom	20.14a	20.50a	6.71a	6.97a	3.07a	3.13a
F-Test at 0.5%	**	**	**	**	**	**
(B) Nitrogen fertilizer rates/fed						
70 kg N	15.24c	15.72c	5.08c	5.29c	2.08c	2.08c
95 kg N	18.98b	19.50b	6.16b	6.54b	2.84b	2.98b
120 kg N	20.55a	20.30a	6.86a	6.81a	3.05a	3.02a
F-Test at 0.5%	**	**	**	**	**	**
(C) Spraying zinc sulphate levels/fed						
Zero	16.01c	16.46c	5.34c	5.53c	2.23c	2.26c
2.25 g/L zinc	18.30b	18.32b	6.10b	6.15b	2.67b	2.65b
4.50 g/L zinc	20.46a	20.75a	6.66a	6.96a	3.06a	3.17a
F-Test at 0.5%	**	**	**	**	**	**
A×B	NS	NS	NS	NS	NS	NS
A×C	NS	NS	NS	NS	NS	NS
B×C	NS	NS	NS	NS	NS	NS
A×B×C	**	**	NS	NS	**	**

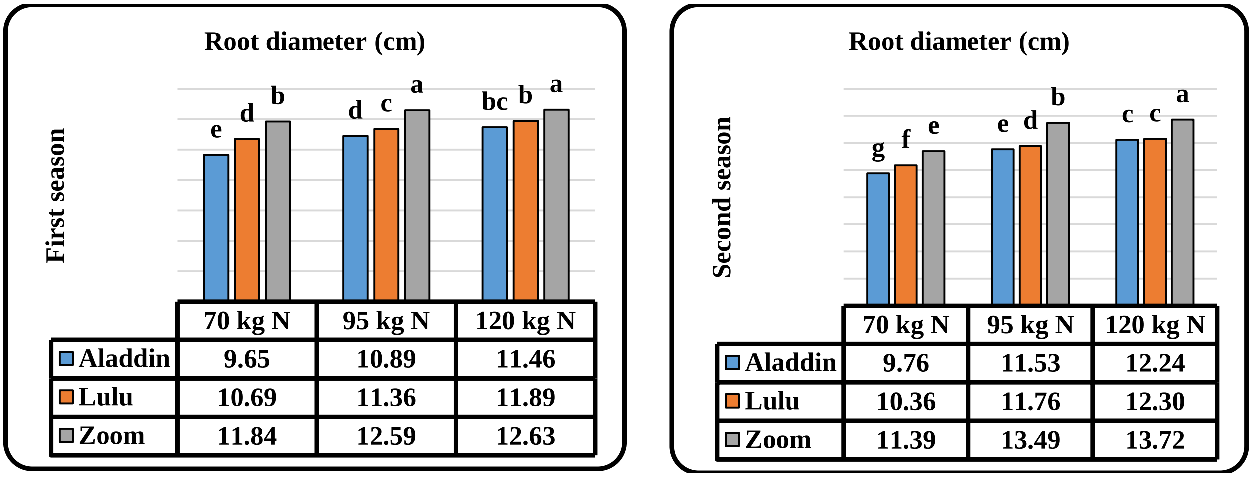
The first-order interactions effect

Data in Figure 1 reveals that the interaction between the tested varieties and nitrogen fertilizer levels significantly affected root diameter in both seasons. The Zoom variety ranked first and gave the highest root diameter values when fertilized with 95 kg and/or 120 kg N/fed (without significant differences in between), compared with root diameters obtained from Lulu and Aladdin varieties in both seasons. This result may be due to nitrogen's role, which could lead to the energy required for growth, photosynthesis and the transformation of sugars, hence the transfer of genetic information in plants, El- Hassanin et al. (2016). Also, agrees with the finding by Enan, et al. (2016) who explained that the differences between varieties are basically may be due to the genetic structures or specific genetic structures of sugar beet varieties.

Data in Figure 2 illustrates that beet's thickest roots were obtained by fertilizing with 120 kg over those supplied with 95 kg nitrogen/fed in case of spraying beets with 4.5 g/L zinc sulphate compared to other treatments in both seasons. Fertilizing beet plants with 120 kg N/fed and sprayed 4.5 g/L zinc gave an increase in root diameter by about (8.86% and 4.84%) in 1st and 2nd seasons compared with those receiving 120 kg N/fed and were sprayed 2.25 g/L zinc in either of the two seasons. These results are in agreement with Enan (2014), who explained that higher values of root diameter and what was built on it from increasing the root and foliage fresh weights/plant, increasing sucrose% as a signifier to improve foliar zinc absorption, which led to enhanced growth, especially in sandy soils suffering from a lack of organic manure and zinc element.

Also, data in Figure 3 reveal that root fresh weight/plant was significantly affected by the interaction between varieties and nitrogen levels in both seasons. It was clear that the differences between Aladdin and Lulu varieties in root fresh weight were significant when they enhanced with 120 and/or 95 kg N/fed, in the first season. However, these differences in root fresh weight of both varieties between the same two levels of nitrogen were insignificant in 2nd season. Fertilizing the Zoom variety by 120 kg N/fed, produced the heaviest roots, compared to the other two tested varieties. These findings pertain to nitrogen's structural function in the development of organs and the stimulation of their growth, which results in an increase in the fresh weight and number of plants of the root.

Data in Figure 4 indicate a significant interaction effect between nitrogen and zinc fertilizer rates on root fresh weight/plant in both seasons. It was found that the differences in root fresh weight/plant of plants sprayed with 2.25 and 4.5 g/L zinc were insignificant when beets were fertilized with 95 kg N/fed in 2nd season. However, these variances in root fresh weight/plant between those two zinc levels were significant when beets were received (95 kg N/fed) in the first season. The concurrent fertilization of 120 kg N/fed and spraying with 4.5 g/L zinc sulphate produced the heaviest roots in both seasons. This might explain the involvement of N in promoting meristematic development activity, which contributes to a rise in the number and size of cells, in addition to zinc's role in an increase in root weight as reported by Wael *et al*. (2017).



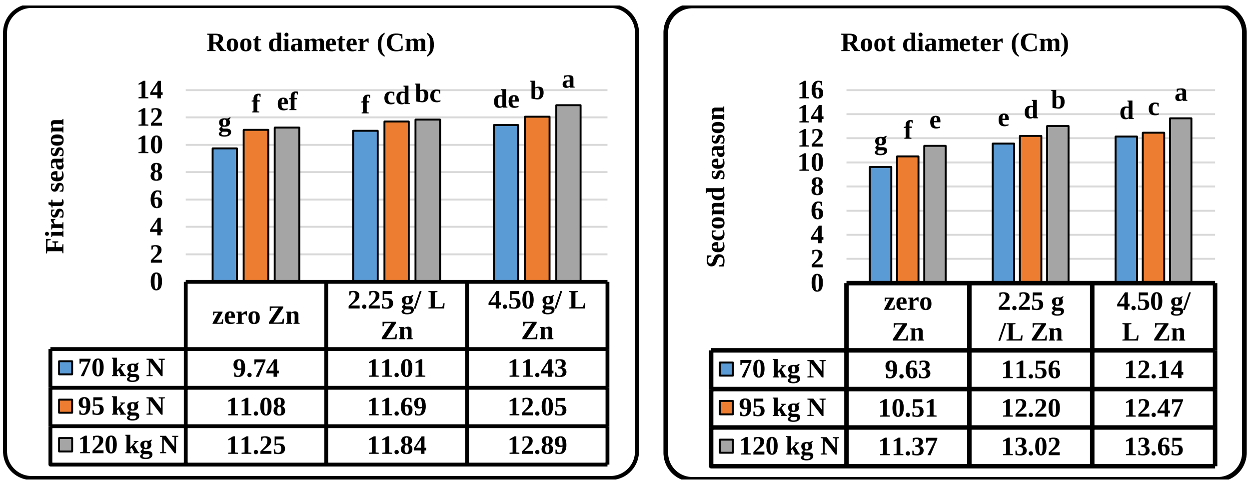
First season:

	70 kg N	95 kg N	120 kg N
Aladdin	9.65	10.89	11.46
Lulu	10.69	11.36	11.89
Zoom	11.84	12.59	12.63

Second season:

	70 kg N	95 kg N	120 kg N
Aladdin	9.76	11.53	12.24
Lulu	10.36	11.76	12.30
Zoom	11.39	13.49	13.72

Fig 1. A significant interaction between nitrogen fertilization rate x varieties on root diameter of sugar beet in 2020/2021and 2021/2022.



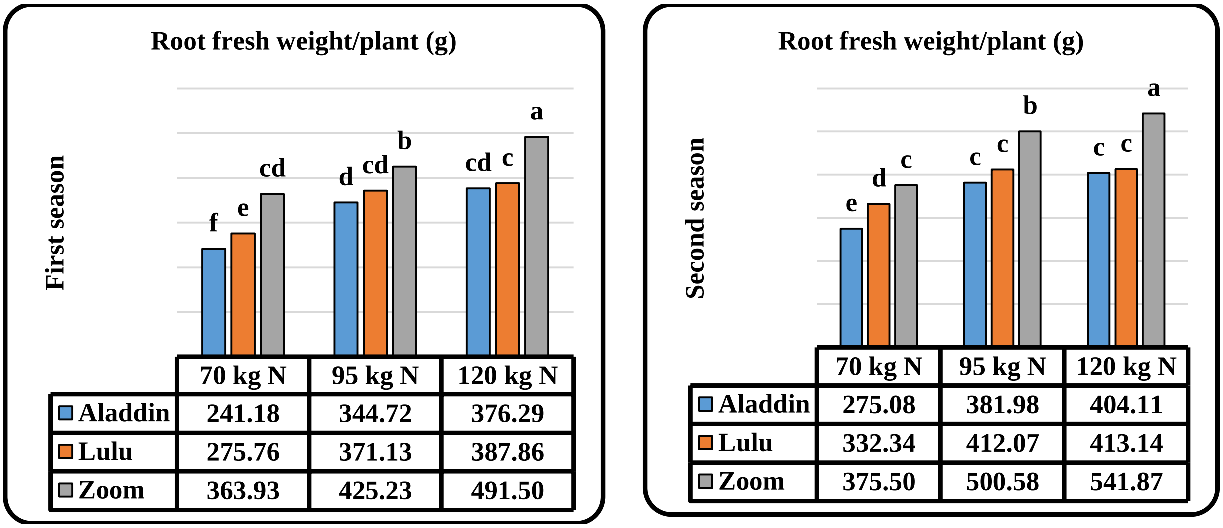
First season:

	zero Zn	2.25 g/ L Zn	4.50 g/ L Zn
70 kg N	9.74	11.01	11.43
95 kg N	11.08	11.69	12.05
120 kg N	11.25	11.84	12.89

Second season:

	zero Zn	2.25 g /L Zn	4.50 g/ L Zn
70 kg N	9.63	11.56	12.14
95 kg N	10.51	12.20	12.47
120 kg N	11.37	13.02	13.65

Fig 2. A significant interaction between nitrogen fertilization rate x spraying zinc levels on root diameter of sugar beet in 2020/2021and 2021/2022.



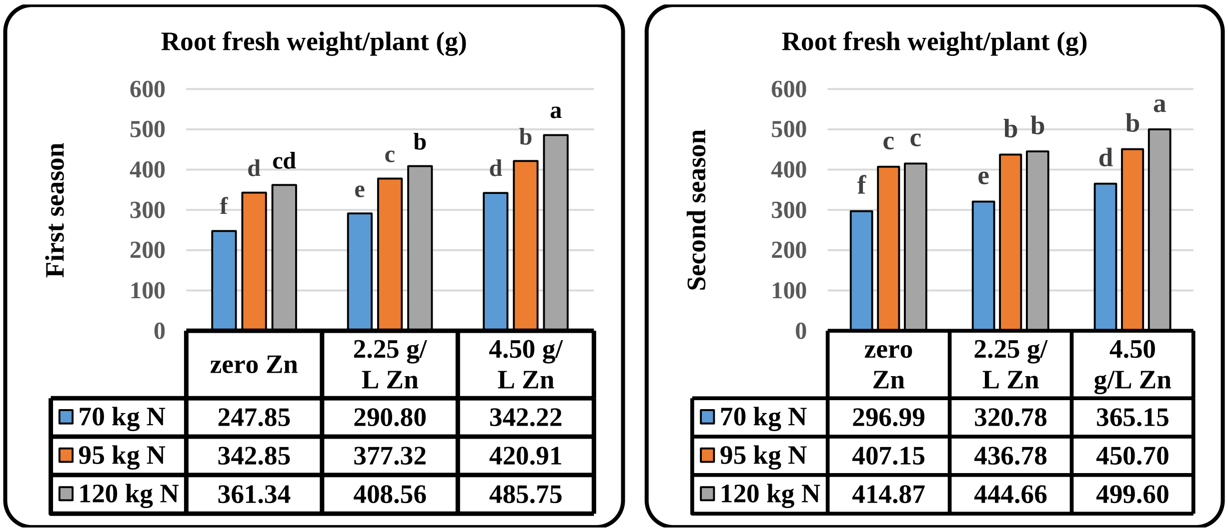
First season:

	70 kg N	95 kg N	120 kg N
Aladdin	241.18	344.72	376.29
Lulu	275.76	371.13	387.86
Zoom	363.93	425.23	491.50

Second season:

	70 kg N	95 kg N	120 kg N
Aladdin	275.08	381.98	404.11
Lulu	332.34	412.07	413.14
Zoom	375.50	500.58	541.87

Fig 3. A significant interaction between varieties x nitrogen fertilization levels on root fresh weight/plant of sugar beet in 2020/2021and 2021/2022.



First season:

	zero Zn	2.25 g/ L Zn	4.50 g/ L Zn
70 kg N	247.85	290.80	342.22
95 kg N	342.85	377.32	420.91
120 kg N	361.34	408.56	485.75

Second season:

	zero Zn	2.25 g/ L Zn	4.50 g/L Zn
70 kg N	296.99	320.78	365.15
95 kg N	407.15	436.78	450.70
120 kg N	414.87	444.66	499.60

Fig. 4. A significant interaction between nitrogen fertilization rate x spraying zinc levels on root fresh weight/plant of sugar beet in 2020/2021and 2021/2022.

Data in Figure 5 clear that the leaf area index (LAI) tended to significantly increase when raising nitrogen fertilizer levels from 70 to 95 and 120 kg N/fed in either season. The differences in leaf area between varieties were more distinguishable when fertilized Zoom variety with 120 kg N/fed, compared with the other levels of nitrogen application in both seasons. This result may refer that sugar beet varieties cannot make full use of vegetation space when nitrogen is low availability in the experimental site and/or the inadequate applied dose (Table 2), where nitrogen fertilizers role in enhanced growth and increase leaf area per plant. This observation agrees with those reported by Elwan and Helmy (2018) and El-Mansuop et al. (2020).

Data in Figure 6 manifest that sucrose% was significantly affected by the interaction between different varieties and their response to nitrogen fertilizer levels in both seasons. It was shown that the differences between the Zoom variety that fertilized with 95 and/or 120 kg N/fed were insignificant than other varieties in 1st season. However, these variances in sucrose% between those two levels of nitrogen were significant in the case of Zoom variety in the second season. The sugar beet variety Zoom responded to fertilization with 95 kg N/fed bypassing other cultivars that received 95 and/or 120 kg N/fed in both seasons. The superior performance of the Zoom variety may be due to the varying gene makeup and environmental factors. The results attained are consistent with those of Aly et al. (2017).

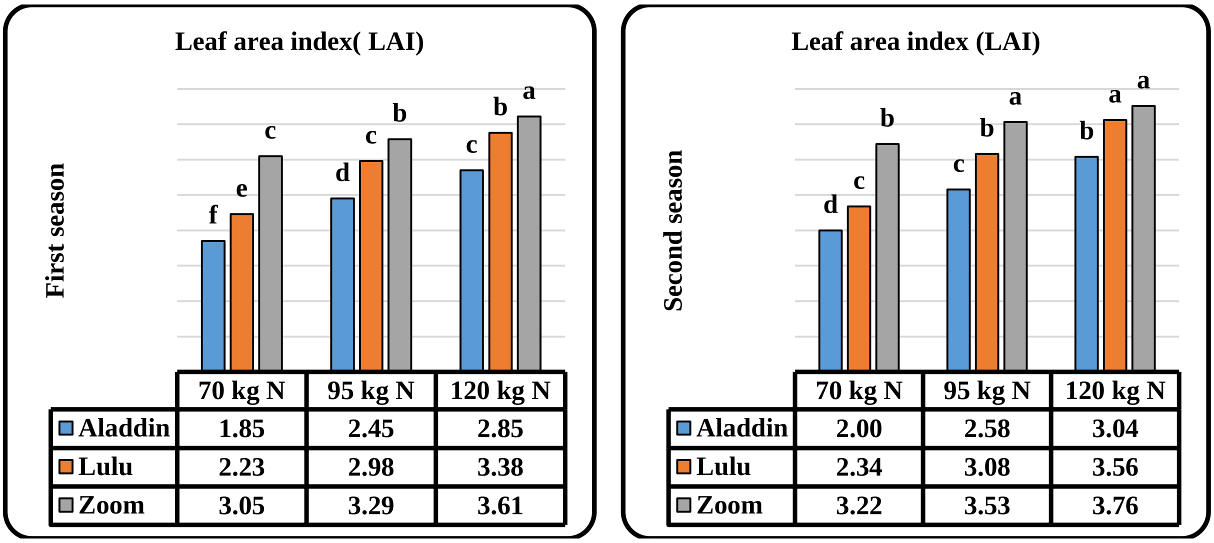


Fig 5. A significant interaction between varieties x nitrogen fertilization rate leaf area index of sugar beet 2020/2021and 2021/2022.

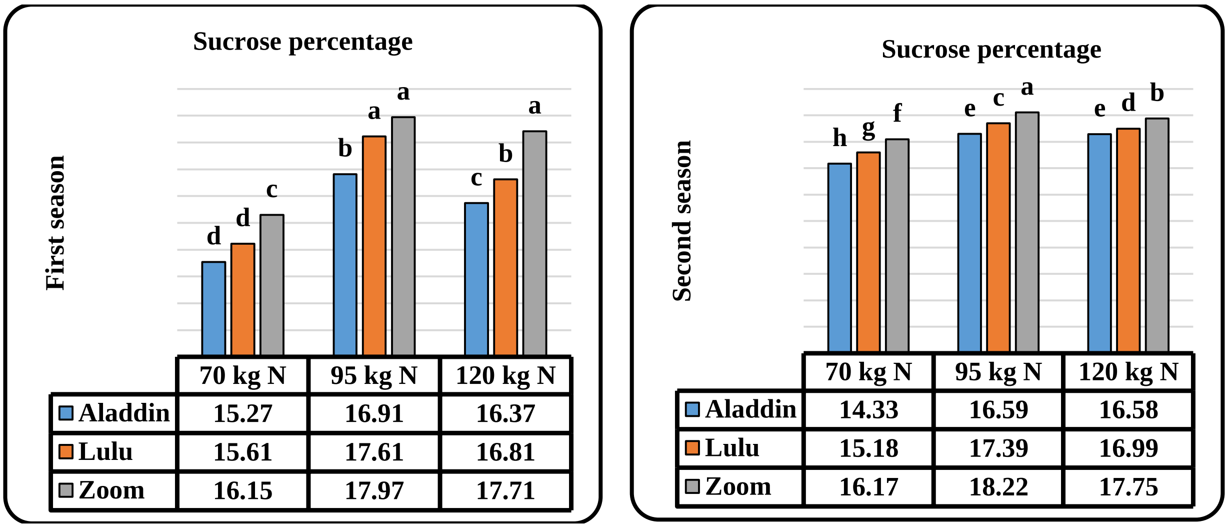


Fig. 6. A significant interaction between varieties x nitrogen fertilization rate on sucrose% of sugar beet in 2020/2021and 2021/2022.

Also, data in Figure 7 display quality traits that were impacted by the interaction between nitrogen rates and zinc spraying levels. The trend to increase sucrose% was observed under the impact of nitrogen fertilizer at a rate of 120 kg per fed and spraying sugar beet leaves with 4.5 g/L zinc, compared with other combinations in both seasons. These increases in sucrose % amounted to 5.26 % in 1st season against 6.25 % in 2nd season, compared with those that received 120 kg N/fed and sprayed 2.25 g/L zinc. These increases return to the significance of nitrogen and zinc fertilizers as growth promoters in these traits as mentioned by both Abd El-Kader (2011) and Moustafa et al. (2011).

Data in Figure 8 reveal that extracted sugar% was significantly affected by the interaction between varieties x nitrogen fertilizer levels in both seasons. There was a higher significant increase in extracted sugar% obtained from sowing the Zoom sugar beet variety and fertilizing it with 95 kg N/fed, over that which was fertilized by adding 120 kg nitrogen/fed. These increases amounted to 0.29 and 0.63 in the first and second seasons, respectively. Fertilizing the Zoom variety with 95 kg N/fed resulted in the highest values of extracted sugar % in the two growing seasons. The increased sugar content with the lowest sugar loss to molasses may refer to the role of nitrogen and zinc elements as well as environmental effects that led to the best-performing genotypes.

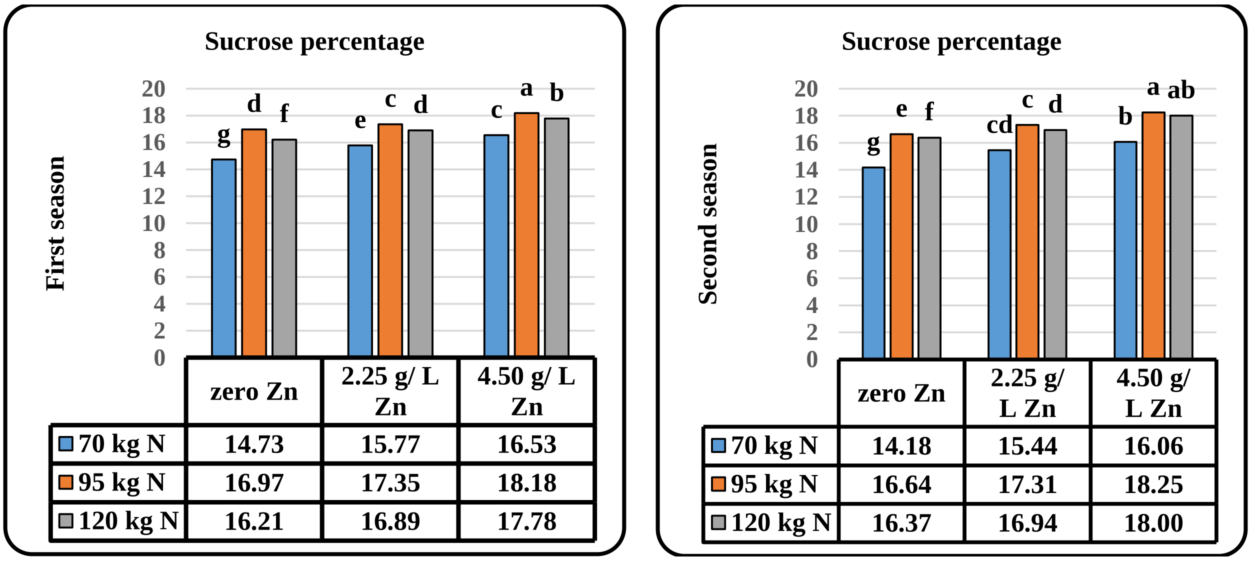


Fig. 7. A significant interaction between nitrogen fertilization rate x spraying zinc levels on sucrose% of sugar beet in 2020/2021and 2021/2022.

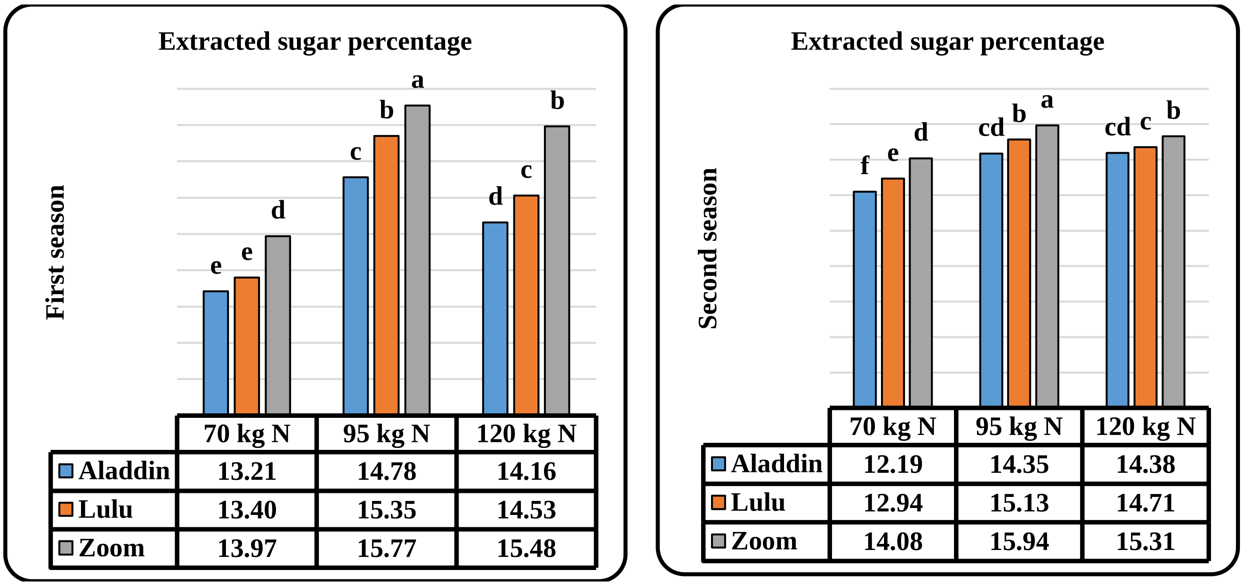


Fig. 8. A significant interaction between varieties x nitrogen fertilization levels on extracted sugar% in 2020/2021and 2021/2022.

The second-order interactions effect

Among the studied traits taproot diameter, root and sugar yields/fed were affected by the interaction between varieties x nitrogen rates x foliar doses of zinc in (Table 7, 8 and 9). The Zoom variety outperformed the Lulu and Aladdin varieties in root diameter, root and sugar yields/fed when treated with 120 kg N/fed and sprayed twice with 4.5 g/L zinc. The increases in these traits were estimated at approx (0.75 cm, 4.83-ton roots and 0.98-tons sugar) in root diameter, root and sugar yields/fed in 1st season. Nevertheless, in 2nd season were (1.40 cm, 3.62-ton roots and 0.52-ton sugar), respectively over that gained from the Lulu variety. These results may be related the balancing of N doses with foliar doses of zinc interpreted by both Abdel-Motagally and Attia (2009) reported that nitrogen affects plants' photosynthesis and the translocation of assimilates in the aboveground part and roots, where uptake of nitrogen is associated with levels of added nitrogen. In addition to what was mentioned by Cakmak et al. (1999) that zinc has particular physiological functions in all living systems, such as the maintenance of structural and functional integrity of biological membranes, but rather the facilitation of protein synthesis gene expression.

Table 7. Effect of interaction between nitrogen rates x varieties x spraying zinc levels on root diameter of sugar beet in 2020/2021and 2021/2022 seasons.

Sugar beet varieties	Nitrogen fertilizer rates/fed	Spraying zinc levels (g/L)					
		First season			Second season		
		Zero	2.25	4.50	Zero	2.25	4.50
Aladdin	70 kg N	8.30ma	10.10kl	10.52jk	8.65r	9.91q	10.72op
	95 kg N	10.51jk	10.73ijk	11.43e-i	10.91no	11.34k-n	12.34e-h
	120 kg N	10.88ij	11.38e-i	12.11cde	11.80h-k	12.13f-j	12.79de
Lulu	70 kg N	9.78l	11.06g-j	11.23f-j	9.58q	10.37p	11.11mno
	95 kg N	10.61jk	11.65e-h	11.80d-g	11.13mno	11.74i-l	12.43efg
	120 kg N	11.00hij	11.67e-h	13.00b	11.57j-m	11.96g-j	13.37c
Zoom	70 kg N	11.13f-j	11.86def	12.53bcd	10.67op	11.24l-o	12.28e-i
	95 kg N	12.13cde	12.69bc	12.91b	12.64def	13.53c	14.31b
	120 kg N	11.87def	12.46bcd	13.75a	13.04cd	13.34c	14.77a
F-test at 0.5%			**			**	

Table 8. Effect of interaction between nitrogen rates x varieties x spraying zinc levels on root yield/fed of sugar beet in 2020/2021and 2021/2022 seasons.

Sugar beet varieties	Nitrogen fertilizer rates/fed	Spraying zinc levels (g/L)					
		First season			Second season		
		Zero	2.25	4.50	Zero	2.25	4.50
Aladdin	70 kg N	12.16m	13.83kl	16.92ij	11.94m	13.41l	16.78ghi
	95 kg N	16.49j	18.04ghi	19.14efg	15.44ij	17.76fg	19.84de
	120 kg N	15.16k	19.02efg	20.23cde	17.44fgh	18.33fg	18.62ef
Lulu	70 kg N	13.09lm	14.31kl	16.29j	15.00jk	16.09hij	17.47fgh
	95 kg N	17.06ij	18.22ghi	19.75def	18.30fg	19.80de	20.50d
	120 kg N	20.25cde	20.32cde	21.43c	17.64fg	18.40fg	22.38c
Zoom	70 kg N	13.98kl	16.65j	19.94de	14.05kl	16.72ghi	20.03d
	95 kg N	17.33hij	20.59cd	24.21b	18.10fg	20.67d	25.08a
	120 kg N	18.57fgh	23.73b	26.26a	20.20d	23.68b	26.00a
F-test at 0.5%			**			**	

Table 9. Effect of interaction between nitrogen rates x varieties x spraying zinc levels on sugar yield/fed of sugar beet in 2020/2021and 2021/2022 seasons.

Sugar beet varieties	Nitrogen fertilizer rates/fed	Spraying zinc levels (g/L)					
		First season			Second season		
		Zero	2.25	4.50	Zero	2.25	4.50
Aladdin	70 kg N	1.50l	1.83k	2.38i	1.28l	1.67k	2.22ij
	95 kg N	2.34i	2.61gh	2.30i	2.08j	2.56fg	3.00d
	120 kg N	2.07j	2.67fgh	2.99e	2.30hij	2.66ef	2.85de
Lulu	70 kg N	1.61l	1.94jk	2.34i	1.81k	2.12ij	2.35ghi
	95 kg N	2.50hi	2.78efg	3.19d	2.66ef	2.93d	3.28c
	120 kg N	2.79efg	2.94ef	3.28d	2.51fgh	2.57fg	3.56b
Zoom	70 kg N	1.88jk	2.34i	2.88ef	1.87k	2.35ghi	2.96d
	95 kg N	2.68fgh	3.22d	3.92b	2.75def	3.26c	3.80c
	120 kg N	2.74efg	3.66c	4.26a	2.99d	3.65b	4.07a
F-test at 0.5%			**			**	

Conclusion

Fertilizing Zoom sugar beet variety with 120 kg N/fed as soil application and sprayed 4.5 g/L zinc on beet foliage can be recommended to get the highest root and sugar yields/fed under sandy soil in Wady El-Natron.

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