Egyptian Sugar Journal(2024), 21: 19- 31
https://doi.org/10.21608/esugj.2024.259521.1047

RESEARCH ARTICLE

Effect of sowing dates and geometrical distribution-based planting densities on the yield and quality of sugar beet

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Received: 30 December 2023\ Revised: 27 January 2024\ Accepted: 31 January 2024\ Published online: 31 January 2024.

Abstract

Growing of sugar beet in the tropics and subtropics is rapidly increasing as an important component of the sugar industry. The present study was carried out at the Agricultural Research Farm of the Delta sugar Company, El-Hamoul, Kafr El-Sheikh, Egypt during the two successive growing seasons 2020/2021 and 2021/2022 to evaluate the response of sugar beet varieties to three sowing dates under four geometrical distribution-based planting densities.

The analysis of variance (ANOVA) revealed significant and highly significant effects of sowing dates, planting densities and varieties as well as their interactions on the yield and quality parameters of sugar beet, i.e., sucrose% (Pol%), Na%, K%, α-amino-N%, quality index (Qz)%, root yield (RY), recoverable sugar (RS)%, recoverable sugar yield (RSY), sugar loss (SL)% and sugar loss yield (SLY). The highest root and recoverable sugar yields were produced from the late cultivation of the variety Santoline on October 16. Early cultivation of the Steel variety on August 17 at a high planting density (80,000 plants fed^{-1}) produced the highest values of sucrose content, RS% and Qz%, but the lowest values of Na%, K%, α-amino-N% and SL% in the two growing seasons. Whereas late sowing of the Santoline variety on October 16 at a moderate-low planting density of 53,300 plants fed^{-1} produced the highest RY and RSY in the two growing seasons. The results of the current study are crucial for sustainable and improved cultivation of sugar beet in Egypt.

Keywords: Beta vulgaris; Planting date; Plant density; Geometrical distribution; Root yield; Sugar yield

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Introduction

Sugar beet (*Beta vulgaris, L.*) is an important sugar crop worldwide. Although, it is relatively new in the Egyptian agricultural system (introduced in the early 1980's) it has acquired more importance and has become the first source of sugar in Egypt with a total cultivated area of more than 600,000 feddan, producing about 20 million Mt of sugar beets with an average sucrose content of about 18% (www.fao.org 2023; Abou-Elwafa et al. 2020). Growing of sugar beet in the tropical and subtropical areas to replace or supplement sugar production from sugarcane is steadily growing (Abou-Elwafa et al., Citation 2020; Simova-Stoilova et al., Citation 2016). Several advantages have been demonstrated for the cultivation of sugar beet as a promising sugar crop in these regions including its ability to grow efficiently in the newly reclaimed soils dominating these regions, its lower irrigation requirement, and its higher sugar productivity in a short growing period as compared to sugarcane (Abo-Elwafa et al. 2013; Abou-Elwafa et al. 2020; Balakrishnan and Selvakumar 2009). Besides, growing sugar beet in developing countries could be profitable for both farmers and sugar industry by diversifying farmers income by enabling them to grow an additional cash crop, and 2) supplying sugar plants with raw material in addition to the sugarcane which could extend the processing seasons of the sugar plants for up to 10 months of the year (Abou-Elwafa et al. 2020; Balakrishnan and Selvakumar 2009; Mandere et al. 2010). Optimizing agronomical practices, which depends on climatic conditions, is essential to achieve the potential yield and for sustainable cultivation of sugar beet in the tropics and subtropics where the crop is relatively new. Moreover, several studies revealed that the yield potential of sugar beet is largely associated with the adapted agronomical practices rather the number of plants per unit area per se (Galal et al. 2021; Elmasry and Al-Maracy 2023; Hussien et al. 2023). Besides, the negative association between sucrose concentration and root yield, and the need to maintain an acceptable level of sucrose concentration restrict to some extent the improving the potential root and sugar yields of sugar beet, thus maximizing the potential yield of sugar beet seems to be a slow process (Abou-Elwafa et al. 2020). Several studies have been conducted to determine the appropriate agronomical practices for enhancing the productivity and quality of sugar beet under different climatic conditions (Curcic et al. 2018; Gameh et al. 2020).In the light of the adverse consequences of global warming and climate change that negatively influence the productivity and quality of crop plants and greatly affect the sustainability of the agricultural production, the find out the most proper sowing date for sugar beet is essential for sustainable cultivation and production of sugar beet (Curcic et al. 2018).

However, considering other influencing factors such as, pests activity and industrial-related issues, the most proper sowing date is defined as the time of sowing that enables the crop to achieve the required heat units without excessive heat-or cold-shocks (Abdallah 2012; Alsadon 2002). Studies on the effect of planting density on the growth and development of sugar beet have major importance because it contributes to a better seed utilization and is decisive for the yield and quality. It is thought that the number and distribution of plants per unit area is a controllable problem in the technological production process of all field crops. Plant density and geometrical distribution of plants (inter- and intra-row planting distance) are essential for water conservation and the efficient use of water and fertilizers; therefore, they should be highly considered for improving the productivity and quality of sugar beet. The present study was conducted to study: 1) The effect of sowing dates on the yield and quality of sugar beet, and 2) The response of sugar beet varieties to geometrical distribution-based planting densities in terms of the yield and quality.

Materials and methods

Plant material and field experiments

A field experiment was conducted at the Agricultural Research Farm of the Delta Sugar Company, El-Hamoul (latitude of 31.92 N and longitude 31.14 E, at an elevation of 14 m above sea level), Kafr El-Sheikh, Egypt, in the two successive growing seasons 2020/2021 and 2021/2022 to study the effect of sowing dates and geometrical distribution on the yield and quality of sugar beet. The randomized complete block design (RCBD) in a split-split plot arrangement with three replicates was implemented in both growing seasons. Three sowing dates, i.e., August 17 (SD1), September 16 (SD2) and October 16 (SD3), were allocated to the main plots, whereas the four geometrical distribution-based planting densities, i.e., 50 cm two inter-row and 10 cm intra-row planting distances (high planting density of 80,000 plants fed^{-1}), 60 cm two inter-row and 10 cm intra-row planting distances (moderate-high planting density of 66,600 plants fed^{-1}), 50 cm inter-row and 15 cm intra-row planting distances (moderate-low planting density of 53,300 plants fed^{-1}) and 60 cm two inter-row and 15 cm intra-row planting distances (low planting density of 44,400 plants fed^{-1}), were allocated to the sub-plots and three monogerm varieties, i.e.,

Avetage, Santoline and Steel., were allocated to the sub-sub plots. The plot area was (21 m^2), in the case of 50 cm inter-row planting distance, the plot consists of 6 ridges, each 7 m long. Meanwhile, at the conditions of 60 cm inter-row planting distance, the plot consists of 5 ridges, each 7 m long. The outer two ridges were considered a belt or band, whereas the central ridges were kept determining the yield and quality traits. Harvest was performed 210 after sowing. Seeds were sown by machine at the rate of one seed per hill. Recommended doses of N, P and K and all other cultural practices were performed according to locally recommended practices for sugar beet production. In brief, single super phosphate (15.5% P_2O_5) at a rate of 200 kg/ fed. was applied during soil bed preparation. Nitrogen in the form of urea (46.5% N) at a rate of 120 kg/ fed. was applied in two equal doses, i.e., the first one after 45 days from the sowing, and the second one was applied 30 days later.

Potassium sulphate (50% K_2O) at the rate of 100 kg/ fed. was added with the first irrigation. Other agronomical practices were performed as locally recommended for sugar beet cultivation and production. The average daily temperatures during the 2020/2021 and 2021/2022 growing seasons (Figure 1) were obtained from the online meteorological tool Wunderground (https://www.wunderground.com). The preceding crop was rice in both seasons.

Soil analysis of the experimental sites

Composite representative soil samples (0-30 cm) were randomly collected from the experimental sites before sowing and after harvest and prepared for both physical and chemical analysis. Samples were air dried, ground and finally sieved using 2 mm sieves to determine the physical and chemical properties.

Mechanical analysis was determined according to the international pipette method (Piper 1950). Soil pH was measured in (1: 2.5) soil: water suspension using HannapH-meter (Jackson 1967).

The total soluble salts were determined by measuring the electrical conductivity (ECe) using electrical conductivity meter (EC meter model consort 410) in saturation extract of soil in dS/ m, United States Salinity Laboratory staff (Richards 1954).

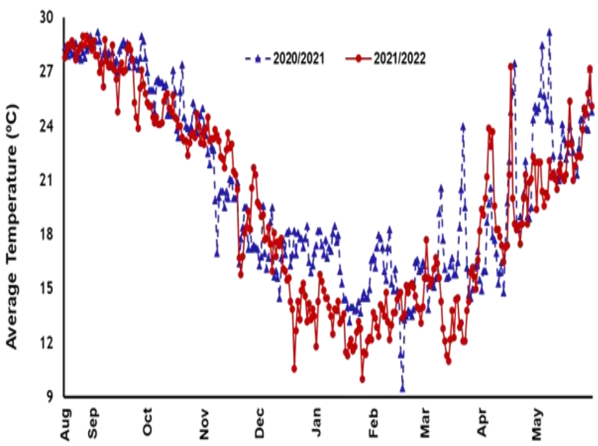

Figure 1. Average daily temperatures during the two 2020/2021 and 2021/2022 growing seasons.

The total carbonates were determined using Collins calcimeter (Dexter et al. 1967). The soil organic matter was determined using walkley and Blacks method (Hesse 1974). The basic physical and chemical properties of the experimental soils are presented in Table 1.

Table 1. Basic physical and chemical properties of the experimental soils in the 2020/2021 and 2021/2022 growing seasons.

Variable	Growing season 2020/2021	2021/2022
Physical analysis:		
Sand %	24.58	26.24
Silt %	22.84	23.45
Clay %	52.58	50.31
Texture class	Clay	Clay
Chemical analysis:		
Soil reaction pH (1:2.5)	8.20	8.18
EC (m. mhos/cm)	5.21	5.47
Organic matter %	1.25	1.32
Available N (ppm)	16.57	16.24
Available P (ppm)	10.45	10.32
Available K (ppm)	362	374
Soluble cations (meq/L):		
Ca2+	5.63	5.83
Mg2+	6.07	6.56
Na+	45.05	41.82
K+	1.37	1.15
B	0.32	0.38
Mo	0.21	0.25
Soluble anions (meq/L):		
HCO-3	3.93	3.62
Cl-	31.13	28.78
SO-4	15.88	14.34
CO-3	0.00	0.00

Phenotypic evaluation

At harvest, only the central area of each plot was considered for determining yield and yield-related traits. In the case of 50 cm inter-row planting distance, plot was considered as the 4 inner rows of 7 m in length to yield an area of 14 m^2, while in the case of 60 cm intra-row spacing, the plot was considered as the 3 inner rows of 7 m in length resulting in an area of 12.6 m^2.

A representative root sample of about 20 kg of roots from each plot was used for juice quality analysis by measuring sucrose%, potassium (K)%, sodium (Na)% and α-amino-N% in the root juice. Root juice quality parameters were estimated using the Venema, Automation BV AnalyzerIIG-16-12-99, 9716JP/Groningen/Holland at Delta Sugar Company Limited Laboratories according to the procedure used by Le Docte (1927). Quality index, sucrose loss%, and sugar loss yield were calculated using the following equations (Reinefeld et al. 1974). The collected data in the experiments involved the following traits:

1- Root yield: at maturity (210 days from sowing), the central area from each plot was harvested (root yields for this area were converted to metric tons per feddan) in the two growing seasons.

Quality parameters: the quality parameters of the roots include:

2- Sucrose content (Pol %).

3- Sodium content (Na %).

4- Potassium content (K %).

5- α-amino-N (%).

6- Quality index (Qz %), was calculated according to the following formula:

Qz=Pol%-0.29+0.343 (K+Na)+0.0939(α-amino N) x100/Pol%

7- Rcoverable sugar (RS %), was calculated according to the following formula:

Sugar recovery% =Pol-0.29-0.343(K+Na)-0.094(α-amino N)

8-Sugar losses (SL %), was calculated according to the following formula:

Sugar loss% = 0.343(K+Na) + 0.094(α-amino N)+0.29

9- Recoverable sugar yield (RSY; ton fed^{-1}).

RSY=Root yield ×Recoverable sugar%

10- Sugar loss yield (SLY; ton fed^{-1}).

SLY = Root yield ×sugar losses%

Statistical analysis

The Proc Mixed of SAS 130 package version 9.2 was used to perform analysis of variance (ANOVA) and Fisher's least significant difference (LSD) of significantly differed treatments.

Results and Discussion

Effect of sowing dates on the yield, beet juice quality parameters and sugar losses

Plant growth, development and yield are the result of the genetic composition, environmental factors, and the interaction of these two components. The phenomenon of genotypes × environment interaction (G×E) is always present in crop production causing genotypes to have different results and ranks in various environmental conditions (Ndhlela et al. 2014). Environments differ in the amount and quality of inputs and stimuli that they convey to plants including the amount of water, nutrients, and radiation (Malosetti et al. 2013). G×E is often associated and explained with genetic terms of adaptation and stability (Dimitrijević and Petrović 2000; Das et al. 2010). The yield and quality of sugar beet are affected by several agronomical and environmental factors.

The identification of the most suitable planting date for sugar beet is pivotal for sustainable production and cultivation of sugar beet (Al-Dhumri et al. 2022). Modifying the sowing dates is one of the most often used adaptations in sugar beet cultivation. Results suggest that prolonging the vegetation period by early sowing significantly increases sugar yields, and decreases the differences in sugar yields obtained from different varieties (Curcic et al. 2018).

The analysis of variance (ANOVA) exhibited significant effects of sowing dates on the root yield of sugar beet in both growing seasons (Table 2). Root yield was significantly increased when sugar beet was sown late on October 16 (37.32 and 38.13 t fed^{-1}) compared to that sown early on August 17 (25.39 and 25.93 t fed^{-1}) (Table 3). Data shown in Table 3 revealed that root growth in both seasons followed the same trend, significant increase in values of root yield with delaying sowing dates from August to October. This significant increase is due to the available good chance for growth from optimum temperature for growth and accumulation of photosynthesis substances which resulted in higher root yield (Lauer 1997; Shirvan et al. 2019; Tayyab et al. 2023; Javaheri 2023; Figure 1).Delaying sowing led to a significant increase in Na%, K%, α-amino-N%, and RSY, and a significant reduction in the sucrose %, Qz% and RS%. Sucrose content resulted from the early sowing sugar beet on August 17 (18.77 and 18.98%) significantly surpassed that resulted from the delayed sowing sugar beet date October 16 (17.35 and 17.56%) in the first and second growing seasons, respectively (Table 3). Delaying sowing from August 17 to October 16 is associated with a significant reduction in the Qz% and RS% in both growing seasons from 83.25 and 83.83%, and 15.82 and 16.12 % to 76.03 and 76.78%, and 12.13 and 13.47 in the first and second growing seasons, respectively. Whereas delaying sowing from August 17 to October 16 led to a significant increase in the RSY 4.01 and 4.17 t fed^{-1} to 4.89 and 5.12 t fed^{-1}, in the first and second growing seasons respectively.

Table 2. Analysis of variance for sowing dates, geometrical distribution-based planting densities, varieties and their interactions on evaluated traits in the 2020/21 and 2021/22 growing seasons.

S.O.V.	d.f	Sucrose (%)		Na (%)		K (%)		α-amino-N (%)		Qz (%)	
		2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
Rep.	2	0.007ns	1.458ns	0.003ns	0.042ns	0.101ns	0.020ns	0.060ns	0.027ns	30.986ns	0.101ns
Sowing date (S)	2	18.530**	18.768**	5.165**	6.087**	24.689**	18.670**	7.861**	4.376**	355.11**	310.262**
Error	4	0.013	0.010	0.002	0.004	0.010	0.009	0.010	0.004	1.763	0.010
Planting density (D)	3	1.767**	1.771**	0.0162*	0.049**	0.150*	0.183ns	0.123ns	0.052ns	28.010ns	4.597ns
S×D	6	0.079ns	0.023ns	0.001ns	0.006ns	0.021ns	0.059ns	0.099ns	0.020ns	18.934ns	0.399ns
Error	18	0.006	0.002	0.000	0.001	0.004	0.008	0.0188	0.002	2.023	0.177
Varieties (V)	2	2.494**	1.824**	0.003ns	0.004ns	1.385**	1.634**	0.186ns	0.018**	1.199ns	14.056**
S×V	4	0.175*	0.054*	0.005ns	0.004ns	0.051ns	0.047*	0.085ns	0.006**	16.543ns	0.039ns
D×V	6	0.0291ns	0.154**	0.016**	0.005ns	0.163*	0.179**	0.205ns	0.004**	23.076ns	0.941**
S×D×V	12	0.040ns	0.097**	0.004ns	0.004ns	0.037ns	0.035*	0.201ns	0.006**	18.767ns	0.183ns
Error	48	0.005	0.001	0.000	0.000	0.006	0.001	0.017	0.000	1.990	0.020

*, ** and ns denote significant, highly significant and non-significant effects, respectively.

Table 2. Continu

S.O.V.	d.f	RY (t fed^{-1})		RS (%)		SL (%)		RSY (t fed^{-1})		SLY (t fed^{-1})	
		2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
Rep.	2	0.940ns	13.37ns	0.074ns	0.611ns	0.101ns	0.058ns	0.008ns	0.039ns	0.003ns	0.003ns
Sowing date (S)	2	1306.48**	1367.7**	48.853**	43.834**	7.482**	6.403**	9.802**	14.22*	3.964**	3.726**
Error	4	0.013	0.003	0.002	0.064	0.002	0.006	0.004	0.007	0.000	0.000
Planting density (D)	3	813.79**	824.68**	1.879**	2.057**	0.013ns	0.030**	15.93**	16.130**	0.836**	0.787**
S×D	6	5.430**	5.842**	0.046ns	0.042ns	0.002ns	0.009ns	0.044ns	0.029ns	0.025**	0.017**
Error	18	0.029	0.004	0.008	0.010	0.001	0.000	0.003	0.009	0.000	0.001
Varieties (V)	2	36.910**	38.00**	3.775**	3.313**	0.229**	0.213**	0.870**	0.480**	0.115**	0.106**
S×V	4	0.067ns	0.333**	0.189ns	0.016ns	0.006ns	0.005ns	0.027ns	0.011ns	0.000ns	0.001**
D×V	6	0.150ns	0.065ns	0.010ns	0.161*	0.018*	0.015**	0.027ns	0.019ns	0.002**	0.001**
S×D×V	12	0.025ns	0.070*	0.034ns	0.066ns	0.009ns	0.006ns	0.026ns	0.013ns	0.001*	0.001**
Error	48	0.049	0.003	0.012	0.005	0.001	0.000	0.007	0.005	0.000	0.001

*, ** and ns denote significant, highly significant and non-significant effects, respectively.

Table 3. Mean values for all evaluated traits of the three sowing dates in the 2020/2021 and 2021/2022 growing seasons.

Trait	Growin season	SD1	SD2	SD3	LSD$_{0.05}$
Sucrose (%)	2020/2021	19.00	18.27	17.26	0.07
	2021/2022	19.23	18.47	17.53	0.06
Na (%)	2020/2021	2.49	2.98	3.55	0.03
	2021/2022	2.37	2.88	3.51	0.04
K (%)	2020/2021	5.18	6.03	6.70	0.06
	2021/2022	5.12	5.79	6.57	0.06
α-amino-N (%)	2020/2021	2.70	2.99	3.46	0.06
	2021/2022	2.59	2.91	3.37	0.04
Qz (%)	2020/2021	83.25	79.90	76.03	0.87
	2021/2022	83.83	80.80	76.78	0.07
RY (t fed^{-1})	2020/2021	28.39	32.83	37.32	0.07
	2021/2022	25.93	33.56	38.13	0.03
RS (%)	2020/2021	15.82	14.61	12.13	0.03
	2021/2022	16.12	14.93	13.47	0.17
SL (%)	2020/2021	3.17	3.66	4.13	0.03
	2021/2022	3.10	3.54	4.06	0.05
RSY (t fed^{-1})	2020/2021	4.01	4.79	4.89	0.04
	2021/2022	4.17	5.00	5.12	0.05
SLY (t fed^{-1})	2020/2021	0.81	1.20	1.54	0.01
	2021/2022	0.80	1.19	1.55	0.01

SD1; sowing on August 17, SD2; sowing on September 16, SD3; sowing on October 16

The early sowing on August 17 produced the lowest values of Na% (2.49 and 2.37%), K% (5.18 and 5.12%) and α-amino-N% (2.70 and 2.59%) compared to the late sowing on October 16 that produced the highest values of Na% (3.55 and 3.51%), K% (6.70 and 6.57%) and α-amino-N% (2.67 and 2.23%) in the first and second growing seasons respectively. Early sowing significantly reduces SL% and SLY (Table 2). On the other hand, early sowing is associated with a significant increase in the sucrose %, quality and recoverable sugar%. SL% and SLY were significantly increased in response to delaying sowing from August 17 (3.17 and 3.10%, and 0.81 and 0.80 t fed^{-1}) to October 16 (4.13 and 4.06%, and 0.1.54 and 1.55 t fed^{-1}, in the first and second growing seasons respectively (Table 3). The changes observed in the quality related traits in response to delaying sowing dates (reduced RS% and increased SL% SLY and RSY) might be due to that the effect of delaying sowing on root weight was higher than its effect of sucrose content (Çakmakçi and Oral 2002; Öztürk et al. 2008; Pavlů et al. 2017; Vahidi et al. 2018).

Effect of geometrical distribution-based planting densities on the yield, beet juice quality parameters and sugar losses

The number of plants per unit area is one of the most important factors for high yield, therefore, it has been investigated for decades. The most common causes for a reduced number of plants per unit area are the reduced field germination and the agronomical practices such as poor seedbed preparation, sowing time, but also the destruction of plants through cultivating. There are several biotic factors (weediness and pests attack) and abiotic factors (flooding and drought stress) which can also reduce the number of plants per unit area (Jursík et al. 2008; Viric Gasparic et al. 2020). Geometrical distribution-based planting densities exhibited significant or highly significant effects on sucrose %, Na%, K%, α-amino-N%, RY, RS%, RSY, SL% and SLY (Table 2). The results revealed that increasing geometrical distribution-based planting density from led to significant increases sucrose %, Qz% and RS%. On the other hand, increasing geometrical distribution-based planting density significantly decreases Na%, K%, α-amino-N%, RY, SL%, RSY as well as SLY. The reduction in the RSY in response to increasing inter- and intra-row planting distances (60×15 cm), although increasing the root yield, is due to the high reduction in the sucrose% and the increase in the impurity levels (Na, K and α-amino-N) under the low planting density (Table 4). These results could be attributed to the wider planting distances that would favor the partitioning of more photoassimilates towards increasing storage root growth over storing of sucrose in the roots, and thus reducing root juice quality parameters (Smit (1993; Smit et al. 1996; Bosemark 1993). The highest planting density of 80,000 plants fed^{-1} that resulted from sowing sugar beet at 50 cm inter-row and 10 cm intra-row planting distances produced the highest values of sucrose% (18.76 and 19.01%), RS% (15.07 and 15.34 %) and Qz% (80.90 and 81.41%), and lowest values of Na% (2.88 and 2.84%), K% (5.84 and 5.69 %) and SL% (3.56 and 3.51%) in the first and second growing seasons, respectively.in the first and second growing seasons, respectively (Table 4). On the other hand, sowing sugar beet at 50 cm inter-row distances and 15 cm intra-row distances (moderate-low planting density of 53,300 plants fed^{-1}) produced the highest values of RY (37.05 and 37.79 t fed^{-1}) and RSY (5.38 and 5.60 t fed^{-1}) in the first and second growing seasons, respectively. The increase in RY and RSY in response to increasing planting density might be ascribed to that higher plant densities produce the largest number of moderate-weight roots per unit area with higher sucrose content. Besides, growing sugar beet plants at narrow planting distances would be in favor of partitioning more photo assimilates towards the storage of more sucrose in the roots (Ahmad et al. 2015; Varga et al. 2021; Elnoury 2022).

Table 4. Mean values for all evaluated traits of the geometrical distribution-based planting densities in the 2020/2021 and 2021/2022 growing seasons.

Trait	Growin season	50×10 cm	50×15 cm	60×10 cm	60×15 cm	$LSD_{0.05}$
Sucrose (%)	2020/2021	18.76	18.31	17.95	17.68	0.05
	2021/2022	19.01	18.51	18.18	17.94	0.03
Na (%)	2020/2021	2.88	2.97	3.05	3.13	0.01
	2021/2022	2.84	2.90	2.94	3.01	0.01
K (%)	2020/2021	5.84	5.95	6.04	6.06	0.03
	2021/2022	5.69	5.82	5.87	5.93	0.05
α-amino-N (%)	2020/2021	2.97	2.97	3.01	3.26	0.08
	2021/2022	2.84	2.88	3.00	3.11	0.03
Qz (%)	2020/2021	80.90	80.04	79.30	78.67	0.81
	2021/2022	81.41	80.82	80.12	79.52	0.24
RY (t fed^{-1})	2020/2021	27.62	37.05	26.62	36.10	0.10
	2021/2022	28.29	37.79	27.27	36.80	0.04
RS (%)	2020/2021	15.07	14.68	14.26	13.94	0.05
	2021/2022	15.34	14.99	14.59	14.29	0.06
SL (%)	2020/2021	3.56	3.63	3.69	3.75	0.02
	2021/2022	3.51	3.53	3.59	3.65	0.01
RSY (t fed^{-1})	2020/2021	4.15	5.38	3.75	4.97	0.03
	2021/2022	4.33	5.60	3.93	5.20	0.05
SLY (t fed^{-1})	2020/2021	1.02	1.36	1.00	1.37	0.01
	2021/2022	1.04	1.35	0.99	1.37	0.01

Effect of varietal differences on the yield, beet juice quality parameters and sugar losses

Significant and highly significant variations among the three evaluated varieties, i.e., Avetage, Santoline and Steel, in the ten studies traits were observed in the two growing seasons (Table 2). The monogerm variety Steel produced the highest values of sucrose% (18.68 and 18.86%), and the lowest Na (2.86 and 2.77 %), K (5.66 and 5.51 %), α-amino-N (2.81 and 2.71 %), RY (30.93 and 31.59 t fed-1), SL% (3.48 and 3.38%) and SLY (1.10 and 1.09 t fed-1) in the first and second growing seasons, respectively, however, due to its higher sucrose content it has surpassed the two other varieties in Qz% (81.24 and 81.92 %) and RS% (15.20 and 15.47 %) in the two growing seasons (Table 5).

The superiority of the variety Steel in these particular quality parameters could be ascribed to its genetic makeup that enabled it from partitioning more photoassimilates towards increasing sucrose content.

Table 5. Mean values for all evaluated traits of three varieties in the 2020/2021 and 2021/2022 growing seasons.

Trait	Growin season	Avetage	Santoline	Steel	$LSD_{0.05}$
Sucrose (%)	2020/2021	17.67	18.18	18.68	0.03
	2021/2022	17.94	18.43	18.86	0.02
Na (%)	2020/2021	3.19	2.96	2.86	0.01
	2021/2022	3.13	2.86	2.77	0.01
K (%)	2020/2021	6.23	6.02	5.66	0.04
	2021/2022	6.11	5.86	5.51	0.02
α-amino-N (%	2020/2021	3.35	2.99	2.81	0.06
	2021/2022	3.25	2.90	2.71	0.00
Qz (%)	2020/2021	78.16	79.78	81.24	0.67
	2021/2022	78.89	80.59	81.92	0.07
RY (t fed^{-1})	2020/2021	31.68	32.93	30.93	0.11
	2021/2022	32.40	33.63	31.59	0.03
RS (%)	2020/2021	13.44	14.52	15.20	0.05
	2021/2022	13.87	14.88	15.47	0.04
SL (%)	2020/2021	4.23	3.65	3.48	0.01
	2021/2022	4.07	3.55	3.38	0.01
RSY (t fed^{-1}	2020/2021	4.33	4.72	4.64	0.04
	2021/2022	4.54	4.94	4.82	0.03
SLY (t fed^{-1}	2020/2021	1.34	1.22	1.10	0.01
	2021/2022	1.32	1.22	1.09	0.01

The highest RY (32.93 and 33.63 t fed^{-1}) and RSY (4.72 and 4.94 t fed^{-1}), in the first and second growing seasons respectively, were produced from the variety Santoline (Table 5). The superiority of the variety Santoline in RY might be attributed to its genetic makeup that enabled maximizing light interception, enhance its photosynthetic capacity and partitioning more photoassimilates towards promoting the growth of storage roots.

Table 6. Mean values for all evaluated traits as affected by the interaction between sowing date and geometrical distribution-based planting densities in 2020/2021 and 2021/2022 seasons.

Trait	Sowing date	SD1				SD2				SD3				$LSD_{0.05}$
	Growin season	50×10 cm	50×15 cm	60×10 cm	60×15 cm	50×10 cm	50×15 cm	60×10 cm	60×15 cm	50×10 cm	50×15 cm	60×10 cm	60×15 cm	
Sucrose (%)	2020/2021	19.71	19.12	18.70	18.46	18.73	18.43	18.11	17.78	17.85	17.34	17.03	16.81	0.078
	2021/2022	19.88	19.41	18.92	18.68	19.14	18.52	18.20	18.02	18.00	17.61	17.41	17.1	0.045
Na (%)	2020/2021	2.43	2.45	2.50	2.58	2.85	2.99	3.01	3.06	3.34	3.46	3.62	3.76	0.018
	2021/2022	2.26	2.54	2.31	2.38	2.81	2.86	2.90	2.96	3.34	3.39	3.60	3.70	0.023
K (%)	2020/2021	5.05	5.12	5.21	5.35	5.90	5.95	6.16	6.12	6.56	6.70	6.76	6.77	0.059
	2021/2022	4.99	5.14	5.10	5.23	5.64	5.74	5.89	5.91	6.45	6.58	6.11	6.63	0.086
α-amino-N (%)	2020/2021	2.62	2.65	2.68	2.84	2.97	2.93	2.92	3.16	3.32	3.33	3.43	3.77	0.136
	2021/2022	2.48	2.50	2.64	2.74	2.85	2.78	2.95	3.06	3.28	3.25	3.41	3.55	0.049
Qz%	2020/2021	84.23	83.56	82.92	82.24	80.90	80.27	79.48	78.97	77.57	76.26	75.49	74.80	1.408
	2021/2022	84.32	84.22	83.69	83.08	81.91	81.08	80.30	79.90	77.98	77.18	76.35	75.59	0.417
RY	2020/2021	21.89	29.84	20.92	28.91	28.42	38.28	27.42	37.20	32.55	43.02	31.50	42.20	0.169
	2021/2022	22.30	30.38	21.50	29.53	29.17	38.92	28.24	37.90	33.39	44.08	32.07	42.97	0.062
RS (%)	2020/2021	16.61	15.99	15.51	15.19	15.16	14.82	14.40	14.04	13.85	13.23	12.86	12.58	0.088
	2021/2022	16.78	16.35	15.85	15.53	15.68	15.02	14.62	14.40	14.04	13.59	13.30	12.93	0.099
SL (%)	2020/2021	3.10	3.13	3.19	3.27	3.57	3.63	3.71	3.74	4.00	4.11	4.17	4.23	0.031
	2021/2022	3.12	3.06	3.08	3.16	3.46	3.50	3.58	3.62	3.96	4.02	4.11	4.17	0.019
RSY (t fed^{-1})	2020/2021	3.63	4.77	3.24	4.39	4.30	5.67	3.95	5.22	4.51	5.69	4.05	5.31	0.058
	2021/2022	3.74	4.97	3.41	4.58	4.57	5.84	4.13	5.46	4.69	5.99	4.26	5.56	0.092
SLY (t fed^{-1})	2020/2021	0.68	0.94	0.67	0.95	1.02	1.39	1.02	1.39	1.30	1.77	1.31	1.79	0.016
	2021/2022	0.69	0.93	0.66	0.93	1.01	1.36	1.01	1.37	1.32	1.77	1.32	1.79	0.018

SD1; sowing on August 17, SD2; sowing on September 16, SD3; sowing on October 16

Table 7. Mean values for all evaluated traits as affected by the interaction between geometrical distribution-based planting densities and varieties in 2020/21 and 2021/22 seasons.

Trait	Inter-×intra-row planting distances	50×10 cm			50×15 cm			60×10 cm			60×15 cm			$LSD_{0.05}$
	Varieties	Avetage	Santoline	Steel	Avetage	Santoline	Steel	Avetage	Santoline	Steel	Avetage	Santoline	Steel	
Sucrose (%)	2020/2021	18.19	18.73	19.37	17.79	18.26	18.87	17.47	17.97	18.41	17.25	17.75	18.05	0.068
	2021/2022	18.32	19.03	19.67	18.21	18.44	18.88	17.74	18.23	18.56	17.47	18.02	18.32	0.042
Na (%)	2020/2021	3.14	2.81	2.67	3.15	2.94	2.81	3.21	3.00	2.92	3.28	3.09	3.03	0.019
	2021/2022	3.31	2.75	2.63	3.01	2.83	2.67	3.08	2.88	2.85	3.12	2.98	2.94	0.015
K (%)	2020/2021	6.05	5.92	5.54	6.17	5.97	5.70	6.34	6.10	5.69	6.38	6.09	5.70	0.075
	2021/2022	5.86	5.75	5.46	6.07	5.85	5.34	6.19	5.95	5.47	6.33	5.9	5.55	0.036
α-amino-N (%)	2020/2021	3.16	2.98	2.76	3.28	2.88	2.76	3.37	2.90	2.76	3.59	3.20	2.97	0.123
	2021/2022	3.18	2.82	2.63	3.07	2.75	2.69	3.38	2.95	2.66	3.37	3.11	2.87	0.003
Qz%	2020/2021	79.36	80.85	82.49	78.55	80.05	81.51	77.67	79.38	80.83	77.05	78.81	80.14	1.337
	2021/2022	79.53	81.66	83.04	79.63	80.75	82.10	78.56	80.20	81.59	77.86	79.77	80.94	0.135
RY	2020/2021	27.88	28.67	26.62	36.74	38.31	36.09	26.53	27.58	25.74	35.91	37.16	35.25	0.210
	2021/2022	28.21	29.36	27.29	37.58	38.97	36.83	27.22	28.32	26.28	36.60	37.86	35.94	0.051
RS (%)	2020/2021	14.45	15.16	16.00	14.00	14.64	15.41	13.59	14.28	14.90	13.31	14.01	14.49	0.106
	2021/2022	14.59	15.56	16.36	14.52	14.92	15.52	13.96	14.64	15.17	13.62	14.39	14.85	0.070
SL (%)	2020/2021	3.74	3.57	3.37	3.79	3.62	3.47	3.88	3.68	3.50	3.94	3.74	3.56	0.024
	2021/2022	3.73	3.47	3.31	3.69	3.53	3.36	3.79	3.60	3.39	3.85	3.63	3.47	0.019
RSY (t fed^{-1})	2020/2021	3.94	4.30	4.21	5.08	5.55	5.50	3.56	3.89	3.79	4.73	5.15	5.05	0.078
	2021/2022	4.07	4.52	4.41	5.40	5.75	5.65	3.75	4.10	3.92	4.93	5.39	5.28	0.069
SLY (t fed^{-1})	2020/2021	1.05	1.04	0.93	1.42	1.41	1.27	1.05	1.03	0.90	1.44	1.41	1.28	0.017
	2021/2022	1.07	1.04	0.92	1.41	1.40	1.26	1.05	1.04	0.91	1.43	1.40	1.27	0.010

Effect of the binary interactions of the studied factors on the yield, beet juice quality parameters and sugar losses

The interaction between sowing dates and geometrical distribution-based planting densities exhibited significant effects on the studied traits in both growing seasons (Table 2). The results showed that early sowing of sugar beet on August 17 with a higher planting density of 80,000 plants fed^{-1} (50×10 cm, inter- and intra-row planting distances) resulted in the significantly highest values of sucrose% (19.71 and 19.88%), RS% (16.61 and 16.78%) and Qz% (84.23 and 84.32%), and the lowest values of Na% (2.43 and 2.26%), K% (5.05 and 4.99%), α-amino-N% (2.62 and 2.48%) in the first and second growing seasons, respectively. Whereas late sowing of sugar beet on October 16 with a low planting density of 44,400 plants fed^{-1} (60×15 cm, inter- and intra-row planting distances) produced the highest values of Na% (3.76 and 3.70%), K% (6.77 and 6.63%), α-amino-N% (3.77 and 3.55%), SL% (4.23 and 4.17%) and SLY (1.79 and 1.79 t fed^{-1}) in the first and second growing seasons, respectively. Delayed sowing to October 16 in combination with a moderate-low planting density of 53,300 plants fed^{-1} (60×15 cm, inter- and intra-row planting distances) produced the highest values of RY (43.02 and 44.08 t fed-1) and RSY (5.69 and 5.99 t fed^{-1}) in both growing seasons (Table 6).

The variety Steel was superior in sucrose% (19.37 and 19.67%), Qz% (82.49 and 83.04%), RS% (16.00 and 16.36%), Na% (2.67 and 2.63%), K% (5.54 and 5.46%), α-amino-N% (2.76 and 2.63%) and SL% (3.37 and 3.31%), in the first and second growing seasons respectively, when cultivated at a high geometrical distribution based-planting density of 80,000 plants fed^{-1} (50×10 cm, inter- and intra-row planting distances). The highest RY (38.31 and 38.97 t fed^{-1}) and RSY (5.55 and 5.75 t fed^{-1}) in the first and second growing seasons, respectively, resulted from the variety Santolina cultivated at a moderate-low planting density of 53,300 plants fed^{-1} (50×15 cm, inter- and intra-row planting distances).

The variety Steel cultivated early on August 17 yielded the highest values of sucrose% (19.55 and 19.75%), RS% (16.54 and 16.85%) and Qz(84.59 and 8533%), but the lowest values of Na% (2.39 and 2.17%), K% (4.84 and 4.76%), α-amino-N (1.740 and 1.507%), RY (24.56 and 25.14 t fed-1), SL% (3.01 and 2.89%) and SLYd (0.74 and 0.73 t fed^{-1}) in the first and second growing seasons, respectively (Table 7).

Table 8. Mean values for all evaluated traits as affected by the interaction between sowing s and varieties in 2020/21 and 2021/22 seasons.

Trait	Sowing date	SD1			SD2			SD3			$LSD_{0.05}$
	Varieties	Avetage	Santoline	Steel	Avetage	Santoline	Steel	Avetage	Santoline	Steel	
Sucrose (%)	2020/2021	18.45	19.01	19.55	17.70	18.27	18.84	16.88	17.26	17.64	0.059
	2021/2022	18.74	19.20	19.75	17.92	18.52	18.97	17.15	17.58	17.86	0.037
Na (%)	2020/2021	2.68	2.40	2.39	3.11	2.99	2.83	3.79	3.50	3.35	0.017
	2021/2022	2.77	2.17	2.17	2.95	2.91	2.79	3.68	3.50	3.35	0.013
K (%)	2020/2021	5.48	5.22	4.84	6.33	6.12	5.66	6.88	6.73	6.48	0.065
	2021/2022	5.45	5.14	4.76	6.06	5.85	5.47	6.83	6.60	6.28	0.031
α-amino-N (%)	2020/2021	2.89	2.66	2.54	3.24	2.97	2.77	3.92	3.34	3.13	0.107
	2021/2022	2.82	2.57	2.38	3.15	2.89	2.96	3.79	3.26	3.07	0.002
Qz%	2020/2021	81.74	83.41	84.59	78.33	79.77	81.60	74.40	76.14	77.54	1.158
	2021/2022	81.99	84.16	85.33	79.47	80.74	82.18	75.21	76.88	78.24	0.117
RY	2020/2021	25.18	26.43	24.56	32.96	33.91	31.89	37.17	38.46	36.33	0.182
	2021/2022	25.68	26.97	25.14	33.45	34.85	32.64	38.08	39.33	36.97	0.045
RS (%)	2020/2021	15.07	15.85	16.54	13.87	14.57	15.38	12.56	13.14	13.68	0.091
	2021/2022	15.36	16.16	16.85	14.24	14.96	15.59	12.90	13.51	13.89	0.061
SL (%)	2020/2021	3.36	3.15	3.01	3.83	3.69	3.46	4.32	4.11	3.96	0.021
	2021/2022	3.37	3.04	2.89	3.68	3.56	3.38	4.25	4.06	3.88	0.017
RSY (t fed^{-1})	2020/2021	3.79	4.18	4.05	4.53	4.94	4.89	4.66	5.04	4.96	0.068
	2021/2022	3.95	4.35	4.22	4.76	5.16	5.08	4.91	5.30	5.16	0.059
SLY (t fed^{-1})	2020/2021	0.85	0.83	0.74	1.25	1.25	1.10	1.61	1.58	1.44	0.014
	2021/2022	0.86	0.82	0.73	1.23	1.23	1.10	1.62	1.60	1.44	0.009

SD1; sowing on August 17, SD2; sowing on September 16, SD3; sowing on October

Table 9. Mean values for all studied traits as affected by the interaction between sowing dates, planting densities and sugar beet varieties in the 2020/21 and 2021/22 growing seasons.

Sowing date	Planting density	Variety	Sucrose (%)		Na (%)		K (%)		α-amino-N (%)	
			2020/	2021/	2020/	2021/	2020/	2021/	2020/	2021/
SD1	50×10 cm	Avetage	18.95	19.17	2.6	3.35	5.29	5.17	2.79	2.84
		Santoline	19.73	19.83	2.42	2.19	5.09	5.0٣	2.6	2.45
		Steel	20.45	20.65	2.28	2.07	4.75	4.57	2.46	2.21
	50×15 cm	Avetage	18.58	18.99	2.5٨	2.47	5.32	5.38	2.8	2.65
		Santoline	19.03	19.36	2.32	2.15	5.09	5.11	2.62	2.43
		Steel	19.76	19.88	2.45	2.15	4.9٤	4.9٣	2.54	2.36
	60×10 cm	Avetage	18.22	18.5	2.75	2.58	5.58	5.54	2.96	2.87
		Santoline	18.73	18.85	2.4٠	2.15	5.3١	5.20	2.57	2.59
		Steel	19.15	19.43	2.36	2.2٠	4.75	4.77	2.51	2.45
	60×15 cm	Avetage	18	18.29	2.81	2.67	5.74	5.٧٠	3.02	2.91
		Santoline	18.53	18.74	2.44	2.2٠	5.37	5.2٢	2.84	2.79
		Steel	18.85	19.02	2.48	2.26	4.٩٣	4.٧٩	2.65	2.51
SD2	50×10 cm	Avetage	18.12	18.38	3.04	2.92	6.03	5.7٠	3.17	3.01
		Santoline	18.64	19.18	2.81	2.77	6.1٢	5.83	2.99	2.83
		Steel	19.43	19.85	2.7٠	2.75	5.56	5.37	2.74	2.7
	50×15 cm	Avetage	17.83	18.05	3.12	2.92	6.26	6.0٣	3.19	2.95
		Santoline	18.46	18.52	3.04	2.96	5.98	5.70	2.88	2.71
		Steel	19.07	18.98	2.82	2.7٠	5.6٢	5.48	2.72	2.68
	60×10 cm	Avetage	17.53	17.71	3.12	2.98	6.48	6.1٩	3.2	3.35
		Santoline	18.11	18.3	3.04	2.88	6.21	5.96	2.82	2.97
		Steel	18.7	18.6	2.88	2.83	5.78	5.53	2.74	2.53
	60×15 cm	Avetage	17.33	17.54	3.16	2.97	6.5٥	6.3٣	3.4	3.28
		Santoline	17.85	18.09	3.08	3.02	6.1٥	5.89	3.19	3.06
		Steel	18.16	18.45	2.93	2.88	5.67	5.51	2.89	2.83
SD3	50×10 cm	Avetage	17.5	17.42	3.78	3.66	6.81	6.70	3.53	3.7
		Santoline	17.82	18.07	3.21	3.29	6.55	6.39	3.35	3.17
		Steel	18.22	18.51	3.04	3.07	6.32	6.25	3.09	2.97
	50×15 cm	Avetage	16.95	17.59	3.74	3.64	٦.85	6.8١	3.85	3.62
		Santoline	17.28	17.45	3.47	3.39	6.85	6.73	3.13	3.1
		Steel	17.79	17.78	3.16	3.15	6.54	6.21	3.01	3.03
	60×10 cm	Avetage	16.66	17.02	3.76	3.69	٦.٩٥	6.83	3.96	3.92
		Santoline	17.06	17.55	3.57	3.61	6.77	6.68	3.29	75.6٩
		Steel	17.38	17.66	3.53	3.51	6.55	6.32	3.01	76.٨٠
	60×15 cm	Avetage	16.42	16.58	3.86	3.72	6.92	٦.٩6	4.35	3.91
		Santoline	16.87	17.23	3.76	3.71	6.74	6.59	3.58	3.48
		Steel	17.15	17.49	3.67	3.68	6.51	6.35	3.38	3.26
	$LSD_{0.05}$		0.118	0.073	0.034	0.026	0.130	0.062	0.213	0.005

SD1; sowing on August 17, SD2; sowing on September 16, SD3; sowing on October 16

Table 9. Continu.

Sowing date	Planting density	Variety	Qz (%)		RY (t fed^{-1})		RS (%)		SL (%)	
			2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
SD1	50×10 cm	Avetage	82.٨٠	81.84	21.72	22.11	15.69	15.69	3.26	3.48
		Santoline	84.23	84.89	22.97	23.38	16.62	16.83	3.11	3.00
		Steel	85.66	86.2٣	20.98	21.40	17.52	17.81	2.93	2.84
	50×15 cm	Avetage	82.4٤	82.98	29.62	30.03	15.32	15.76	3.26	3.23
		Santoline	83.8٣	84.4٦	30.94	31.52	15.95	16.35	3.08	3.01
		Steel	84.50	85.2٢	28.97	29.59	16.70	16.94	3.06	2.94
	60×10 cm	Avetage	81.٢٠	81.9٢	20.73	21.26	14.79	15.16	3.43	3.35
		Santoline	83.0٥	83.79	21.92	22.46	15.55	15.79	3.18	3.06
		Steel	84.5٢	85.37	20.12	20.79	16.19	16.59	2.96	2.84
	60×15 cm	Avetage	80.5٢	81.2٣	28.66	29.31	14.49	14.86	3.51	3.43
		Santoline	82.5٤	83.4٨	29.89	30.50	15.29	15.64	3.24	3.10
		Steel	83.66	84.5٣	28.19	28.79	15.77	16.08	3.08	2.94
SD2	50×10 cm	Avetage	79.5٩	80.٨٠	28.40	29.12	14.42	14.85	3.70	3.53
		Santoline	80.5١	81.7٢	29.43	30.24	15.01	15.67	3.63	3.51
		Steel	82.60	83.22	27.42	28.16	16.05	16.52	3.38	3.33
	50×15 cm	Avetage	78.64	79.8٦	37.99	38.74	14.02	14.41	3.81	3.64
		Santoline	80.٢٠	81.01	39.58	40.04	14.80	15.00	3.66	3.52
		Steel	81.96	82.36	37.27	37.99	15.63	15.63	3.44	3.35
	60×10 cm	Avetage	77.84	78.83	27.36	28.12	13.65	13.96	3.89	3.75
		Santoline	79.4١	80.32	28.37	29.16	14.38	14.70	3.73	3.60
		Steel	81.18	81.7٥	26.53	27.43	15.18	15.20	3.52	3.40
	60×15 cm	Avetage	77.27	78.4١	37.02	37.81	13.39	13.75	3.94	3.79
		Santoline	78.9٧	79.9١	38.26	38.90	14.10	14.46	3.74	3.63
		Steel	80.66	81.3٩	36.32	36.99	14.65	15.02	3.51	3.43
SD3	50×10 cm	Avetage	75.68	75.93	32.55	33.40	13.25	13.23	4.26	4.19
		Santoline	77.8٢	78.3٧	33.61	34.46	13.87	14.16	3.95	3.91
		Steel	79.19	79.65	31.49	32.32	14.43	14.74	3.79	3.77
	50×15 cm	Avetage	74.٥٨	76.0٥	42.60	43.97	12.64	13.38	4.31	4.21
		Santoline	76.13	76.7٨	44.42	45.36	13.16	13.40	4.12	4.05
		Steel	78.0٨	78.71	42.05	42.91	13.89	13.99	3.90	3.79
	60×10 cm	Avetage	73.٩٧	74.92	31.51	32.26	12.32	12.75	4.34	4.27
		Santoline	75.6٩	76.47	32.45	33.33	12.91	13.42	4.15	4.13
		Steel	76.٨٠	77.66	30.55	30.61	13.34	13.72	4.03	3.94
	60×15 cm	Avetage	7٣.٣٧	73.٩٤	42.03	42.69	12.05	12.26	4.37	4.32
		Santoline	74.9٤	75.91	43.34	44.18	12.64	13.08	4.23	4.15
		Steel	76.١٠	76.9٢	41.22	42.04	13.05	13.45	4.10	4.04
	$LSD_{0.05}$		2.315	0.234	0.213	0.005	0.183	0.122	0.041	0.034

SD1; sowing on August 17, SD2; sowing on September 16, SD3; sowing on October 16

Table 9. Continu.

Sowing date	Planting density	Variety	RSY (t fed^{-1})		SLY (t fed^{-1})	
			2020/2021	2021/2022	2020/2021	2021/2022
SD1	50×10 cm	Avetage	3.41	3.47	0.71	0.77
		Santoline	3.82	3.94	0.71	0.70
		Steel	3.67	3.81	0.62	0.61
	50×15 cm	Avetage	4.54	4.73	0.97	0.97
		Santoline	4.94	5.15	0.95	0.95
		Steel	4.84	5.01	0.89	0.87
	60×10 cm	Avetage	3.07	3.22	0.71	0.71
		Santoline	3.41	3.55	0.70	0.69
		Steel	3.26	3.45	0.60	0.59
	60×15 cm	Avetage	4.15	4.35	1.01	1.01
		Santoline	4.57	4.77	0.97	0.94
		Steel	4.45	4.63	0.87	0.85
SD2	50×10 cm	Avetage	4.10	4.32	1.05	1.03
		Santoline	4.42	4.74	1.07	1.06
		Steel	4.40	4.65	0.93	0.94
	50×15 cm	Avetage	5.32	5.58	1.45	1.41
		Santoline	5.86	6.01	1.45	1.41
		Steel	5.82	5.94	1.28	1.27
	60×10 cm	Avetage	3.73	3.93	1.06	1.05
		Santoline	4.08	4.28	1.06	1.05
		Steel	4.03	4.17	0.93	0.93
	60×15 cm	Avetage	4.96	5.20	1.46	1.43
		Santoline	5.39	5.62	1.44	1.41
		Steel	5.32	5.55	1.28	1.27
SD3	50×10 cm	Avetage	4.31	4.42	1.38	1.40
		Santoline	4.66	4.88	1.33	1.35
		Steel	4.54	4.77	1.19	1.22
	50×15 cm	Avetage	5.39	5.88	1.84	1.85
		Santoline	5.84	6.08	1.83	1.84
		Steel	5.84	6.01	1.64	1.62
	60×10 cm	Avetage	3.88	4.11	1.37	1.38
		Santoline	4.19	4.47	1.35	1.38
		Steel	4.08	4.20	1.23	1.21
	60×15 cm	Avetage	5.06	5.23	1.84	1.84
		Santoline	5.48	5.78	1.83	1.83
		Steel	5.38	5.66	1.69	1.70
	$LSD_{0.05}$		0.136	0.119	0.029	0.018

SD1; sowing on August 17, SD2; sowing on September 16, SD3; sowing on October 16

These results could be attributed to that some varieties might respond differently to the prolongation of the vegetation period, light interception, and available nutrients which positively affect their photosynthetic capacity and dry matter accumulation (Pavlů et al. 2017; Öztürk et al. 2008; Hemayati et al. 2012; Curcic et al. 2018). Early cultivation of the variety Steel on August 17 at a high planting density of 80,000 plants fed^{-1} (50×10 cm, inter- and intra-row planting distances) produced the highest values of sucrose% (20.45 and 20.65%), RS% (17.52 and 17.81%) and Qz% (85.66 and 86.23%), but the lowest values of Na% (2.28 and 2.07%), K% (4.75 and 4.57%), α-amino-N (2.46 and 2.21%) and SL% (2.93 and 2.84%) in the first and second growing seasons, respectively. The highest RY and RSY of 44.42 and 45.36, and 5.84 and 6.08 t fed^{-1}, in the first and second growing seasons respectively, were produced from the late sowing of the Santoline variety on October 16 at a moderate-low planting density of 53,300 plants fed^{-1} (50×15 cm, inter- and intra-row planting distances) (Table 9). The data emphasize the differential response of the evaluated varieties to the different environments in term of the length of the growing season, light interception, nutrients uptake and photosynthetic capacity which eventually affect the partitioning of photoassimilates, dry matter accumulation and sucrose storage (Pavlů et al. 2017; Öztürk et al. 2008; Hemayati et al. 2012; Curcic et al. 2018).

Acknowledgments

The authors gratefully acknowledge the staff of the Delta Sugar Company Research Farm, Kafr El-Sheikh, Egypt for excellent technical assistance.

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