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RESEARCH ARTICLE

Evaluation of the quantitative and qualitative characteristics of sugar beet cultivars in different sowing times and transplanting and direct-seeding systems

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Abstract

To study the characteristics of sugar beet cultivars in transplanting and direct-seeding systems on three different sowing times (March 29, April 8, and April 18), a split plot experiment based on randomized complete blocks in three replications was carried out in Miandoab and Bokan regions, Northwest of Iran in 2016. The results showed that the highest nitrogen content was observed between the two test locations in the Bukan area. Results showed that the low root sodium, alkalinity, and molasses content was recorded for transplanting system. The minimum content of root sodium, nitrogen, and molasses sugar was observed in the plants sown on March 29. The Dorotea cultivar showed the highest root yield, sugar yield, and white sugar yield and the lowest root nitrogen and molasses sugar content compared to Isabella and Ekbatan. The highest white sugar content, coefficient of sugar extraction, sugar yield, root yield, and white sugar yield were recorded in the transplanting system with the sowing time of March 29; however, the highest content of root potassium and sugar content was observed in the transplanting system sown on April 18. The highest root yield was observed in the Dorotea cultivar, with a sowing time of March 29. Among the locations in the cultivar and planting system interaction treatments, the highest sugar content was found in the Bukan area's Dorotea cultivar in the transplanting system. Finally, the highest sugar yield was related to the transplanting system on March 29 in the Bukan area. It can be stated that an early sowing time (March 29), transplanting, and Dorotea variety were identified as the most appropriate treatments to improve the economic traits of sugar beet.

Keywords

Cultivar; Dorotea; planting system; root yield

Introduction

Sugar beet (*Beta vulgaris*) is one of the most important crops in various climate considerations (1). The crop requires a relatively long growing period, normally ranging from 140-200 days (2); therefore, the planting time has a significant role in sugar beet production.

It has been shown that one of the most critical factors in crop management is sowing time, which affects crop yield and other agronomic traits. Many studies have revealed that all quantitatively inherited traits in sugar beet that depend upon environmental conditions and cultivation practices, such as the sowing time, can significantly vary (3-5). Sowing either too early or too late is undesirable (6-8).

The sowing time is essential in sugar beet growth, yield, and root quality. The previous crop, weather conditions, and cultivar in a given location influence the sowing time (9). The quantity and quality of crops can be significantly affected by planting time (10).

An early sowing time prolongs the growth period, one of the most essential determining factors of sugar beet yield changes (11). It has been reported that late harvesting cannot compensate for the adverse effect of delaying planting (12). Developing new sugar beet cultivars resistant to bolting has made it possible to determine the optimal planting time for sugar beet (13). Lamichhane *et al.* (14, 15) have emphasized the positive effect of optimal sowing time on improving sugar beet's quantitative and qualitative characteristics. The researchers found that the delay in the sugar beet's planting time significantly reduced this crop's root yield (16, 17). Some researchers believe that there is a linear relation between sugar beet yield quality and quantity and sowing and harvesting times (18).Sugar beet yield can be affected by other factors such as planting methods. Direct-seeding in main fields has a negative effect on crops and reduces desirable yields due to the higher susceptibility of the early growth stages of the plant to undesirable environmental conditions, such as unfavorable temperature. The transplant method lengthens the growing season by planting earlier in greenhouses when direct seeding may not be feasible due to inadequate environmental conditions outside the greenhouse (19). Therefore, transplants grown under greenhouse or nursery conditions help to accelerate the sugar beet germination and growth (12) by preventing the seed exposure to unacceptable environmental conditions and escaping from bolting damage due to early season cold weather in spring (20). The transplanting method is one way to save more water to increase water productivity (WP) in sugar beet cultivation (21). In research, transplanting reduced the amount of water consumption and evapotranspiration in sugar beet by 24%, leading to water savings and an increase in root yield by 7.7% (21).

This study aimed to determine sugar beet cultivars' quantitative and qualitative characteristics in transplanting and direct-seeding systems.

Materials and Methods

A two-location field experiment was conducted during the growing season of 2016 at the farm agricultural research station of Bokan (36° 31′N, 46° 12′E, altitude 1338 m) and Miandoab (36° 58′N, 46° 6′E, altitude 1314 m) in the north-west of Iran, in a semi-arid environment. To determine the physicochemical characteristics of the soil of the test site, samples were taken from a depth of 30 cm (Table 1).

Experimental design and cultural practices

The experimental design was a split-plot factorial based on a randomized complete block design with three replications. The design included two planting systems, i.e., the direct-seeding system and the transplanting method, as the main plots, three sowing times of March 25, April 8, and April 18, and three cultivars Dorotea, Isabella, and Ekbatan as subplots.

In autumn, a deep plowing was conducted to prepare the seed bedding. The field preparation operations in the spring included the implementation of surface plowing, disc, leveling, and preparation of planting lines (using a sheeper). The distribution of fertilizer was performed according to the results of soil analysis. Accordingly, 225 kg ha^{-1} urea fertilizer was applied to the field during two stages of planting, 2-4 and 6-8 leaves. In addition, 135 and 110 kg triple super phosphate and potassium sulfate fertilizers were applied to the field with autumn plow. Each plot consisted of 5 rows and was 5 m long, and spacing between rows and plant spacing per row were 50 and 15 cm, respectively.

All operations were related to each experimental unit, including irrigation (every 15 days). Controlling weeds, pests, and plant diseases was carried out during the growing season.

Seedlings of three cultivars were planted in greenhouses at 5°C for 45 days in paper pots. Before transferring the transplants to the mainland, a part of the seedling leaves was removed to prevent transpiration. The first irrigation was immediately carried out following transplantation after the transfer of transplants to the mainland based on planting times.

Assessment of traits

The final harvest was conducted on October 31, 2016. The three middle rows were harvested at the harvest stage for sampling and assessing the traits. The roots were washed, and pulp samples were prepared randomly. The pulp samples were used to measure the quantitative and qualitative characteristics at the Sugar Technology Laboratory of SBSI, Karaj. To this end, the dried samples were taken out of the frozen state and mixed with 177 ml of lead (II) hydroxide acetate for three minutes. After the solution passed through a filter, a clear liquid was obtained, which was used in Betalysis (An automated system for quality analysis of sugar beet) to measure sugar (%), sodium (Na), alpha-amino nitrogen (N), and potassium (K) content. After determining the sugar, N, Na, and K contents, the other studied traits were estimated as follows (22):

Table 1. Physical and chemical properties of the soil in the Bukan and Miandoab area.

Texture	K (ppm)	Z (ppm)	Ca (ppm)	NH4 (ppm)	NO3 (ppm)	Mg (ppm)	N (total) (ppm)	O.C (%)	T.N.V (%)	pH	EC Ds/(m)
Clay loam (Bokan)	423	13.35	5.3	13.78	20.71	3.81	0.14	1.25	0.18	7.60	1.21
Silty loam (Miandoab)	256	8.04	8.0	13.16	19.54	3.52	0.13	0.77	8.0	8.1	2.13

MS= 0.0343 (K +Na) + 0.094 (alpha amino N) - 0.31

WSC= SC - (MS+0.6).

ALC= (K +Na)/(alpha amino N)

WSY= WSC × RY

Where, SC = sugar content, MS = the molasses sugar percentage, ALC = alkalinity, and WSC = the white sugar content.

Statistics

Data were analyzed using analysis of variance (ANOVA) and generalized linear model (GLM) in SAS9.2. The Duncan multiple range test was conducted for mean comparisons.

Results

The results of the ANOVA test (Supplementary Table) revealed that the difference between the two locations was significant only in nitrogen content. There was a significant difference between the planting systems regarding all treatments except root potassium. The effect of the sowing time on all the measured characteristics was significant. The interaction of planting times with planting systems significantly affected the root potassium content, sugar content, white sugar content, coefficient of sugar extraction, root yield, and white sugar yield. The difference between cultivars was significant regarding all investigated traits except for root potassium content. The interaction between variety and the sowing time significantly affected root alkalinity, sugar content, and root yield. Finally, the interaction effect between location, variety, and sowing time was significant in white sugar yield.

Root impurities

Root sodium content

The results showed that the direct-seeding)3.88 ppm. (had a higher root sodium content compared with the transplanting method)2.25 ppm. (Table 2).

Table 2. Mean comparison effect of planting system on studied traits of sugar beet.

Planting system	Root sodium content (ppm)	Root nitrogen content (%)	Alkalinity (%)	Molasses sugar (%)
Direct-seeding	3.38a	3.36a	2.50b	2.53a
Transplanting	2.25b	2.62b	3.10a	1.71b

In each column, mean with same character do not have a significant difference at the 5% level.

Among the studied sowing times, the highest root sodium content)3.54 and 3.22ppm. (were recorded on April 8 and 18, respectively, while the lowest root sodium content was observed on March 29 (2.52 ppm) (Table 3).

The mean comparison of cultivars revealed that Ekbaran (3.28 ppm) had the highest root sodium content, and Isabella and Dorotea cultivars (2.96 and 2.95 ppm) had the lowest content (Table 4).

Root potassium content

The results indicated that the highest root potassium contents (4.28 and 4.1 ppm, respectively), were obtained in the direct-seeding system on the sowing times of April 8, while the lowest value was observed in the transplanting method on the sowing time of March 29 (2.61 ppm) (Table 5). The results also showed that the direct-seeding system had the highest root potassium content on all the sowing times compared with the transplanting method.

Nitrogen content

A comparison of the tested area in terms of the nitrogen content showed that the roots harvested from the Bokan area had significantly higher nutrient content (2.2%) than those of the Miandoab region (2.33%) (Fig. 1).

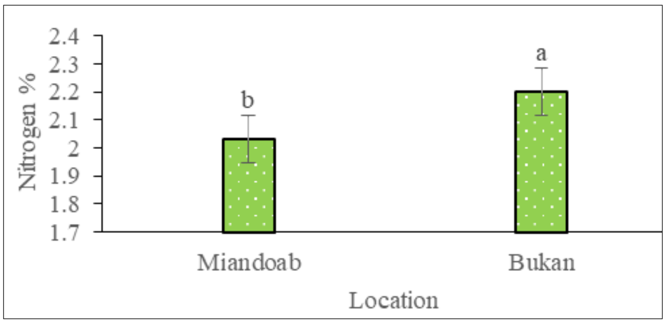

Fig. 1. Comparison of the two studied locations in terms of the root nitrogen content.

The mean comparison of different sowing times revealed that the amount of nitrogen content was higher on April 18 (2.25%) and lower on March 29 and April 8 (2.02% and 2.07%), respectively (Table 3).

Among the three examined cultivars, Ekbatan (2.25%) had the highest nitrogen content, while Isabella and Dorotea's cultivars had the lowest nitrogen (2.27% and 0.22%, respectively) (Table 4).

In the present study, the nitrogen content had a positive and significant correlation with the potassium content at 1% (Table 6).

Alkalinity

In the plants obtained using the transplanting method, the

Table 3. Mean comparison effect of sowing data on studied traits of sugar beet

Sowing data	Root sodium content (ppm)	Root nitrogen content (%)	Molasses sugar (%)
29 March	2.52b	2.02b	1.67b
8 April	3.54a	2.07b	2.32a
18 April	3.22a	2.25a	2.37a

In each column, mean with same character do not have a significant difference at the 5% level.

Table 4. Mean comparison effect of cultivars on studied traits of sugar beet.

Cultivar	Sodium content (ppm)	Root nitrogen content (%)	White sugar content (%)	Coefficient of sugar extraction (%)	Sugar yield t/ha	White sugar yield t/ha	Molasses sugar (%)
Ekbatan	3.28a	2.25a	12.51b	75.65b	9.44b	7.21b	1.99b
Isabella	2.96 b	2.07b	13.01b	73.36b	10.29b	7.62b	2.22a
Dorotea	2.95b	2.02b	15.02a	81.57a	10.38a	8.39a	2.15a

In each column, mean with same character do not have a significant difference at the 5% level.

Table 5. Mean comparison of effect of sowing data and planting system on studied traits of sugar beet.

Sowing data	Planting system	Root potassium content (pm)	Sugar content (%)	White sugar content (%)	Coefficient of sugar extraction (%)	Root yield t/ha	White sugar yield t/ha
29 March	Direct-seeding	3.27b	17.68ab	13.52bc	77.08b	58.34b	7.77bc
	Transplanting	2.61c	17.54ab	15.01a	87a	62.58a	9.50a
8 April	Direct-seeding	4.28a	18.2a	12.44d	68.79c	51.84c	6.56d
	Transplanting	3.52b	16.9b	14.34ab	85.36a	59.77ab	8.71ab
18 April	Direct-seeding	4.1a	18.45a	12.81cd	70.42c	53.39c	6.90cd
	Transplanting	3.26b	18.02a	12.90cd	72.5bc	53.77c	6.99cd

In each column, mean with same character do not have a significant difference at the 5% level.

Table 6. Correlation coefficient between studied traits.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Root sodium content (1)	1									
Root potassium content (2)	0.12^{ns}	1								
Root nitrogen content (3)	-0.13^{ns}	0.35**	1							
Alkalinity (4)	0.66**	0.52**	-0.27**	1						
Sugar content (5)	-0.11^{ns}	-0.14^{ns}	0.06^{ns}	0.23*	1					
White sugar content (6)	-0.42**	-0.02^{ns}	-0.08^{ns}	-0.23*	0.11^{ns}	1				
Coefficient of sugar extraction (7)	-0.26**	-0.33**	-0.09^{ns}	-0.36**	-0. 60**	0.70**	1			
Root yield (8)	0.14^{ns}	0.03^{ns}	-0.07^{ns}	0.23*	-0.12^{ns}	0.89**	0.70**	1		
Sugar yield (9)	-0.12^{ns}	0.14^{ns}	-0.01^{ns}	-0.01^{ns}	0.72**	0.76**	0.09^{ns}	0.77**	1	
White sugar yield (10)	-0.42**	0.03^{ns}	-0.07^{ns}	-0.23*	0.12^{ns}	0.79**	0.70**	0.95**	0.77**	1
Molasses sugar content (11)	0.73**	0.76**	0.37**	0.75**	0.27**	-0.25**	-0.40**	-0.24**	0.04^{ns}	-0.24**

ns, * and ** were no significant, significant at level 1 and 5% respectively.

alkalinity was observed to be lower as compared in the plants obtained using the direct-seeding system. The alkalinity amount was reduced by 28.41% as compared to the direct-seeding system (Table 2).

The results showed that between sowing times and variety interaction treatments, all three varieties showed the least alkalinity on March 29 sowing time, and there was no significant difference between the studied cultivars on this sowing time; the highest root alkalinity was recorded in the Isabella cultivar sown on April 8 (3.78%); however, no significant difference was observed between this treatment and the treatments of the Dorotea cultivar and Ekbatan and Isabella cultivars on April 8 sowing times (Table 5).

In our study, alkalinity had a positive and significant correlation with the root sodium and potassium content and a negative and significant correlation with the nitrogen content (Table 6).

Sugar content

The results revealed that the direct-seeding system (sown on 18 April) had the highest sugar content (18.45%), and the transplanting method (sown on April 8) had the lowest sugar content (16.9%) (Table 5).

The highest sugar content was observed in the Isabella cultivar on all three sowing times (18.50%, 17.95%, and 18.69%). The lowest value of this trait was related to the Ekbatan cultivar on April 8 sowing data (16.82%) (Table 7).

The results also showed a positive and significant correlation coefficient between sugar and alkalinity content (Table 6).

White sugar content

Our data demonstrated that the Dorotea cultivar (15.02%) had the highest and Ekbatan (12.51%) had the lowest white sugar content; the difference between Ekbatan and Isabella was not significant (Table 4).

Table 7. Mean comparison of effect of sowing data and cultivars on studied traits of sugar beet

Planting data	Cultivar	Alkalinity (%)	Sugar content (%)	Root yield t/ha
	Ekbatan	2.91bc	16.89cd	58.40b
29 March	Isabella	2.7c	18.50ab	59.33ab
	Dorotea,	2.55c	17.44bcd	62.64a
	Ekbatan	3.23b	16.82d	54.80bc
8 April	Isabella	3.78a	17.95abc	54.41bcd
	Dorotea,	3.39ab	17.88a-d	58.17b
	Ekbatan	3.34ab	18.59a	48.20d
18 April	Isabella	3.37ab	18.69a	50.72cd
	Dorotea,	3.02bc	17.42bcd	53.62bcd

In each column, mean with same character do not have a significant difference at the 5% level.

The results revealed that the transplanting system on March 29 (15.01%) and the direct-seeding system on April 8 (12.44%) produced the highest and lowest white sugar content, respectively. It should be noted that in two planting times, March 29 and April 8, the transplanting system remarkably improved the white sugar content compared to the direct-seeding system. However, on April 18, planting time, the difference between the planting systems was insignificant regarding white sugar content (Table 5).

According to the results, the correlation between white sugar and root sodium content and alkalinity was negative and significant (Table 6).

Coefficient of sugar extraction

Among the studied varieties, the highest coefficient of sugar extraction (81.57%) belonged to the Dorotea cultivar, while the lowest amount was observed in Isabella and Ekbatan cultivars (73.36% and 75.65%, respectively) (Table 4).

In the present study, using the transplanting system increased the coefficient of sugar extraction compared with the direct-seeding system. This increase was not statistically significant on the sowing time of April 18. In this research, the transplanting system showed the highest coefficient of sugar extraction on March 29 and April 8 sowing times (87.10% and 85.36%, respectively) and increased the amount of this trait by 12.86% and 24.08% as compared with the direct-seeding system, respectively; the lowest coefficient of sugar extraction (70.42%) was produced in the direct-seeding system on 18 April sowing data (Table 5).

In our study, the coefficient of sugar extraction had a negative and significant correlation with the root sodium and potassium content, alkalinity, and sugar content and had a positive and significant correlation with the white sugar content (Table 6).

Root yield

Among the planting systems and sowing times interaction treatments, the highest root yield (62.58 t/ha) was recorded in the transplanting system of March 29, while the lowest yield was observed in the direct-seeding system of April 8 and 18 and in the transplanting method of April 18 (51.84, 53.39, and 33.77 t/ha, respectively). In the present study, in both planting systems, the highest root yield belonged to early planting on March 29. The difference between the two planting systems on late sowing time could have been more remarkable (Table 5).

In this study, all three cultivars showed the highest and lowest root yields on March 29 and April 18 respectively. In the March 29 sowing system, the Dorotea cultivar (62.64 t/ha) showed the highest root yield, followed by the Isabella cultivar (59.33 t/ha). The Ekbatan cultivar (48.20 t/ha) had the lowest root yield in the sowing system of April 18 (Table 7).

Based on the traits correlation table results, the root yield had a positive and significant correlation with the white sugar content and coefficient of sugar extraction (Table 6).

Sugar yield

In the present study, although the maximum sugar yield (10.38 t/ha) was recorded for the Dorotea variety, there was no significant difference between this variety and Isabella regarding sugar yield. The lowest sugar yield was recorded for the Ekbatan (9.44 t/ha) (Table 3).

The mean comparison of triple effects of location, planting system, and sowing times on the sugar yield revealed that using the transplanting system for the March 29 sowing system in the Bokan location resulted in the highest sugar yield (11.74 t/ha); however, there was no significant difference between this triple treatment and the transplanting system established on April 8 in Miandoab location and the direct-seeding system on March 29 in Miandoab location, In this experiment, the minimum sugar yield (6.38 t/ha) was recorded in the direct-seeding system, on April 18 sowing time in Miandoab (Fig. 2).

The current results showed that the correlation between the sugar yield and sugar content, white sugar content, coefficient of sugar extraction, and root yield was positive and significant (Table 7).

White sugar yield

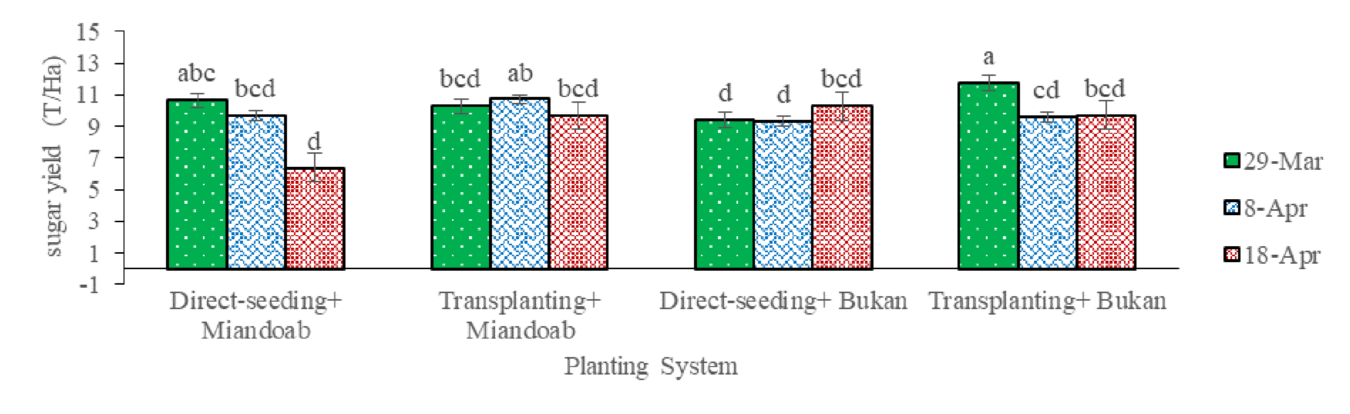

Fig. 2 .Mean comparison of triple effects of location in planting system in sowing dates in terms of sugar yield

According to the results, among the studied varieties, the Dorotea cultivar had the maximum white sugar yield (8.39 t/ha). In addition, the Ekbatan cultivar showed the lowest amount of white sugar yield (7.21 t/ha); however, there was no significant difference between this cultivar and the Isabella cultivar (Table 4).

The results showed that on both sowing times, March 29 and April 8, the highest white sugar yield was observed in the transplanting method. These treatments had the highest white sugar yield (9.5 and 8.71 t/ha), which was increased by 22.26% and 32.77% compared with the direct-seeding system on the mentioned sowing times. For the sowing time of April 18, no significant difference was detected between planting systems. The least white sugar yield (6.56 t/ha) was related to direct-seeding systems on April 8 (Table 5).

The results revealed that the correlation between the white sugar yield and white sugar content, coefficient of sugar extraction, and root and sugar yield was positive and considerable. However, this trait had a negative and significant relationship with the root sodium content and alkalinity (Table 6).

Molasses sugar content

The molasses sugar content was lower in the transplanting system than in the direct-seeding system, and its amount was reduced by 34.41% (Table 2).

Among the three studied sowing times, the highest molasses sugar content (2.37% and 2.32%, respectively) was related to April 8 and 18 sowing times, respectively. The lowest amount of molasses sugar content was observed for March 29 sowing time (1.67%) (Table 3).

The results showed that although the Isabella cultivar had the highest molasses sugar content with an average of 1.22%, there was no significant difference between this cultivar and the Ekbatan cultivar. The lowest molasses sugar content was recorded in the Dorotea cultivar, with an average of 1.99% (Table 4).

In the present study, molasses sugar content had a positive and meaningful relationship with root sodium, potassium and nitrogen content, alkalinity, and sugar content and a negative and significant correlation with white sugar content, coefficient of sugar extraction, root yield, and white sugar yield (Table 7).

Discussion

In the present study, root impurities were decreased by the transplanting method and early sowing times. The common aspect of both treatments is increasing the length of the plant growth period. Increasing the growth period will give the plant more time to store sugars and increase root mass. Root impurities such as sodium, nitrogen, and potassium will be used in biological processes, reducing their amount (12). In a study by Karbalaei *et al.* (23), the sowing time and transplant root size and their interaction did not affect root impurities. Among the examined cultivars, the Ekbatan variety had the highest root impurities; the said variety is Iranian, and its most important feature is resistance to the fungal disease Rhizoctonia, however, its other qualitative features are not at a desirable level.

In this study, the transplanting method and early sowing had lowered root alkalinity than other treatments. Alkalinity has a positive relationship with sodium and potassium content and a negative relationship with nitrogen content. The decrease in alkalinity content in the mentioned treatments is related to the decrease in the content of root impurities. In a study on sugar beet, the delay in planting increased sodium, potassium, and alpha-amine-nitrogen content (24).

The results of our study showed that sugar content showed a positive reaction to the planting system and seeding time on April 18. The Isabella cultivar had the highest sugar content in all three-sowing time. It can be stated that the genotype of the Isabella variety significantly influenced the sugar content, and the change in the sowing time could not change the effect of the genes related to the sugar content. Qasim and Al-Rawi (25) showed that delaying the sugar beet sowing time from October to December reduced the root yield and increased the sugar content.

It was found that the early planting and transplanting systems had a synergistic effect in improving the white sugar content, the common point in both treatments is time, and both treatments provide a suitable time for sugar production and storage and reduce the percentage of root impurities. Results revealed that the Dorotea cultivar had the highest white sugar content in both locations and planting systems; it can be said that this characteristic, like sugar content, is more influenced by genetic factors than environmental factors. It has been stated that the Hercules hybrid produced the highest and the lowest sugar content when sown on May 7 and June 11 (24).

Early plant deployment to the farm provides suitable conditions for achieving high root and sugar yield by increasing the leaf area and making it possible to receive the maximum radiation from the sun in May and June, which coincide with the maximum solar radiation. Studies have shown that shortening the growth period leads to a reduction in the white sugar content followed by a decrease in the root sugar yield (9, 26).

Coefficient of sugar extraction is one of the essential traits in sugar beet, and high values of this trait are desirable. This trait is the ratio of the white sugar content to the sugar content. The high values of the coefficient of sugar extraction in the transplanting system, the early planting time, and the Dorotea cultivar can be related to the high proportion of white sugar content in these treatments. The existence of a positive and significant correlation between the coefficient of sugar extraction and white sugar content can prove this claim.

This study's early planting and transplanting system significantly increased root yield in sugar beet. Also, Dorotea's variety showed the most positive reaction to the two mentioned treatments. The long growth period of March 29 and April 18, the optimal use of environmental factors such as light, temperature, and humidity, and the better matching of the growth stages with suitable environmental conditions were the reason for the higher yield on the March 29 and April 18 planting times. On April 18, the root yield will decrease due to the short growth period and reduced radiation absorption compared to the planting time on March 29, and the lack of absorption of part of the sun's rays by plant shading due to the delay in planting. This is explained by the fact that as the days become shorter, the "working day" of the photosynthetic apparatus of plants also decreases (27). The difference in root yield among different cultivars is related to different physiological characteristics and the amount of light absorption in different sugar beet cultivars. It seems that the Dorotea cultivar has a better genetic ability in optimal use of environmental conditions and has been able to transform production inputs into vegetative characteristics. Previous research found that the transplanting system positively affected the increase in root yield)(28-30) In research, transplanting led to an increase in root yield by 7.7% (31).

In the present study, the March 29 sowing time with the transplant system in the Bokan location had the highest sugar yield. Furthermore, the Dorotea variety had the highest sugar yield. Root yield and sugar content are two components of sugar yield; the high sugar yield in the early sowing time and transplanting system of sugar beet cultivars is related to the high content of the mentioned components. The positive correlation of sugar yield with sugar content and root yield proves this claim. It has been reported that the transplanting system had a higher sugar yield than the direct-sowing system for sugar beet (32). The positive effect of optimal planting times on increasing the economic yield of sugar beet has been reported in several studies (14-17).

According to the results, the Dorotea and Ekbatan cultivars had the highest and lowest white sugar yield among the studied varieties. In the study by Hoffman *et al.* (32), there was a significant difference between sugar beet genotypes regarding root, sugar, and white sugar yield.

Results revealed that on both March 29 and April 8 sowing times, the highest white sugar yield was observed in the transplanting method. The present study demonstrates that the effect of late planting on sugar yield can be compensated by planting as a transplant. However, planting on April 8th in the direct-seeding system reduced the white sugar yield by 8.31% compared with planting on March 29 in the same planting system.

White sugar yield was introduced as the most important characteristic of sugar beet, and the purpose of all the operations is to increase this trait. The mentioned trait is also influenced by root yield and white sugar content; early sowing time and transplanting system have improved the mentioned components and, finally, the white sugar yield.

In this study, the white sugar yield was influenced by the white sugar content, coefficient of sugar extraction, root yield, and sugar content; with the increase of each of the mentioned traits, the white sugar yield will increase. In the present study, an early sowing time and transplanting system could increase the economic yield of sugar beet, so an early sowing time of March 29 in the transplanting system and using the appropriate variety can be helpful in increasing the white sugar yield in sugar beet. Tahisin and Hali (26) reported that the short growth period decreases the root, sugar, and white sugar yield. Karbalaei *et al.* (23) found that delayed transplanting time reduced root yield, sugar yield, and white sugar yield significantly, such that the planting time of May 9 had the highest root yield, and white sugar yield with averages of 66.77, 10.35, and 8.21 t/ha. In the present study, the transplanting system reduced the molasses sugar content; also, the lowest amount of this trait was detected on March 29 sowing time. Furthermore, the Isabella cultivar had the highest molasses sugar content. The high molasses sugar content in these treatments can be related to the maximum content of impurities in the roots, such as sodium, potassium, and nitrogen (based on the molasses sugar content formula). It has been found that the value of K concentration was decreased, and the value of Na, white sugar content, and white sugar yield was increased in the transplanting method versus the direct seeding method (21).

Conclusion

In this study, early seeding versus late seeding and transplantation versus direct seeding improved the quality and quantity attributes of sugar beet. Thus, adopting the transplanting system and achieving maximum economic yield can save inputs such as water, fertilizers, and chemical pesticides. The transplanting system is also economical for sugar factories due to the increased sugar extraction efficiency. Therefore, using the transplanting system in early sowing can effectively increase the sugar beet yield in northwest Iran. In our research, the most optimal qualitative and quantitative traits were determined, and the Dorotea was identified as the best cultivar compared with others.

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Authors contributions

SHPM and TMM designed the experiment. MRD and SPM wrote the manuscript with support from AS and HAN.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

Supplementary data

Supplementary Table 1: Analysis of sources of variance for assessed traits.

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