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Assessment of heritability and identification of suitable hybrids for late sowing in sugar beet

A. Rajabi[(1)*], P. Pirniya[(2)], R. Amiri[(3)], S. Salimi[(4)], M. Ebrahimi[(5)] and M. Aghaee zade[(6)]

[(1)] *Assistant professor of Sugar Beet Seed Institute (SBSI), Karaj, Iran*
[(2)] *Former student of MSc of Plant breeding Sciences, College of Aburaihan, University of Tehran, Tehran, Iran.*
[(3)] *Associate Professor of Dept. of Agronomy and Plant Breeding Sciences, College of Aburaihan, University of Tehran, Tehran, Iran.*
[(4)] *MSc student of Plant breeding Sciences, College of Aburaihan, University of Tehran, Tehran, Iran.*
[(5)] *Assistant professor of Plant breeding Sciences, College of Aburaihan, University of Tehran, Tehran, Iran*
[(6)] *Instructor of Sugar beet Seed Institute (SBSI), Karaj, Iran.*

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ABSTRACT

In order to assess short vegetation period of sugar beet hybrids, an experiment was carried out in 2009 in randomized complete block (RCB) design with 4 replications in Abdolrasoul Motahari Agricultural Research Station of Sugar Beet Seed Institute, Karaj, Iran. In this research, the heredity of the traits in test crosses of 18 half sib families accompanied by a short vegetation period check variety under late sowing condition (about late July) was evaluated. ANOVA results showed that hybrids populations 3, 9, and 16 had significant difference with other populations and also with check variety for most quantitative and qualitative traits. Testcross 3 was considered suitable for short growth period which was comparable with a commercial variety. For morphological traits (such as leaf number and crown height) and some impurity traits (such as sodium and extraction coefficient of sugar) broad sense heritability was high. For root yield, sugar yield, and white sugar yield it was about zero. Root yield had significant positive correlations with sugar yield, white sugar yield, root diameter, and crown height and had a significant negative correlation with sugar content.

Keywords: breeding for short vegetation period, heritability, late sowing, root yield, water deficit

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is one of the most important plants of the Chenopodiaceae family. The production increase and productivity of this strategic crop depends on understanding the agronomy problems and applying new methods within agricultural framework. Sugar beet planting in Iran began 100 years ago and its planting area in 2007, 2008, and 2009 was 134000, 51000, and 52000 hectares, respectively with average root yield of 33, 34, and 35 ton ha^{-1} (Agricultural statistics 2010). It provides about 40% of sucrose need (Scott 1968). Depending on climatic conditions, it is planted in spring or autumn and by on time planting, an increase in optimal leaf area, resistant against pest and disease, proper density, and ultimately yield will be achieved. Delay in planting will cause poor growth and yield decrease (Lauer 1995). Lee et al. (1987) reported that photosynthesis materials allocation also depends on planting date and in late planting plant, leaves are destroyed more rapidly. In early planting, the total amount of dry matter is lost during the growing season than late planting. Delay in planting decreases dry matter production. Sugar beet planting is a function of temperature so that in cold and temperate regions, it is planted in late winter or early spring to decrease cold weather risk when both soil and weather temperature is not less than 4 °C. In warm and arid regions which have mild winter, it is planted in early autumn (Khodabandeh 1994). Abusalm and Elsyiad (2000) reported that each sugar beet cultivar has different planting and harvest date and cultivar selection

*Corresponding author's email: rajabi@sbsi.ir

Table 1. List of the 18 sugar beet testcrosses together with early check variety

No.	Testcross	No.	Testcross
1	261×276.p.77.sp.01	11	261×276.p.77.sp.24
2	261×276.p.77.sp.02	12	261×276.p.77.sp.25
3	261×276.p.77.sp.05	13	261×276.p.77.sp.27
4	261×276.p.77.sp.06	14	261×276.p.77.sp.28
5	261×276.p.77.sp.07	15	261×276.p.77.sp.44
6	261×276.p.77.sp.10	16	261×276.p.77.sp.45
7	261×276.p.77.sp.16	17	261×276.p.77.sp.47
8	261×276.p.77.sp.17	18	261×276.p.77.sp.48
9	261×276.p.77.sp.19	19	DS 4057 (Check)
10	261×276.p.77.sp.23		

should be done based on its performance in relation to planting and harvest date. Lauer (1996) showed that 46 days delay in planting caused 38% decrease in yield, 4% sugar reduction, and 42% sugar yield reduction. He concluded that yield and quality relation with planting and harvest date is linear and almost parallel. Genotype differences for grain yield and quality is higher in early planting than late planting. Ramazan and Oral (2002) reported that late planting reduced root yield owing to decrease in vegetative growth period. Fortune et al. (1999) stated that early planting resulted in increase of leaf area index, radiation absorption, and consequently dry matter and crown weight. Longer growing season, exposure to solar radiation, better leaves growth in early season, water use efficiency, and nutrients may lead to the above result. Studies showed that sugar beet planting in middle of March until middle of April resulted in similar sugar content however late planting caused a rapid reduction in yield (Hall and Webb 1970). On the other hand, one of the major problems of sugar beet planting is the coincidence of early growth irrigation need of sugar beet with late growth of some cereals such as wheat and barley so that the first two months of sugar beet growth (May and June) coincides with cereals irrigation peak and in competition between cereals and sugar beet farmers give priority to cereals. Rainfall amount is limited in Iran and owing to the plants need of more than 500 mm water the water supply is a major problem. Although sugar beet is known as a resistant plant to drought stress but it's susceptible to drought stress in early growth (Monti et al. 2006). There are two mechanisms to overcome this problem; using resistant cultivars or cultivars with short growth period which can be planted after cereal harvest (early July) (Basra and Basra 1997). Since the above cultivars reach the optimum yield in a shorter time, therefore they can be used for low irrigation problem in early sugar beet growth. However no remarkable study has been done for the measurement of heritability in suitable varieties of second planting (short growth period) or identification of suitable hybrids. It is clear that indirect selection in early generation via the traits which have good correlation with yield and also higher heritability than yield is one of the key strategies. Thus, knowledge of inheritance process and genotypic control of different traits under late planting condition is of importance in breeding programs (Chowdhry et al. 1999). This study aimed to identify suitable hybrids for short growth period and to calculate the heritability of the traits in late planting, and finally to determine the best testcrosses.

MATERIALS AND METHODS

This study was conducted at Abdolrasoul Motahari Research Station under Sugar Beet Seed Institute, Karaj (Latitude 35°52′N and Longitude 51°6′E, 1300 m above sea level) in 2007.

It has a hot and dry Mediterranean climate with heavy to moderate sediment soil texture (Rajabi et al. 2002). A trial which consisted of 18 testcrosses derived from a cross between 18 half-sib families with male sterile 261, and an early variety as check (Table 1) was conducted in a randomized complete block design with four replications. Seeds were planted on 24th June 2007 (as late planting) and were harvested on 6th November 2007.

Before planting, nitrogen fertilizer was added to the soil. Each plot consisted of three rows with 8 m length. Row to row and plant to plant distances were 50 and 9 cm, respectively with 2 cm planting depth.

First irrigation was performed on 27th June and the second irrigation was on 3rd July 2007. Weeding, plant thinning and fertilizers adding were done. Agronomical and morphological characteristics of 10 testcross plants were recorded in each plot. At harvest, plants per plot were harvested separately and root number, root length, root diameter and crown height were measured. To evaluate the qualitative traits of the testcross progenies, after root weighing and pulp preparing, sugar content, sodium, potassium, amino nitrogen, and extractable sugar percentage were measured by Betalyzer. Sugar yield and white sugar yield were measured based on the following equations (Abdollahian et al. 2005):

$$RY \times SY = SC \quad (1)$$

Table 2. Expected mean squares in complete randomised blocks

S.O.V.	Df	Ms	EMS
Replication	dfb	MS3	$\sigma^2 + t\sigma^2 r$
Treatment	dft	MS2	$\sigma^2 + r\sigma^2 g$
Error	dfe	MS1	$\sigma^2 e$

$$WSC = WSY \times RY \quad (2)$$

where SY is sugar yield, SC is sugar content, RY is root yield, WSY is white sugar yield, and WSC is white sugar content. To check normal distribution of the data, SAS software (V. 9.1) was used. For heritability measurement, data were not converted. Analysis of variance was performed on 18 testcrosses and then according to the expected mean squares in Table 2 and the following equations, heritability was calculated (Halluaer and Miranda 1982). Treatment means were separated by Duncan's multiple range test.

$$COV_{H.S} = \sigma^2 g = \frac{MS2 - MS1}{r} \quad (3)$$

$$\sigma^2 A = 4^{\sigma^2} g = 4^{COV_{H.S}} \quad (4)$$

$$H^2_{N.S} = \frac{\sigma^2 A}{\sigma^2 A + \frac{\sigma^2 e}{r}} \quad (5)$$

$$t(\sigma^2 A) = \frac{\sigma^2 A}{\sqrt{V(\sigma^2 A)}} \quad (6)$$

$$V(\sigma^2 A) = \frac{2 \times 4^2}{r^2}\left[\frac{MS2^2}{dft + 2} + \frac{ms1^2}{dfe + 2}\right] \quad (7)$$

$$S.E(h^2_{N.S}) = \frac{S.E(\sigma^2 A)}{\sigma^2 A + \frac{\sigma^2 e}{r}} \quad (8)$$

RESULTS AND DISCUSSION

ANOVA results showed that there was a significant difference among genotypes for most of the traits. Significant differences were found for leaf number, crown height, sodium content, amino nitrogen, and sugar extraction coefficient ($P < 0.01$), and also for root diameter and white sugar yield ($P < 0.05$, ANOVA table is not reported). Significant difference between genotypes suggests the existence of genetic variation so the genetic analysis of these traits is plausible. Duncan results showed that testcross 14 had the highest root diameter and sodium content but lower sugar extraction coefficient. Kashani (1987) reported that delay in planting in first growth stage had greater influence on root growth reduction. He also pointed out that sugar content in both early and late planting was lower than on time planting which can be due to insufficient leaf area and as a result reduction in elaborated sap. Because of negative correlation between sugar content and root enlargement, root weight loss can be partly

Table 3. Mean comparison of 18 sugar beet testcrosses together with check variety in late planting

Testcross number	Traits							
	Leaf number	Root diameter	Crown height	Sodium	Sugar extraction coefficient	Root yield	Sugar yield	White sugar yield
1	28.15 c-e	9.30 d	4.80 d	1.91 c-e	82.12 ab	47.07 c	9.14 c	7.50 bc
2	30.35 b-e	9.88 b-d	4.90 cd	1.35 de	83.47 a	46.01 c	9.15 c	7.63 bc
3	33.90 ab	11.40 a	6.08 a	1.75 c-e	80.25 ab	65.31 ab	12.61 ab	10.8 ab
4	31.33 a-e	9.60 cd	5.3 b-d	1.32 de	80.00 ab	49.35 a-c	8.51 c	6.88 c
5	32.40 a-e	10.75 a-c	5.53 a-c	1.92 c-e	79.39 ab	47.66 c	9.02 c	7.14 c
6	27.83 de	10.40 a-d	5.25 b-d	3.58 ab	78.25 b	54.85 a-c	10.26 a-c	7.98 bc
7	32.50 a-d	10.18 a-d	5.35 b-d	1.60 c-e	81.60 ab	47.16 c	9.31 bc	7.59 bc
8	30.80 b-e	10.00 b-d	5.68 ab	2.77 bc	78.93 b	51.94 a-c	9.55 bc	7.48 bc
9	30.48 b-e	10.23 a-d	5.25 b-d	2.22 c-e	78.43 b	59.60 a-c	11.27 a-c	7.84 a-c
10	27.30 e	9.80 b-d	4.90 cd	2.43 b-e	80.58 ab	54.30 a-c	10.74 a-c	8.69 a-c
11	30.25 b-e	10.33 a-d	5.25 b-d	2.44 b-e	79.15 ab	45.35 c	8.68 c	6.87 c
12	30.25 b-e	10.50 a-d	5.25 b-d	2.38 b-e	78.57 b	52.66 a-c	9.84 a-c	7.76 bc
13	28.58 c-e	9.95 b-d	4.80 d	1.70 c-e	81.42 ab	50.85 a-c	9.91 a-c	8.50 bc
14	28.75 c-e	11.00 ab	3.37 b-d	4.15 a	74.44 c	60.75 a-c	10.53 a-c	7.86 bc
15	31.83 a-e	10.03 b-d	4.93 cd	1.27 e	83.46 a	48.63 bc	9.23 a-c	8.28 a-c
16	29.28 b-e	10.55 a-d	5.35 b-d	1.81 c-e	81.42 ab	58.00 a-c	11.60 a-c	9.44 a-c
17	33.25 a-c	10.33 a-d	4.77 d	1.51 c-e	82.34 ab	46.13 c	9.30 bc	7.65 bc
18	35.60 a	10.68 a-c	5.38 b-d	2.64 b-d	79.22 ab	49.10 a-c	9.45 bc	7.49 bc
Check	28.85 b-e	10.50 a-d	5.33 b-d	2.46 b-e	82.14 ab	66.19 a	13.15 a	10.81 a
LSD	4.27	1.05	0.57	11.10	3.73	14.53	2.83	2.26

Means with same letter are not significantly different

Table 4. Additive variance, half-sib covariance, and heritability of the traits in 18 sugar beet testcrosses under late planting

	Leaf number	Root length	Crown height	Sugar content	Sodium	Potassium	Amino nitrogen	Extractable sugar content	Extractable sugar coefficient	Root yield	Sugar yield	White sugar yield
CovH.S = δ2g	4.02	0.34	0.10	-0.04	0.56	0.02	0.08	0.30	3.71	6.31	0.26	0.15
δ2A	11.20	0.96	0.30	-0.12	1.56	0.06	0.24	0.86	10.34	25.95	0.75	0.42
h2 n.s	0.83	0.31	0.89	-0.23	0.91	0.29	0.59	0.57	0.86	0.51	0.44	0.41
V(δ2A)	42.34	11.79	0.02	0.86	0.44	0.07	0.11	1.63	30.02	3044.34	4.78	2.16
t(δ2A)	1.72	0.28	2.15	-0.13	2.36	0.24	0.72	0.67	1.89	0.47	0.34	0.29
S.E. (h2 n.s)	0.03	0.01	1.26	0	0.64	0.03	0.96	1.08	0.03	0.00	0.02	0.02

compensated by sugar content increase. Lee et al. (1987) reported that photosynthesis allocation process has a direct correlation with planting date. Vegetative growth stage coincidence with temperatures more than 30 ^{o}C resulted in early senescence of the leaves and as a result increase in leaf production coefficient so that in late planting (124 days after planting) 20% of dry matter was lost and for early planting it was 10%. Testcross 18 had the highest number of leaves. Testcrosses 3 and 9 had no significant difference with check variety for root yield and white sugar yield. Testcross 3 was located in group A in terms of crown height and root diameter. In general, testcrosses 3, 9 and 16 had slight difference with check variety for most of the traits. At least one hybrid (testcross 3) is suitable for short growth period which is compatible with a commercial cultivar.

Using 18 half-sib families covariance, heritability of the traits was estimated for short growth period under late planting (Table 4). For morphological traits (leaf number and crown height), and some traits related to impurities (such as sodium and sugar extraction coefficient) high heritability was found. Thus, it was still possible to modify the above traits in half-sib families but heritability was relatively low for root yield, sugar yield, and white sugar yield (0.51, 0.44, and 0.41%, respectively). Therefore, selection procedure is not effective for increase of these traits and it is recommended to increase root yield by producing new hybrid varieties through hybridization with new sources (Orazizadeh 2001). For some morphological traits such as root length and potassium impurities, heritability was low (0.31 and 0.29%, respectively). In general, low additive effects for root yield, root diameter, root length, and sugar content was not unexpected owing to their polygenic character (Table 4). In other words, parameters which determine gene effects are in fact under moderate to medium influence of segregating loci. Since the additive effect or the interaction related to additive effect is a function of additive gene dispersion among parents, therefore the additive effect may be small (Alizadeh et al. 2007) and to improve these traits hybrid production should be used in breeding programs. Owing to the low heritability of root yield in late planting, consideration of the traits with higher heritability than yield is advisable as indirect selection.

Falconer and Mackay (1996) reported that in the absence of equilibrium in gene linkage, dominance effect may cause a bias in heritability. Low heritability of the traits may be due to higher contribution of non-additive effects than additive effects. Such estimates were done by Duhoon et al. (1982) and Labana and Jindal (1982) on yield. Sodium heritability was high (0.91) which corroborate with Rajabi et al. (2002) results and indicates that breeding of these traits is plausible through selection in pollinator 276. However, no difference was found for sugar content among genotypes which supports the results previously reported in a study where the genotypes difference was decreased in late planting (Lauer 1996). In addition, it confirms Sadeghian et al. (1999) results for sodium importance under stress condition. The results differ from those reported by Smith and Martin (1989), who observed sodium and amino nitrogen heritability in normal condition. The reason for this difference is late planting or genotype difference. They also observed that non-sugar material in sugar beet sap including K^+, Na^+, and amino nitrogen prevent crystallisation and ultimately reduces the amount of sucrose. Selection for low Na^+ will increase sugar purity. In this study, K^+, Na^+, and amino nitrogen heritability were 0.29, 0.91, and 0.59%, respectively. Assessment of genetic diversity in 49 sugar beet breeding bulks showed that sodium content, leaf width, root weight, and petiole length had the highest heritability (Rajabi et al. 2002). Table 5 shows the correlation coefficient among 13 traits. Extractable sugar content had significant ($P < 0.01$) correlation with sugar extraction coefficient (r = 0.84) which is associated with Rajabi et al. (2002) results. Sugar content had significant positive correlation with white sugar content (0.83) and sugar

Table 5. Correlation coefficient among traits under late planting

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Leaf number	1												
2. Root length	-0.16^{ns}	1											
3. Root diameter	0.25^{*}	0.17^{ns}	1										
4. Crown height	-0.03^{ns}	-0.03^{ns}	0.19^{ns}	1									
5. Sugar content	0.13^{ns}	-0.12^{ns}	-0.17^{ns}	-0.25^{*}	1								
6. Sodium	0.08^{ns}	-0.09^{ns}	-0.2^{ns}	-0.11^{ns}	-0.64^{**}	1							
7. Potassium	0.33^{**}	-0.13^{ns}	0.32^{*}	0.16^{ns}	0.1^{ns}	-0.05^{ns}	1						
8. Amino nitrogen	-0.24^{*}	-0.16^{ns}	0.14^{ns}	-0.04^{ns}	0.24^{*}	0.35^{**}	-0.17^{ns}	1					
9. Extractable sugar content	-0.03^{ns}	0.1^{ns}	0.11^{ns}	-0.33^{**}	-0.83^{**}	-0.67^{**}	0.1^{ns}	-0.3^{**}	1				
10. Sugar extraction coefficient	-0.06^{ns}	-0.09^{ns}	-0.27^{*}	-0.31^{**}	0.76^{**}	0.77^{**}	-0.38^{**}	0.42^{**}	0.84^{**}	1			
11. Root yield	-0.18^{ns}	0.15^{ns}	0.22^{*}	0.42^{**}	-0.38^{**}	-0.34^{**}	0.03^{ns}	-0.04^{ns}	0.37^{**}	-0.34^{**}	1		
12. Sugar yield	-0.12^{ns}	0.1^{ns}	0.22^{ns}	0.28^{*}	-0.08^{ns}	-0.21^{ns}	0.1^{ns}	0.0005^{ns}	0.09^{ns}	-0.11^{ns}	0.92^{**}	1	
13. White sugar yield	-0.13^{ns}	0.1^{ns}	0.16^{ns}	0.23^{*}	0.06^{ns}	0.06^{ns}	0.05^{ns}	0.08^{ns}	0.06^{ns}	0.07^{ns}	0.86^{**}	0.98^{**}	1

*, ** significant at 5% and 1% probability level, respectively, ns: non significant

extraction coefficient (0.76). Root yield and sugar content had significant negative correlation (-0.38) which is consistent with previous studies (Duhoon et al. 1982; Kampel and Kern 1983; Labana and Jindal 1982; Ramazan and Oral 2002). Sodium and amino nitrogen correlation with extractable sugar content was negative which indicates that with increase of crude syrup impurities, sugar extraction will face difficulty which leads to reduction in sugar extraction coefficient and yield (Gornish et al. 1990). The highest correlation was found between root yield and sugar yield (0.92), root yield and white sugar yield (0.86), white sugar yield and sugar yield (0.89). Positive correlation between sugar yield and root yield is logical since sugar yield is estimated from root yield and sugar content (Cook and Scott 1998; Fathollah Taleghani 2008). It also shows the possibility of common desirable gene among populations. Campbell and kern (1983) reported that variation in sucrose accumulation had high influence on sucrose amount. They also stated that the most important factor in sugar yield per hectare is root yield. Positive correlation was found between Na^{+} and amino nitrogen however they had negative correlation with extractable sugar content. Sodium content had also negative correlation with root yield.

CONCLUSION

This study showed that late planting after cereal harvest is a proper approach to deal with water shortage at early growth stage. Check variety and testcross 3 had the highest root yield (66.19 and 65.31 t/ha, respectively). In late planting, morphological (leaf number and crown height) and technological (sodium content and sugar extraction coefficient) traits had high heritability. Therefore, it is still possible to breed the above traits for short growth duration in half-sib families. For root yield, sugar yield, and white sugar yield, heritability was low (0.51, 0.44, and 0.41, respectively) which demands new variety production and evaluation in late planting for drought stress control. The additive and gene dominance effects are variable due to the type of materials, cross type, and experiment environment. Therefore, understanding the genetic structure of the traits related to yield and also their heritability facilitates selection and success of breeding programs for compatibility in late planting.

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