International Journal of Agriculture & Biology
ISSN Print: 1560–8530; ISSN Online: 1814–9596
18–0762/201x/00–0–000–000
DOI: 10.17957/IJAB/15.1029
http://www.fspublishers.org

Full Length Article

Genotypes *vs.* Sowing Methods and their Interactive Effects on Sugar Beet (*Beta vulgaris* L.) Performance for Morphological and Yield Attributes under Arid Climatic Conditions

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Abstract

Sugar beet (*Beta vulgaris* L.) has been emerged as an excellent sugar crop which can perform well under diverse climatic conditions. In view of severe scarcity of irrigation water for sugarcane under arid climates and ever mounting population pressure, there is dire need to exploit the potential of sugar beet genotypes under arid climates. For this reason, a 2–year field experiment was conducted to evaluate the potential of different sugar beet genotypes for yield and quality parameters under different sowing methods under the arid climate. Five sugar beet genotypes *viz.*, California, Arinka, Sandrina, Estiban and Ernistina were grown under three sowing methods *i.e.* flat, ridge and bed sowing. The results revealed that various sowing methods significantly affected the growth, yield and quality parameters of all the sugar beet genotypes. The highest numbers of leaves per plant, chlorophyll content index, root length, root diameter, root yield and sugar yield was recorded in genotype 'California' under ridge sowing. The sugar recovery, purity percentage, pol and brix percentage was also highest in genotype 'California' under ridge sowing. In crux, genotype 'California' should be grown under the arid climatic conditions to harvest higher yield and improved quality attributes of sugar beet. Ridge sowing of sugar beet is superior to other methods for obtaining the higher sugar beet yield and quality. © 2019 Friends Science Publishers

Key words: Water scarcity; Brix percentage; Sugar yield; Yield attributes; Sowing methods; Thal region

Introduction

Sugar beet (*Beta vulgaris* L.) is the second most important sugar producing crop after sugarcane, all over the world (Amr and Ghaffar, 2010). It is better than sugarcane in many aspects as it has short growth duration (5–6 months), higher sucrose contents and sugar recovery (Pathak and Kapur, 2013). Sugar beet is generally, considered as a temperate region crop. However, due to development of new resistant varieties, now it has become a potential cash crop of tropics and subtropics (Cosyn *et al.*, 2011). The water and fertilizers requirement of sugar beet crop is less than sugarcane and it can be grown under various climatic conditions (Cosyn *et al.*, 2011). Sugar beet is a sucrose rich crop made up of approximately 90% root tissue and 10% hypocotyl tissues. Up to 20% of the sucrose is present in the fresh weight of the root at maturity (Ada *et al.*, 2012). Sugar beet could be a best sugar crop for the dryland areas where sugarcane cannot be grown. Moreover, the harvest time of sugar beet is different than the sugarcane, therefore it can keep the mills running when sugarcane crushing season is over.

The performance of sugar beet is affected by the sowing methods (Brar *et al.*, 2015). In sugar beet, the root is the main economic component. Thus, the soil environment in the rhizosphere of sugar beet may affect the root growth which may impact the final root and sugar yield. In a study, El-Sarag (2009) found that root yield and sugar contents were higher in ridge sown sugar beet. In another study, Zahoor *et al.* (2007) compared the performance of two sugar beet genotypes (KWS 1451 and Kawe Terma) under three different sowing methods viz., flat, bed and ridge sowing and found maximum leaf weight and number of beets in ridge sowing followed by bed sowing. The performance of genotype 'Kawe Terma' was better than the genotype 'KWS 1451' in terms of beet yield. Indeed, in ridge sowing, the soil around the root is very loose which improves the soil aeration and facilitates root penetration thus improving the crop growth (Hernandez *et al.*, 2010). In a recent study, Saini and Brar (2018) found that the sowing of sugar beet as two rows on beds or two rows on both side of ridge on sandy loamy soil under sub-tropical conditions was a viable option to obtain the higher beet yield. In another study,

To cite this paper: Sher, A., M. Kashif, A. Nawaz, A. Sattar, A. Manaf, A. Qayyum and M. Ijaz, 201x. Genotypes *vs.* sowing methods and their interactive effects on sugar beet (*beta vulgaris* L.) performance for morphological and yield attributes under arid climatic conditions. *Intl. J. Agric. Biol*. 00: 000-000

Ahmad *et al.* (2010) found that the root diameter, root weight, leaf area, brix percentage, sugar percentage, sugar yield and purity percentage was affected by the sowing method in sugar beet. The mean root diameter, sugar and purity percentage was highest on bed sown sugar beet. The sugar yield was similar for the sugar beet grown either on beds or ridges.

Variation exists among the sugar beet genotypes and sowing methods for beet/sugar yield in previous studies (Ahmad *et al.,* 2010; Ulaković *et al.,* 2015; Curcic *et al.,* 2018). However, the different sugar beet genotypes have never been compared for their yield potential and quality attributes under different sowing methods in the arid climatic conditions.

As the economical portion of the sugar beet is root; thus sowing method may massively impact the root yield and sugar recovery. Therefore, this study hypothesized that root and sugar yield may vary among various sugar beet genotypes under arid climate. The specific objective of this study was to compare different sugar beet genotypes for root/sugar and quality under different sowing methods in arid climate of Punjab, Pakistan.

Materials and Methods

Experimental Site and Weather Conditions

The field experiment was carried out during two years (2015–16 and 2016–17) at Research Farm (30°57'N; 70°56'E; 151m above sea level), College of Agriculture, Bahauddin Zakariya University, Bahadur Campus Layyah, Pakistan. The experimental soil was sandy loam with average ECe of 1.58–1.60 dS m^{-1}, pH of 7.9–8.0, soil organic matter of 0.67–0.69%, available phosphorus of 9–10 mg $kg^{-1}$and nitrate-nitrogen of 1.6–1.8 mg kg^{-1} in the respective years. The climate of Layyah is arid with average annual temperature of 25.2°C and annual precipitation of 195 mm. The data on rainfall and average maximum/minimum monthly temperature recorded during the growth period of crop are given in Table 1.

Table 1: Weather data during the experimental period

Months	Rainfall (mm)		Maximum temperature (°C)		Minimum temperature (°C)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
November	19.0	9.0	27.19	26.93	12.03	11.77
December	23.0	15.0	23.37	21.32	8.00	6.59
January	00	6.0	18.54	17.09	10.0	6.55
February	35	6.0	24.03	21.96	11.22	8.31
March	18	119	26.20	27.75	14.66	14.13
April	26	15.7	33.94	35.43	19.41	19.01
May	8.12	1.0	40.77	40.35	25.39	24.87

Source: Adaptive Research Farm, Karor Lal Eason, District Layyah

Experimental Details

Five sugar beet genotypes viz., California, Arinka, Sandrina, Estiban and Ernistina were sown on flat surface, ridges and beds. The seed of these sugar beet genotypes was obtained from Layyah Sugar Mill, Layyah, Pakistan. The experiment was laid out in a randomized complete block design in split plot arrangement keeping sowing methods in main plots and sugar beet genotypes in sub–plots with three replicates.

Crop Husbandry

Prior to sowing, field was cultivated (0.20 m) three times followed by planking. After seedbed preparation, the sugar beet was sown on November 16 and 03 during 2015 and 2016, respectively. The experimental plot size was 2.7 m×5 m. In flat sowing, the crop was sown with manual hand drill keeping row to row distance of 45 cm. Thinning was done at 2-4 leaf stage of sugar beet by maintaining plant to plant distance of 30 cm in line sowing. In ridge sowing, the crop was sown on 45 cm apart ridges with plant to plant distance of 30 cm. The ridges were made with the help of a tractor driven mechanical ridger. In bed sowing, the beds were made with the help of tractor driven bed shaper and sugar beet seeds were sown on beds (90 cm wide bed with 45 cm furrow) with plant to plant distance of 30 cm. Two lines of sugar beet were planted on each bed with row to row distance of 45 cm. In all sowing methods, the seeds were sown at about 2 cm depth in rows. A fertilizer dose of 90 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} was applied at seedbed preparation using urea (46%) and di-ammonium phosphate (46% P_2O_5, 18% N) as sources, respectively. Weeds in the experimental plots were removed manually. The crop remained pest and diseases free during both of the experimental years. In total, 8 irrigations were applied to raise sugar beet crop to maturity. The crop was harvested on May 02 and 07 during 2016 and 2017, respectively.

Data Recording

Data regarding the number of leaves, root yield, root length and root diameter, leaf area index, chlorophyll content, brix value, pol percentage, sugar recovery percentage and sugar yield were recorded following the standard procedures. After harvesting, the sugar beet plants from each experimental plot were harvested to record the root yield. The root length of 20 plants from each experimental plot was measured with measuring scale and was averaged. The root diameter of 20 plants from each experimental plot was measured with the help of vernier caliper and was averaged. The number of leaves of 20 plants from each experimental were counted manually and were averaged to record number of leaves per plant. The chlorophyll content index of the terminal sugar beet leaf of 20 plants was determined with the help of chlorophyll meter (CL–01) and averaged.

The sugar beetroot samples were sealed in the polythene bags and transported to Layyah Sugar Mills Laboratory, District Layyah, Punjab, Pakistan for determination of brix value, pol percentage, purity percentage, sugar recovery percentage and sugar yield (Bhullar *et al.,* 2009).

The sugar yield was calculated by using the following formula:

$$\text{Sugar yield (ton ha}-^{2}) = \frac{\text{Root yield (ton ha}-^{2}) \times \text{Sugar recovery (\%)}}{100}$$

The purity (%) of sugar beet was calculated by using the following equation.

$$\text{Purity (\%)} = \frac{\text{Sugar (\%)} \times 100}{\text{Brix (\%)}}$$

Statistical Analysis

Analysis of variance was performed for the data by using 'Statistix 8.1 software' to check the significance of treatment means (sowing methods; sugar beet genotypes, interaction of sowing methods with sugar beet genotypes) for each parameter. Tukey HSD test at 5% probability level was used to separate the treatment means if significant. The interaction of sugar beet genotypes with sowing methods was significant for number of leaves per plant, root yield, root diameter, root length, root yield, SPAD chlorophyll contents and purity percentage (Table 2). For brix percentage, pol percentage and sugar yield, the interaction effects was significant for second year, thus the results of main effects and interaction for both years has been presented for these parameters in Table 3.

Results

Morphological and Yield Parameters

This study indicated that the maximum numbers of leaves per plant were observed in genotype 'California' under ridge sowing during both years; that were statistically similar with genotype 'Sandrina' under bed sowing during second year (Table 2). Root length was also the highest in genotype 'California' under ridge sowing during both years; and that was statistically similar with genotype 'Arinka' under ridge sowing and with genotype 'Emistina' under bed sowing during first year (Table 2). The maximum root diameter and root yield was recorded in genotype 'California' under ridge sowing during both years; and was statistically similar with genotype 'Sandrina' under ridge sowing during first year for root diameter (Table 2). The genotype 'California' under ridge and bed sowing produced statistically higher leaf area during both years; and was statistically similar with genotype 'Estiban' under ridge sowing during first year (Table 2). During first year, the highest chlorophyll content index was recorded in genotype 'Arinka' under bed sowing and was statistically similar with genotype 'Sandrina' under bed sowing and genotype 'Estiban' under ridge sowing. During second year, all the sugar beet genotypes under ridge sowing produced significantly higher chlorophyll content index than other two sowing methods (Table 2).

Table 2: Morphological and yield parameters, chlorophyll contents and purity percentage of sugar beet genotypes as affected by different sowing methods during both experimental years

		2015-16			2016-17		
	Treatments	Flat	Ridge	Bed	Flat	Ridge	Bed
Number of leaves per plant	California	27bcd	30a	25def	18g	27a	23d
	Arinka	27bcd	28b	20gh	25bc	24cd	17h
	Sandrina	26cde	24f	28b	20f	16h	26ab
	Estiban	20h	25def	26c-f	16h	22e	20f
	Emistina	22g	27bcd	25ef	18g	14i	13i
	HSD ($p \leq 0.05$)	SM×G = 1.38			SM×G= 1.34		
Root diameter (cm)	California	93 g	117a	101e	82c	101a	89b
	Arinka	108b-d	81h	99ef	91b	76d	88b
	Sandrina	98ef	114ab	91g	89b	97b	80c
	Estiban	99ef	102de	105c-e	86c	87b	90b
	Emistina	83h	93fg	109bc	76d	84c	94b
	HSD ($p \leq 0.05$)	SM×G= 6.04			SM×G= 7.00		
Root length (cm)	California	21b	24a	17d	17g	27a	21b-e
	Arinka	17d	23a	15e	21b-d	23b	18fg
	Sandrina	21b	20bc	20bc	21b-e	20c-f	21bcd
	Estiban	16de	19c	17d	13h	19d-g	22bc
	Emistina	16de	20bc	24a	17fg	23b	18efg
	HSD ($p \leq 0.05$)	SM×G= 1.65			SM×G= 2.35		
Root yield ($t\ ha^{-1}$)	California	79bc	95a	76c	63b	74a	62b
	Arinka	35i	57e-g	84b	34f	51cd	66b
	Sandrina	82bc	55g	61e-g	65b	48d	51cd
	Estiban	61ef	63e	47h	51cd	52c	42e
	Emistina	55g	69d	56fg	47cd	56c	49cd
	HSD ($p \leq 0.05$)	SM×G= 4.23			SM×G= 5.00		
Leaf area (cm^2)	California	115d	149a	149a	122d	144a	145a
	Arinka	85h	99fg	107d-f	82i	94h	105g
	Sandrina	133bc	107d-f	111de	133c	103g	109f
	Estiban	114d	140ab	104ef	114e	139b	97h
	Emistina	93gh	127c	115d	95h	122d	122d
	HSD ($p \leq 0.05$)	SM×G= 9.68			SM×G= 2.68		
SPAD chlorophyll	California	28bc	29ab	28abc	15.5e	27.6a	19.8c
	Arinka	27bcd	26de	30a	24.1b	26.2a	24.1b
	Sandrina	27bcd	23f	29ab	14.3f	27.3a	23.6b
	Estiban	25ef	29ab	25ef	18.3d	27.0a	23.5b
	Emistina	27cd	27bcd	27cd	19.6c	26.3a	20.7c
	HSD ($p \leq 0.05$)	SM×G= 1.72			SM×G=2.00		
Purity (%)	California	67.0ef	70.0c	76.4a	61.5f	70.4a	68.1bc
	Arinka	72.5b	65.1f	66.8ef	63.2ef	64.1de	58.1g
	Sandrina	76.2a	76.9a	70.1c	63.8de	63.1ef	64.7de
	Estiban	60.8g	69.3cd	70.8bc	65.2de	68.3ab	66.1bcd
	Emistina	61.7g	72.7b	67.5de	63.8de	68.3ab	65.9cd
	HSD ($p \leq 0.05$)	SM×G= 2.06			SM×G= 2.22		

Means sharing the same case letter for main effects and interaction do not differ significantly at $p \leq 0.05$; SD= sowing dates; G= sugar beet genotypes

Quality Traits

The study indicated that the highest purity percentage was recorded in genotype 'Sandrina' under flat and ridge sowing or in genotype 'California' under bed sowing during first year. During second year, the highest purity percentage was recorded in genotype 'California' under ridge sowing (Table 2).

The sugar recovery and pol percentage during second year and brix percentage and sugar yield during both years of experimentation was significantly different among various sugar beet genotypes (Table 3). Likewise, sowing methods significantly affected the sugar recovery, sugar yield, brix and pol percentage during both years of experimentation.

Table 3: Quality traits of sugar beet genotypes as affected by different sowing methods during both experimental years

		2015-16				2016-17			
	Treatments	Flat	Ridge	Bed	Mean (G)	Flat	Ridge	Bed	Mean (G)
Sugar recovery (%)	California	10.42	12.44	11.56	11.47	12.2	13.2	13.1	12.8A
	Arinka	10.40	12.46	11.25	11.37	10.8	12.3	12.2	11.8C
	Sandrina	10.98	11.89	11.55	11.47	12.2	12.8	11.7	12.2B
	Estiban	10.16	11.12	10.92	10.73	13.9	12.7	11.6	12.7A
	Emistina	9.95	11.57	11.16	10.89	12.7	14	11.1	12.6AB
	Mean (SM)	10.38B	11.89A	11.29A		12.3B	13.0A	11.9B	
	HSD ($p \leq 0.05$)	SM= 0.65; G= NS; SM×G= NS				SM= 0.61; G= 0.41; SM×G= NS			
Brix (%)	California	17.37	18.84	19.45	18.55A	17cde	19ab	18bc	18.5A
	Arinka	16.47	17.60	17.63	17.23C	16e	18bcd	16de	17.3B
	Sandrina	17.37	18.47	19.25	18.36AB	17cde	17cde	17cde	17.5B
	Estiban	17.80	18.50	19.09	18.46AB	18bc	17cde	19ab	18.5A
	Emistina	16.75	18.28	18.23	17.75BC	17cde	20a	18cde	18.7A
	Mean (SM)	17.14B	18.33A	18.73A		17B	18.5A	18AB	
	HSD ($p \leq 0.05$)	SM= 0.45; G= 0.84; SM×G= NS				SM= 0.76; G= 0.78; SM×G= 1.35			
Pol (%)	California	13.98	14.1	14.26	14.11	15.0bcd	15.8bc	15.8b	15.5A
	Arinka	14.19	15.47	14.26	14.63	12.9g	15.7bc	11.7h	13.4C
	Sandrina	14.13	14.37	14.78	14.40	14.8b-e	15.8b	13.9ef	14.8B
	Estiban	13.27	15.81	14.52	14.52	13.0fg	11.8h	14.8b-e	13.2C
	Emistina	13.29	15.87	13.86	14.34	14.8cde	17.1a	14.4de	15.4A
	Mean (SM)	13.76B	15.11A	14.39B		14.1B	15.2A	14.1B	
	HSD ($p \leq 0.05$)	SM= 0.65; G= NS; SM×G= NS				SM= 0.54; G= 0.55; SM×G= 0.96			
Sugar yield ($t\ ha^{-1}$)	California	6.0	6.6	11.0	7.9A	6.2efg	8.7a	8.1b	7.6A
	Arinka	3.7	10.5	6.4	6.9C	7.2c	5.8gh	8.1b	7.1BC
	Sandrina	9.6	7.2	6.3	7.7B	6.7de	6.1fg	6.6def	6.5D
	Estiban	8.1	8.4	6.8	7.8AB	6.7cd	8.8a	5.8gh	7.1B
	Emistina	5.4	6.9	7.8	6.7C	5.7gh	9.1a	5.4h	6.8C
	Mean (SM)	6.5B	7.9A	7.7A		6.5B	7.7A	6.7B	
	HSD ($p \leq 0.05$)	SM= 1.00; G= 0.51; SM×G= NS				SM= 0.37; G= 0.28; SM×G= 0.50			

Means sharing the same case letter for main effects and interaction do not differ significantly at $p \leq 0.05$; SD= sowing dates; G= sugar beet genotypes

The interaction of sugar beet genotypes with sowing methods was significant for brix, pol percentage and sugar yield during second year of experimentation (Table 3).

Among the sowing methods, maximum sugar recovery was recorded under ridge sowing during both years that was statistically at par with bed sowing during first year of study. Amongst the sugar beet genotypes, the maximum sugar recovery was observed in genotype ‘California’ which was statistically at par with ‘Estiban’ and ‘Emistina’ during second year of experimentation (Table 3).

Among the sugar beet genotypes, the genotype ‘California’ produced the maximum brix percentage than other genotypes that was statistically similar with genotypes ‘Estiban and Sandrina’ during first year. During second year, the maximum brix percentage was recorded in genotype ‘Emistina’ under ridge sowing that was statistically similar with genotype ‘California’ under ridge sowing and genotype ‘Estiban’ under bed sowing (Table 3).

During first year of experimentation, maximum pol percentage and sugar yield were recorded under ridge sowing that was statistically similar with bed sowing for sugar yield. During the second year, the maximum pol percentage was observed in genotype ‘Emistina’ under ridge sowing, while sugar yield was the highest in genotype ‘California’ under ridge sowing (Table 3). Among the sugar beet genotypes, the highest sugar yield was recorded in genotype ‘California’ which followed by genotype ‘Estiban’ during first year (Table 3).

Discussion

This study indicated that the root yield and sugar quality was comparatively better in genotype ‘California’ than other genotypes. The improved root yield in this genotype was attributed to enhanced leaf area, the highest chlorophyll contents and the highest root length and root diameter as compared with the other sugar beet genotypes (Table 2). Moreover, the differences in morphological attributes (number of leaves per plant, leaf area), yield parameters (root diameter, root length), and chlorophyll contents among the sugar beet genotypes might be due to differences in the genetic makeup of these genotypes which ultimately resulted in different root yield in all the sugar beet genotypes (Curcic *et al.*, 2018). Better performance of morphological and yield parameters also resulted in improvement in quality parameters (pol, brix, purity percentage, sugar yield and recovery) in this genotype. Several previous studies have reported that variation exists for the root yield among different sugar beet genotypes (Ahmad *et al.*, 2010; Ulaković *et al.*, 2015; Curcic *et al.*, 2018).

Among the sowing methods, the ridge sowing method had significantly higher root yield and showed good sugar quality which was followed by bed sowing while the root yield and quality was relatively lower in flat sowing than ridge and bed sowing. As sugar beet is grown in winter season, the soil on ridges tends to warm faster than the soil at ground level, which may improve the sugar beet growth

(Bhullar *et al.,* 2009), which might be a possible reason for better root yield of sugar beet in this study. Moreover, the soil around the root is very loose in ridge sowing which improves the soil aeration and facilitates root penetration thus improving the crop growth (Khan *et al.,* 2012). The number of leaves per plant, leaf area, root length and root diameter was the highest in ridge sowing followed by bed sowing which might have improved root yield due to increased leaf surface area for light interception resulting in better photosynthesis (Khan *et al.,* 2012). Turgut (2014) reported that root yield and sugar yield was 3-8% and 3-10% higher in ridge sown (50 cm apart) sugar beet than 60 cm apart ridges, respectively. Ramazan *et al.* (2014) also found that root yield and sugar contents were enhanced by 1% and 4% respectively in 50 cm apart ridges than 60 cm apart ridges. Some other studies have also reported better growth, root and sugar yield in sugar beet in ridge and bed sowing. For example, El-Sarag (2009) found that root yield and sugar contents were the higher in ridge sown sugar beet. Zahoor *et al.* (2007) compared the performance of sugar beet under three different sowing methods i.e., flat, bed and ridge sowing and found maximum leaf weight and number of beets in ridge sowing followed by bed sowing. Saini and Brar (2018) found that the sowing of sugar beet as two rows on beds or two rows on both side of ridge on sandy loam soils under sub-tropical conditions was a viable option to obtain the higher beet yield. Ahmad *et al.* (2010) also found that the mean root diameter, sugar and purity percentage was highest on bed sown sugar beet. They also found that the sugar yield was similar for the sugar beet grown either on beds or ridges.

In present study, the performance of sugar beet in flat sowing was poor owing to less number of leaves per plant, lesser root length and root diameter, which ultimately reduced the quality of sugar beet (Tables 2, 3). The poor performance of the sugar beet in flat sowing might also be attributed to soil compaction which decreases the soil aeration and reduces the total porosity and water permeability of the soil which leads towards poor root growth (Awad *et al.,* 2012). In sugar beet, the economic portion is the root, thus, poor root growth due to soil compaction ultimately led towards poor root yield and quality. In another study, Mahmoud *et al.* (2012) found that soil compaction affected the seed emergence and root growth.

Sowing methods also affected the sugar beet quality that was better in ridge and bed sowing than flat sowing. Indeed, various factors such as differences in genotypes, population density and sowing methods impact the quality of sugar beet by affecting the crop performance (Sögüt and Aroglu, 2004; Ahmad *et al.,* 2012; Awad *et al.,* 2012). Moreover, sowing method directly or indirectly affects the micro-environment of the sugar beet growth which affects sugar beet quality (Seadh *et al.,* 2013). For example, the bed and ridge sowing conserve the soil moisture more efficiently than flat sowing and better moisture contents in soil has been related to better sugar beet yield and quality (Ahmad *et al.,* 2012).

The root yield was the highest during first year as compared with second year. Indeed, the minimum temperature was less during second year as compared with first year during the whole crop season (Table 1). Low temperature decreases the sugar beet crop growth rate (Kenter *et al.,* 2006) as was visible through reduction in leaf emergence and development during second year which resulted in low root yield.

Conclusion

The genotype 'California' should be grown under the arid climatic conditions to harvest higher root yield and improved quality of sugar beet. Ridge sowing of sugar beet is superior to other methods for obtaining the higher sugar beet yield and quality. Further studies are needed in different ecological areas to evaluate the sugar beet yield and sugar recovery before recommending them to growers for general sowing in Thal area.

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(Received 29 May 2018; Accepted 04 February 2019)