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Full Length Article

Influence of Different Tillage Methods on Root Yield, Yield Components and Some Quality Characteristics of Sugar Beet (*Beta vulgaris*)

MAJID RASHIDI[1] AND SAEED ABBASSI
Department of Agricultural Machinery, Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran
[1]Corresponding author's e-mails: majidrashidi81@yahoo.com; m.rashidi@tiau.ac.ir

ABSTRACT

A two years study was carried out at the Research Site of Hamedan Province, Iran to investigate the influence of different tillage methods on yield and quality of sugar beet (*Beta vulgaris*) during, 2008 and 2009 growing seasons. Tillage treatments were moldboard plow + two passes of disk harrow (MDD) as conventional tillage method; moldboard plow + one pass of rotavator (MR), chisel plow + one pass of rotavator (CR) and two passes of disk harrow (DD) as reduced tillage methods; one pass of rotavator (R) and one pass of tine cultivator (C) as minimum tillage methods and no-tillage (NT). Root yield, yield components i.e., root number per hectare (RNPH), sugar yield, root dry matter (RODM), root length, rim diameter and some quality characteristics of sugar beet such as sugar content, K, Na, alpha-amino nitrogen (ALAN) and molasses were measured for different tillage treatments. Different treatments significantly ($P \leq 0.05$) affected RNPH and K, but there was no significant difference in other studied traits. Although effect of different tillage treatments on root yield, sugar yield, RODM, root length, rim diameter, sugar content, Na, ALAN and molasses was not significant, results of the study indicated that tillage operations were useful in improving the yield and quality of sugar beet. The highest values of root yield (82.7 t ha^{-1}), RNPH (135412 roots ha^{-1}), sugar yield (11.4 t ha^{-1}), RODM (23.9%) and sugar content (17.0%) were recorded in the MR treatment, while the highest values of root length (20.5 cm), rim diameter (1.5 cm), K (6.4 mmol/100 g), Na (2.6 mmol/100 g), ALAN (2.5 mg/100 g) and molasses (3.0%) were noted in the NT treatment. In contrast, the lowest values of root yield (71.3 t ha^{-1}), RNPH (115000 roots ha^{-1}), sugar yield (9.15 t ha^{-1}), RODM (20.3%) and sugar content (15.2%) were recorded in the NT treatment, while the lowest values of root length (18.0 cm), rim diameter (1.1 cm), K (4.5 mmol/100 g), Na (1.5 mmol/100 g), ALAN (1.6 mg/100 g) and molasses (2.2%) were noted in the MR treatment. Results also showed that tillage method affected the yield and quality of sugar beet in the order of MR > CR > R > MDD > DD > C > NT. Therefore, the reduced tillage treatments MR and CR and the minimum tillage treatment R were considered as more beneficial and suitable tillage methods in improving the yield and quality of sugar beet.

Key Words: Sugar beet; Tillage method; Root yield; Yield components; Quality characteristics; Hamedan; Iran

INTRODUCTION

Sugar beet (*Beta vulgaris*) is one of the most important crops in a wide variety of temperature climates (Jafari *et al.*, 2006; Sohrabi & Heidari, 2008; Abdel-Motagally & Attia, 2009). It is a hardly biennial plant with large (1-2 kg) storage root and great amount (15-20%) of sucrose. Sugar beet accounts for 30% of the world's sugar production (Draycott, 2006).

The European Union, the United States and Russia are the three biggest sugar beet producers in the world. The top ten sugar beet producer countries are France, Germany, United States, Russia, Ukraine, Turkey, Italy, Poland, United Kingdom and Spain with 29, 25, 25, 22, 16, 14, 12, 11, 8 and 7 million tons, respectively. Also, the European Union and Ukraine are major exporters of sugar from beets. Besides, the United States harvested 406,500 hectares of sugar beets in 2008 alone (FAO Statistical Yearbook, 2009). On the other hand, the average cultivated area and national production of sugar beet in Iran for the last three years was about 178,000 hectares and 5.9 million tons, respectively (FAO Statistical Yearbook, 2009). Although the use of better varieties, mechanical planting, chemical fertilizers, herbicides application and mechanized harvesting have increased sugar beet production to a great extent, the complete potential of sugar beet production has not yet been attained as compared to the top ten sugar beet producers.

Tillage is one of the most essential crop production factors that influence soil properties (Keshavarzpour & Rashidi, 2008; Rashidi & Keshavarzpour, 2008) and consequently crop yield (Khurshid *et al.*, 2006; Rashidi & Keshavarzpour, 2007; Rashidi *et al.*, 2008; Rashidi & Khabbaz, 2009; Rashidi *et al.*, 2009). Appropriate tillage operations can enhance soil properties, while excessive,

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inappropriate and un-necessary tillage operations may result in a range of un-desirable processes (Hill, 1990; Horne *et al.*, 1992; Lal, 1993; Khan *et al.*, 1999; Khan *et al.*, 2001; Iqbal *et al.*, 2005).

Although for most situations, conventional tillage methods have been the main tillage methods for establishing sugar beet since the first part of the 20th century, they are now expensive operations in terms of work rate and fuel consumption (Ecclestone, 2004). The costs, as well as the environmental concerns have leaded farmers and researchers to adopt alternative tillage methods (Ecclestone, 2001). For these reasons, there is a considerable attention and significant emphasis on moving towards the conservation tillage methods i.e., reduced tillage, minimum tillage and no-tillage methods (Cannel, 1985; Hill, 1990; Chaudhary *et al.*, 1992; Ekeberg, 1993; Hao *et al.*, 2001; Iqbal *et al.*, 2005; Rashidi & Keshavarzpour, 2007; Keshavarzpour & Rashidi, 2008; Rashidi & Keshavarzpour, 2008; Rashidi *et al.*, 2008; Rashidi & Khabbaz, 2009; Rashidi *et al.*, 2009). Conservation tillage methods may be used for sugar beet (Romaneckas *et al.*, 2006; Adamaviciene *et al.*, 2009; Romaneckas *et al.*, 2009; Jabro *et al.*, 2010). However, the results of these methods may be contrary (Iqbal *et al.*, 2005). Conservation tillage operations may reduce yield of sugar beet (Draycott, 2006). Conversely, decrease of soil tillage practices may have no significant effect on the yield of other crops (Ekeberg, 1993; Hakansson *et al.*, 1998; Hao *et al.*, 2001; Ozpinar, 2006; Glab & Kulib, 2008). Conservation tillage methods may also lead to raised diversity of weed species and population (Carter & Ivany, 2006; Ozpinar, 2006) and have a harmful effect on crop yield (Borresen, 1993). But, other studies have confirmed the opposite (Campbell *et al.*, 1998).

In Iran, most of the cultivated area is under conventional tillage methods and conservation tillage methods have not been studied enough. For this reason, information on response of sugar beet to different tillage methods is meager. Therefore, this study was planned to study the response of root yield, yield components and some selected quality characteristics of sugar beet to different tillage methods.

MATERIALS AND METHODS

Research site: This study was conducted at the Research Site of Hamedan Province, Iran for two successive growing seasons (2008 & 2009). The research site is located at latitude of 34° 52' N, longitude of 48° 21' E and altitude of 1730 m in semi-arid climate (298 mm rainfall annually) in the west of Iran. Mean temperature and monthly rainfall of the experimental site from sowing to harvest during study years (2008 & 2009) are indicated in Fig. 1.

Soil sampling and analysis: A composite soil sample (from 21 points) was collected from 0-30 cm depth during the study years and was analyzed in the laboratory for pH, EC, OC, N, P, K, Fe, Zn, Cu, Mn, B and particle size distribution. Details of soil physical and chemical properties of the research site during both years (2008 & 2009) are given in Table I.

Field methods: The experiments were laid out in a RCBD with three replications. Tillage treatments were moldboard plow + two passes of disk harrow (MDD) as conventional tillage method; moldboard plow + one pass of rotavator (MR), chisel plow + one pass of rotavator (CR) and two passes of disk harrow (DD) as reduced tillage methods; one pass of rotavator (R) and one pass of tine cultivator (C) as minimum tillage methods and no-tillage (NT). During the study years, tillage treatments were carried out on the same plots. The size of each plot was 20.0 m long and 6.0 m wide. There were 12 rows of sugar beet in each plot with 50-cm row spacing. In both years of study, one of the commercial varieties of sugar beet cv. Zarghan was planted on April 3, 2008 and April 5, 2009 using a 6-row sugar beet drill. Recommended levels of urea (300 kg ha^{-1}) in both years and triple super phosphate (50 kg ha^{-1}) only in the first year of study were used. For all treatments, irrigation scheduling was based on the basis of evaporation from A-class pan installed close to the experimental plots. Also, pest and weed control operations were performed based on common local practices and commendations. All other essential operations were kept identical for all the treatments.

Observation and data collection: At harvest, plants from an area of 12.0 m^2 per each plot were harvested to determine root yield and yield components i.e., root number per hectare (RNPH), sugar yield, root dry matter (RODM), root length and rim diameter for all treatments. Moreover, a sample of 20 kg of sugar beet roots were taken at random and sent to the Sugar Beet Laboratory at Hamedan Sugar Factory to determine some quality characteristics i.e., sugar content, K, Na, alpha-amino nitrogen (ALAN) and molasses for all treatments. Sugar (sucrose) content was measured in fresh root samples by using Saccharometer as described by AOAC (1995). K, Na, alpha-amino nitrogen (ALAN) and molasses were measured using an auto analyzer.

Statistical analysis: All data were subjected to the Analysis of Variance (ANOVA) following Gomez and Gomez (1984) using SAS statistical computer software. Moreover, means of the different treatments were separated by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

RESULTS

Results of ANOVA and means comparison for root yield and yield components of sugar beet under different methods of tillage during the study years (mean of 2008 & 2009) are presented in Tables II and III, respectively. Results showed that different tillage methods significantly ($P \leq 0.05$) influenced RNPH, but there was no significant difference in other studied traits (Table II). Moreover, results of ANOVA and means comparison for the selected quality characteristics of sugar beet under different tillage

Table I: Soil physical and chemical properties of the experimental site (0-30 cm depth), 2008 and 2009

Date	pH	EC (dS m^{-1})	OC (%)	N (%)	Concentration (mg/kg)							Soil texture
					P	K	Fe	Zn	Cu	Mn	B	
2008	7.9	0.72	0.92	0.09	10.5	280	6.2	0.8	2.3	16.2	0.7	Loam
2009	8.3	0.55	0.36	0.04	25.6	310	6.4	1.0	2.4	14.4	0.7	Loam

Table II: Analysis of variance for root yield and yield components of sugar beet under different tillage methods (mean of 2008 & 2009)

Source of variation	Df	Mean square					
		Root yield	RNPH	Sugar yield	RODM	Root length	Rim diameter
Replication	3	257.90 ^{NS}	127777616 ^{NS}	6.10 ^{NS}	7.21 ^{NS}	1.32 ^{NS}	0.10 ^{NS}
Treatment	6	72.36 ^{NS}	184223872 *	3.27 ^{NS}	5.96 ^{NS}	3.40 ^{NS}	0.08 ^{NS}
Error	18	390.70	62268312	10.5	3.17	5.12	0.04
C.V. (%)	---	25.40	6.20	31.3	8.04	11.7	15.2

NS = Non-significant; * = Significant at 0.05 probability level; (RNPH: root number per hectare; RODM: root dry matter)

Table III: Means comparison for root yield and yield components of sugar beet between different tillage methods (means of 2008 & 2009)

Treatment	Root yield (t ha^{-1})	RNPH	Sugar yield (t ha^{-1})	RODM (%)	Root length (cm)	Rim diameter (cm)
MDD	78.5 a	130000 a	10.5 a	22.0 a	19.6 a	1.2 a
MR	82.7 a	135412 a	11.4 a	23.9 a	18.0 a	1.1 a
CR	81.0 a	133333 a	11.2 a	23.4 a	18.6 a	1.1 a
DD	76.5 a	127500 a	9.97 a	21.8 a	19.6 a	1.3 a
R	80.9 a	130833 a	10.8 a	22.4 a	18.9 a	1.2 a
C	73.4 a	124583 ab	9.27 a	21.3 a	20.4 a	1.3 a
NT	71.3 a	115000 b	9.15 a	20.3 a	20.5 a	1.5 a

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.
(RNPH: root number per hectare; RODM: root dry matter)

methods during the years of study (mean of 2008 & 2009) are presented in Tables IV and V, respectively. Results also showed that different methods of tillage significantly ($P \leq 0.05$) influenced K, but there was no significant difference in other studied traits (Table IV).

DISCUSSION

In this study, root yield, yield components (RNPH, sugar yield, RODM, root length & rim diameter) and some quality characteristics (sugar content, K, Na, ALAN & molasses) of sugar beet were studied to investigate the influence of different tillage methods on yield and quality of sugar beet.

Root yield and yield components: The highest value of RNPH (135412 roots ha^{-1}) was recorded in the MR treatment, while the lowest value of RNPH (115000 roots ha^{-1}) was recorded in the NT treatment (Table III). Although there was no significant difference in root yield, sugar yield, RODM, root length and rim diameter during the study years, results indicated that tillage operations were useful in increasing the yield of sugar beet. The highest values of root yield (82.7 t ha^{-1}), sugar yield (11.4 t ha^{-1}) and RODM (23.9%) were recorded in the MR treatment, while the highest values of root length (20.5 cm) and rim diameter (1.5 cm) were noted in the NT treatment (Table III). Based on the results, tillage method affected the yield of sugar beet (root yield, sugar yield & RODM) in the order of MR > CR > R > MDD > DD > C > NT. These results are in line with the results reported by Iqbal *et al.* (2005), Khurshid *et al.* (2006), Rashidi and Keshavarzpour (2007), Rashidi *et al.* (2008), Rashidi and Khabbaz (2009) that tillage practices can be associated with improved soil physical and mechanical properties (increased pore space, decreased bulk density, increased moisture preservation & decreased penetration resistance), enhanced soil structure, better seed-soil/root-soil contact and superior weed control, which positively influence RNPH and consequently root yield and sugar yield of sugar beet. Similar results were also obtained by Romaneckas *et al.* (2006), Adamaviciene *et al.* (2009), Romaneckas *et al.* (2009) and Jabro *et al.* (2010). They concluded that intensive tillage methods enhanced soil quality and had no significant effect on yield and most yield components of sugar beet. In contrast, the lowest values of root yield (71.3 t ha^{-1}), sugar yield (9.15 t ha^{-1}) and RODM (20.3%) were recorded in the NT treatment, while the lowest values of root length (18.0 cm) and rim diameter (1.1 cm) were noted in the MR treatment (Table III). These results are in agreement with those of Bauder *et al.* (1981), Hill (1990), Horne *et al.* (1992), Borresen (1993), Carter and Ivany (2006) and Ozpinar (2006), who concluded that conservation tillage methods may be associated with worse

Table IV: Analysis of variance for some quality characteristics of sugar beet under different tillage methods (mean of 2008 & 2009)

Source of variation	Df	Mean square				
		Sugar content	K	Na	ALAN	Molasses
Replication	3	8.78 NS	0.22 NS	0.33 NS	0.78 NS	0.12 NS
Treatment	6	3.03 NS	0.56 *	0.60 NS	0.54 NS	0.27 NS
Error	18	13.4	0.15	0.68	0.65	0.11
C.V. (%)	---	28.9	7.04	43.0	40.5	13.3

NS = Non-significant; * = Significant at 0.05 probability level; (ALAN: alpha-amino nitrogen)

Table V: Means comparison for some quality characteristics of sugar beet between different tillage methods (mean of 2008 & 2009)

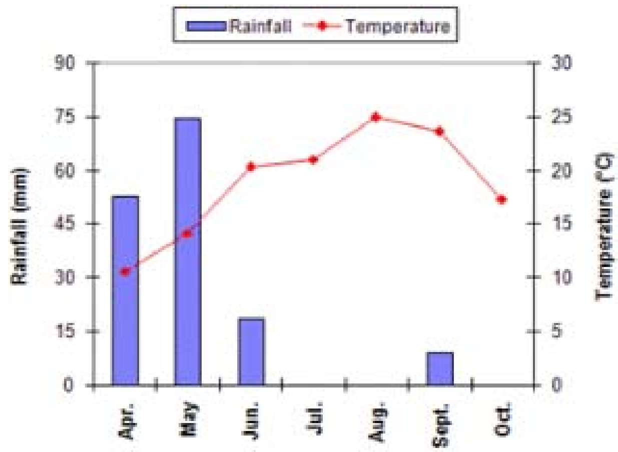
Treatment	Sugar content (%)	K (mmol/100 g)	Na (mmol/100 g)	ALAN (mg /100 g)	Molasses (%)
MDD	16.8 a	5.4 b	1.9 a	1.9 a	2.4 a
MR	17.0 a	4.5 b	1.5 a	1.6 a	2.2 a
CR	17.0 a	5.3 b	1.6 a	1.7 a	2.3 a
DD	15.6 a	5.5 b	2.0 a	2.1 a	2.5 a
R	16.9 a	5.4 b	1.6 a	1.7 a	2.4 a
C	15.2 a	5.7 b	2.2 a	2.5 a	2.5 a
NT	15.2 a	6.4 a	2.6 a	2.5 a	3.0 a

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.
(ALAN: alpha-amino nitrogen)

soil physical and mechanical properties (decreased pore space, increased bulk density, decreased moisture preservation & increased penetration resistance), inferior seed/root-soil contact and raised diversity of weed species and population, which negatively influence RNPH and as a results root yield and sugar yield of sugar beet.

Selected quality characteristics: The highest value of K (6.4 mmol/100 g) was recorded in the NT treatment, while the lowest value of K (4.5 mmol/100 g) was noted in the MR treatment (Table V). Although there was no significant difference in sugar content, Na, ALAN and molasses during the years of study, results again indicated that tillage operations were useful in enhancing the quality of sugar beet. The highest value of sugar content (17.0%) was recorded in the MR treatment, while the highest values of Na (2.6 mmol/100 g), ALAN (2.5 mg/100 g) and molasses (3.0%) were noted in the NT treatment. In contrast, the lowest value of sugar content (15.2%) was recorded in the NT treatment, while the lowest values of Na (1.5 mmol/100 g), ALAN (1.6 mg/100 g) and molasses (2.2%) were noted in the MR treatment (Table V). Again, a similar trend was obtained for the selected quality characteristics and tillage method affected sugar beet quality in the order of MR > CR > R > MDD > DD > C > NT (Table V). Similar results were obtained by Romaneckas *et al.* (2006), Adamaviciene *et al.* (2009), Romaneckas *et al.* (2009) and Jabro *et al.* (2010), who noted that different methods of tillage had no significant effect on most quality characteristics of sugar beet.

Fig. 1: Mean temperature and monthly rainfall during crop growth (mean of 2008 & 2009)



CONCLUSION

Different tillage methods significantly (P ≤ 0.05) affected RNPH and K, but there was no significant difference in root yield, sugar yield, RODM, root length, rim diameter, sugar content, Na, ALAN and molasses. Although there was no significant difference in most studied traits, tillage operations were useful in improving the yield and quality of sugar beet. Also, the reduced tillage treatments MR and CR and the minimum tillage treatment R were considered as more beneficial and suitable tillage methods in improving the yield and quality of sugar beet.

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