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RESPONSE OF ROOT YIELD AND YIELD COMPONENTS OF SUGAR BEET (*Beta vulgaris*) TO DIFFERENT TILLAGE METHODS

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ABSTRACT

A two-year field experiment was conducted to study the response of root yield and yield components of sugar beet (*Beta vulgaris*) to different tillage methods during 2008 and 2009 growing seasons. Tillage treatments in the study 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) as direct drilling method. Root yield (RY) and some yield components such as root number per hectare (RNPH), sugar yield (SUGY), root dry matter (RODM), root length (ROTL), rim diameter (RIMD) were determined for all treatments. Different tillage methods significantly ($P \leq 0.05$) affected RNPH, but there was no significant difference in other studied traits. Although there was no significant difference in RY, SUGY, RODM, ROTL and RIMD, results of the study showed that tillage practices were beneficial in improving the yield of sugar beet. The maximum values of RY (82.7 t ha^{-1}), RNPH (135412 roots ha^{-1}), SUGY (11.4 t ha^{-1}) and RODM (23.9%) were observed in case of MR treatment, while the maximum values of ROTL (20.5 cm) and RIMD (1.5 cm) were noted in case of NT treatment. In contrast, the minimum values of RY (71.3 t ha^{-1}), RNPH (115000 roots ha^{-1}), SUGY (9.15 t ha^{-1}) and RODM (20.3%) were observed in case of NT treatment, while the minimum values of ROTL (18.0 cm) and RIMD (1.1 cm) were noted in case of MR treatment. Results also showed that tillage method affected the yield 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 appropriate and profitable tillage methods in improving the yield of sugar beet.

Keywords: sugar beet, root yield, yield components, conventional tillage, reduced tillage, minimum tillage, no-tillage.

INTRODUCTION

Sugar beet (*Beta vulgaris*) is one of the most important crops (Jafari *et al.*, 2006; Sohrabi and Heidari, 2008; Abdel-Motagally and Attia, 2009). It is a hardly biennial plant whose root contains a high concentration of sucrose. It is grown commercially for sugar production in a wide variety of temperature climates. Sugar beet accounts for 30% of the world's sugar production. During its first growing season, it produces a large (1-2 kg) storage root whose dry mass is 15-20% sucrose by weight. In commercial sugar beet production, the root is harvested after the first growing season. In most temperature climates, sugar beet are planted in the spring and harvested in the autumn (Draycott, 2006).

The European Union, the United States and Russia are the three largest sugar beet producers. 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 significant exporters of sugar from beets. Besides, the United States harvested 406, 500 hectares of sugar beets in 2008 alone (United Nation Food and Agriculture Organization; FAO). 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. Although the use of improved varieties and fertilizers, mechanical sowing, herbicides application for weed control and mechanical harvesting have increased sugar beet production to much extent, the full potential of sugar beet production has not yet been achieved when compared to the top ten sugar beet producer countries (Iranian Ministry of Agriculture, Statistical Yearbook, 2009).

Tillage is one of the most important production factors that influence soil physical and mechanical properties (Keshavarzpour and Rashidi, 2008; Rashidi and Keshavarzpour, 2008), and consequently crop yield (Khurshid *et al.*, 2006; Rashidi and Keshavarzpour, 2007; Rashidi *et al.*, 2008; Rashidi and Khabbaz, 2009; Rashidi *et al.*, 2009 a, b). Appropriate tillage practices can improve soil related constrains, while excessive, inappropriate and unnecessary tillage operations may cause a range of undesirable processes such as destruction of soil structure, accelerated soil erosion, reduction of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrients (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 emphasis on the shift to 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 and Keshavarzpour, 2007; Glab and Kulib, 2008; Keshavarzpour and Rashidi, 2008; Rashidi and Keshavarzpour, 2008; Rashidi *et al.*, 2008; Rashidi and Khabbaz, 2009; Rashidi *et al.*, 2009 a, b). 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 contradictory (Iqbal *et al.*, 2005). Conservation tillage methods may reduce yield of sugar beet (Draycott, 2006). Conversely, reduction of soil tillage intensity may have no significant influence on the yield of many crops (Ekeberg, 1993; Hakansson *et al.*, 1998; Hao *et al.*, 2001; Ozpinar, 2006; Glab and Kulib, 2008). Conservation tillage methods may also lead to raised diversity of weed species and population (Carter and Ivany, 2006; Ozpinar, 2006) and have a negative influence on crop yield (Borresen, 1993). However, other studies have confirmed the opposite (Campbell *et al.*, 1998).

Most of the cultivated area in Iran is under conventional tillage methods, and conservation tillage methods have not been studied enough. For this reason, this study was conducted to investigate the response of root yield and yield components of sugar beet to different tillage methods.

MATERIALS AND METHODS

Experimental site

The study was carried out for two successive growing seasons (2008 and 2009) at the Ekbatan Research Site of Hamedan, Iran. The site is located at latitude of 34° 52' N and longitude of 48° 21' E and is 1730 m above mean sea level, in semi-arid climate (298 mm rainfall annually) in the west of Iran, where the summers are moderate while the winters are cool. Mean temperature and monthly rainfall of the experimental site from sowing to harvest during study years (2008 and 2009) are indicated in Figure-1.

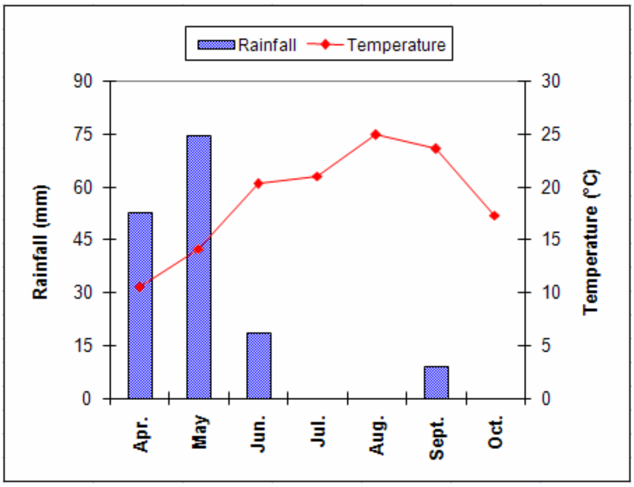

Figure-1. Mean temperature and monthly rainfall during crop growth (mean of 2008 and 2009).

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. Soil sample was analyzed in the laboratory for pH, EC, OC, N, P, K, Fe, Zn, Cu, Mn, B and particle size distribution. Soil pH and EC values were determined by using a HI9813-5 portable pH/EC/TDS/°C meter (HANNA instruments, Romania, 2002). Soil OC was determined by Walkley-Black procedure (Nelson and Sommers, 1982). Total N was determined by the macro-Kjeldahl method (Bremner, 1982). Available P was found using Bray II method according to Olsen (1982). The exchangeable cations were calculated by the method described by Thomas (1982). Particle size distribution was determined by hydrometer method (Gee and Bauder, 1986). Details of soil physical and chemical properties of the experimental site during both years (2008 and 2009) are given in Table-1.

Table-1. Soil physical and chemical properties of the experimental site (0-30 cm depth), 2008 and 2009.

Date	pH	EC (dS m^{-1})	OC (%)	N (%)	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	B (ppm)	Soil texture
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

Field methods

The experiments were laid out in a randomized complete block design (RCBD) with three replications. Tillage treatments in the study 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) as direct drilling method. The treatments were carried out on the same plots during both growing seasons. The size of each plot was 20.0 m long and 6.0 m wide. A buffer zone of 3.0 m spacing was provided between plots. There were 12 rows of sugar beet in each plot with 50-cm row spacing. In both growing seasons, one of the most commercial

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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 standard U.S. weather bureau class-A open-pan installed nearby the experimental plots. Pest and weed control performed according to general local practices and recommendations. All other necessary operations except those under study were kept normal and uniform 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 (RY) and yield components, i.e., root number per hectare (RNPH), sugar yield (SUGY), root dry matter (RODM), root length (ROTL) and rim diameter (RIMD) 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 sugar (sucrose) content for all treatments. Sugar content was measured in fresh root samples by using Saccharometer as described by AOAC (1995).

Statistical analysis

All data were subjected to the Analysis of Variance (ANOVA) as described by Gomez and Gomez (1984) using SAS statistical computer software. Means of the different treatments were also separated by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

RESULTS AND DISCUSSIONS

In this study, root yield (RY) and some yield components of sugar beet, i.e., RNPH, SUGY, RODM, ROTL and RIMD were studied to analyze the response of sugar beet to different tillage methods. Results of ANOVA and means comparison for root yield and yield components of sugar beet under different tillage methods during the study years (mean of 2008 and 2009) are presented in Tables 2 and 3, respectively.

Statistical results of the study showed that different tillage methods significantly ($P \leq 0.05$) affected RNPH, but there was no significant difference in other studied traits (Table-2). The maximum value of RNPH (135412 roots ha^{-1}) was observed in case of MR treatment, while the minimum value of RNPH (115000 roots ha^{-1}) was observed in case of NT treatment (Table-3). Although there was no significant difference in RY, SUGY, RODM, ROTL and RIMD during the years of study, results showed that tillage practices were useful in improving the yield of sugar beet. The maximum values of RY (82.7 t ha^{-1}), SUGY (11.4 t ha^{-1}) and RODM (23.9%) were observed in case of MR treatment, while the maximum values of ROTL (20.5 cm) and RIMD (1.5 cm) were noted in case of NT treatment (Table-3). Based on the results, tillage method affected the yield of sugar beet (RY, SUGY and RODM) in the order of MR > CR > R > MDD > DD > C > NT. These results are in agreement with those of Khan *et al.* (1999), Khan *et al.* (2001), Iqbal *et al.* (2005), Khurshid *et al.* (2006), Rashidi and Keshavarzpour (2007), Keshavarzpour and Rashidi (2008), Rashidi and Keshavarzpour (2008), Rashidi *et al.* (2008), Rashidi and Khabbaz (2009) and Rashidi *et al.* (2009a,b) who concluded that tillage practices can be associated with enhanced soil physical and mechanical properties (increased pore space, decreased bulk density, increased moisture preservation and decreased penetration resistance), improved soil structure, better seed/root-soil contact and superior suppressing of weed growth which positively influence RNPH, resulting in increased RY and consequently SUGY of sugar beet.

Table-2. Analysis of variance for root yield and yield components of sugar beet under different tillage methods (mean of 2008 and 2009).

Source of variation	Df	Mean square					
		RY	RNPH	SUGY	RODM	ROTL	RIMD
Replication	3	257.9 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	390.7	62268312	10.5	3.17	5.12	0.04
C.V. (%)	---	25.4	6.20	31.3	8.04	11.7	15.2

NS = Non-significant
* = Significant at 0.05 probability level
(RY: root yield; RNPH: root number per hectare; SUGY: sugar yield; RODM: root dry matter; ROTL: root length; RIMD: rim diameter)

Table-3. Means comparison for root yield and yield components of sugar beet between different tillage methods (mean of 2008 and 2009).

Treatment	RY ($t\ ha^{-1}$)	RNPH	SUGY ($t\ ha^{-1}$)	RODM (%)	ROTL (cm)	RIMD (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.
(RY: root yield; RNPH: root number per hectare; SUGY: sugar yield; RODM: root dry matter; ROTL: root length; RIMD: rim diameter)

In contrast, the minimum values of RY (71.3 $t\ ha^{-1}$), SUGY (9.15 $t\ ha^{-1}$) and RODM (20.3%) were observed in case of NT treatment, while the minimum values of ROTL (18.0 cm) and RIMD (1.1 cm) were noted in case of MR treatment (Table-3). These results are also in line with the results reported by Bauder *et al.* (1981), Hill (1990), Horne *et al.* (1992), Borresen (1993), Carter and Ivany (2006) and Ozpinar (2006) that conservation tillage methods may be associated with worse soil physical and mechanical properties (decreased pore space, increased bulk density, decreased moisture preservation and increased penetration resistance), poorer seed/root-soil contact and raised diversity of weed species and population which negatively influence RNPH, resulting in decreased RY and as a result SUGY of sugar beet. These results are also in agreement with those of Romaneckas *et al.* (2006), Adamaviciene *et al.* (2009), Romaneckas *et al.* (2009) and Jabro *et al.* (2010) who concluded that intensive tillage methods enhanced soil quality and had no significant effect on RY and most yield components of sugar beet.

CONCLUSIONS

Different tillage methods significantly ($P \leq 0.05$) affected RNPH, but there was no significant difference in RY, SUGY, RODM, ROTL and RIMD. Although there was no significant difference in most studied traits, tillage practices were beneficial in improving the yield of sugar beet. Also, the reduced tillage treatments MR and CR, and the minimum tillage treatment R were considered as more appropriate and profitable tillage methods in improving the yield of sugar beet.

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