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Effect of different tillage methods for monogerm seedbed preparation on yield and quality of sugar beet

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ABSTRACT

The aim of this study was to investigate the effect of tillage methods to obtain suitable seedbed for monogerm seed. Therefore, a split plot experiment based on a randomized complete block design (RCBD) with three replicatians was conducted at Darab station of Fars province. The main plot was seedbed prepration at two levels including fall and spring season. Subplot included 1) Moldboard plow at depth of 30-35 cm + Disk; 2) Moldboard plow at depth of 30-35 cm + Rototiller; 3) Chisel plow at depth of 30-35 cm + Disk; 4) Chisel plow at depth of 30-35 cm + Rototiller; 5) Subsoiler at depth of 30-35 cm + Moldboard plow at depth of 25-30 cm + Disk; 6) Subsoiler at depth 30-35 cm + Moldboard plow at depth of 25-30 cm + Rototiller. Parameters such as soil bulk density, soil cone index, percentage of germination, germination rate index, and yield and quality were measured. The results indicated that the effect of using tillage implement in fall season on bulk density and cone index was significantly different from that of spring season. Percentage of germination, germination rate index and yield increased by using the tillage implements in fall compared with spring season. Results indicated that three factors including application time, tillage implements and depth can be effective on the measured parameters. Moldboard plow at depth of 30-35 cm in fall season along with rototiller produced higher percentage of germination (94.42%), germination rate index(4.93%), purity (82.68%), root yield (81.81 tha-1) and while sugar beet.

Keywords: Soil cone index, Soil bulk weight, Sugar beet, Tillage method, Tillage time

INTRODUCTION

Sugar beets need proper, weeds-free seedbed. The surface soil should be fine and partially condense with no roughness at seedbed to allow uniform and quick germination. Soil porosity plays an important role in root form. Proper seedbed, optimum moisture, accurate row crop planter and weeds management are of importance in monogerm seed cultivation (Khodabandeh 1990).

Adverse conditions of seedbed retards germination, reduces germination rate, decreases the number of plants and finally, decreases the establishment and increases the stress to the plants (Shafiee 1995). The methods of tillage vary in terms of tillage implements and the time and frequency of tillage operations, each one affecting yield or income in its own way depending on their specific advantages and shortcomings as well as their costs. Selecting appropriate soil and soil preparation operations is of crucial importance in sugar beet production, and seedbed preparation in soils with proper depth is a prerequisite for the successful production of roots with adequate sugar content (Koulivand 1987; Khodabandeh 1990).

Gyuricza et al. (1999) studied the effect of reduced and conventional tillage methods on soil parameters and yield of sugar beet. Conventional tillage was practiced by moldboard plow + disking and reduced tillage was practiced by chisel plow + disking. Results of two-year experiment revealed

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that soil bulk density and soil resistance was decreased and the yield was increased by 30% in conventional tillage. Bialczyk et al. (2000) examined the influence of tillage with moldboard plow and rotivator and direct sowing on the physical properties of soil and yield of sugar beet. The application of moldboard plow + rotivator reduced soil resistance and increased the yield. As well, the reduced soil resistance affected the root form of sugar beet. Hao et al. (2000) studied the effects of minimum tillage and conventional tillage on the physical properties of soil in sugar beet field. The conventional tillage of sugar beet was carried out by moldboard plowing, double disking and light cultivation. Minimum tillage operation was conducted by chisel plow and harrow packing in autumn and sowing in spring. It was found that two tillage methods had no significant differences in soil bulk weight and soil cone index. Geometric mean diameter of aggregates was 6.52 mm in minimum tillage method and 3.81 mm in conventional tillage. In terms of yield, conventional method produced 25% higher yield than minimum tillage. Walczyk and Michalek (2000) examined the impact of reduced tillage and conventional tillage with moldboard plow on increasing soil resistance after sugar beet cultivation. Soil cone index measurement showed the compaction at the depth of 30 cm on sowing rows in both tillage methods. However, the compaction was not unacceptable and critical.

In a five-year study, Reinhard et al. (2001) compared the effect of no tillage and conventional tillage with moldboard plow on sugar beets. Root yield had no statistically significant differences between two tillage methods in the first two years of the study following a slight decrease in the yield.

In a study on tillage in sugar beet production, Dotsenko et al. (2002) investigated the appropriate tillage depth. Their experimental treatments included three depths of 3, 5 and 7 cm. They reported that 3-cm tillage depth resulted in higher soil water retention as well as better management of weeds. At the second stage, the field was treated with conventional tillage and on-the-ridge tillage + secondary tillage with disk. The results of the second study showed that further tillage had no positive influence on changing soil conditions and the yield.

Kordas and Zimny (2002) compared the application of direct sowing and conventional method by moldboard plow and disk in terms of soil physical properties and sugar beet yield. Keeping plant residue and the application of moldboard plow and disk was used as the third treatment, too. After six years of study, it was revealed that geometric mean diameter of aggregates was increased under the application of moldboard plow and disk with the plant residue retained as compared to the conventional tillage method. The yield showed statistically significant difference between the application of moldboard plow + disking and the other two methods. The lowest yield was observed in direct sowing method.

The studies imply that three factors play important roles in good tillage: method, depth and time. Therefore, an experiment with different tillage methods in spring and autumn was carried out to determine the optimum soil physical conditions for preparing the best seedbed for sugar beet monogerm seeds and the effect of these conditions on quantitative and qualitative yield.

MATERIALS AND METHODS

The present study was carried out at Darab Agricultural Research Station, Iran in 2005 and 2006. The farm had already been used for wheat production in the previous year. The study was a split-plot experiment on the basis of a Randomized Complete Block Design with three replications. Field preparation in spring (A_1) and autumn (A_2) was devoted to the main plot and the application of tillage implements at the following six levels was devoted to the sub-plots:

- T_1: the application of moldboard plow at 30-35 cm depth + disking
- T_2: the application of moldboard plow at 30-35 cm depth + rototiller
- T3: the application of chisel plow at 30-35 cm depth + disking
- T4: the application of chisel plow at 30-35 cm depth + rototiller
- T5: the application of subsoiler at 30-35 cm depth + moldboard plow at 25-30 cm depth + disking
- T6: the application of subsoiler at 30-35 cm depth + moldboard plow at 25-30 cm depth + rototiller

The experimental plots were composed of 20 rows of 20 m length with inter-row spacing of 50 cm. Four 18-m-long rows were selected from each plot for agronomic traits recording. The main plots were spaced 6 m and the replications were spaced 10 m apart to facilitate the commuting of the implements. The farm was fertilized with 260 kg ha^{-1} superphosphate triple and 200 kg ha^{-1} potassium

Table 1. Some physical and chemical properties of the soil of the study farm in 2005-2006

Study year	Soil sample depth (cm)	Organic C (%)	Absorbable P (ppm)	Absorbable K (ppm)	pH	EC (dS m^{-1})	Silt (%)	Clay (%)	Sand (%)	Texture
2005	0-15	055	3.2	194	8.5	0.56	43.7	20.3	38.1	Loam
	15-35	052	3.4	183	8.2	0.53	41.8	19.6	37.9	Loam
2006	0-15	0.60	3.5	190	8.3	0.59	41.7	22.3	36.4	Loam
	15-35	0.56	3.8	188	8.0	0.53	44.8	20.5	34.6	Loam

phosphate at sowing on the basis of soil analysis and fertilizer recommendations. Table 1 presents soil properties of the study farm.

The studied monogerm cultivar was Rasoul which was sown with inter-seed spacing of 5 cm at early-April. The plots were furrow irrigated with siphon. After the first weeding and thinning, the plots were fertilized with 260 kg ha^{-1} Urea at two phases. Table 2 presents the technical information of the machinery used in the experiment. The variables measured were as follows:

Soil bulk weight

Undisturbed samples were taken from the depth of the soil by specific cylinders and their volume was determined according to the dimensions of the cylinder. Then, the samples were put in oven at 105°C for 24 hours. Soil bulk weight of the plots was measured before tillage and after the first irrigation at the depth of 40 cm with spatial intervals of 10 cm. Having the weight of the sample, soil bulk density was determined by the following equation on the basis of dry weight:

(1) $$BD=\frac{M}{V}$$

where *BD* was soil bulk weight (g cm^{-3}), *M* was the dry weight of the soil of the sampling ring (g), and *V* was the volume of the sampling ring (cm^3).

(2) $$\Delta BD=\frac{BD_1-BD_2}{BD_1}\times 100$$

where BD_1 is the soil bulk weight before irrigation, BD_2 is the soil bulk weight after irrigation, and ΔBD is the variation of soil bulk weight.

Soil cone index

In each plot, 10 penetrations before and after the operation and in each point from the depth of 0 to 40 cm were measured by cone penetrometer (model SP1000). The moisture was 16-18% during the operation.

(3) $$DSCI=\frac{SCIT-SCII}{SCIT}$$

where *DSCI* is the percentage of the decrease in soil cone index, *SCIT* is soil cone index before tillage, and *SCII* is soil cone index after the first irrigation.

Germination percentage

To determine the percentage of germinated plants, the number of germinated plants was daily counted in frames with the area of 0.5 m^2 which had been mounted in the middle of the plots before sowing. Then, the percentage of germinated seeds was calculated by Eq. (4).

(4) $$M=\frac{PPSM}{SPSM\times P\times G}$$

where *PPSM* is the number of germinated plants per m^2, *SPSM* is the number of seeds sown per m^2, *P* is the seed purity percentage and *G* is seed viability.

Germination rate index

Plant establishment is usually used as a criterion for evaluating the performance of tillage and

Table 2. Technical specifications of the implements used in the study (experimental treatments definition)

Implement	Specification
Moldboard plow	Mountable, three moldboards, width of work of each moldboard: 35 cm, width of work: 1.05 m
Chisel plow	Mountable, no. of shanks: 7; shank distance: 25 cm, work width: 1.75 cm
Tandem disk	Tensile with carrier wheels, no. of scraper: 36, scraper spacing: 23 cm, scraper diameter: 55 cm, width of work: 4 m
Rototiller	Mountable, required power: 55 hp, vertical blades with diamond cross-section, width of work: 1.85 m
Subsoiler	Mountable with three curved shanks, tillage agent with winged blade with 2 depth adjustment wheels, width of work: 1.68 m
Pneumatic planter	Four-rows, seed tank capacity: 30 liters, required power: 50-60 hp, row spacing: 75 cm, weight: 700 kg, propulsion rpm: 500

Table 3. Means squares of combined analysis of variance of the quantitative variables of sugar beets in 2005-2006

Source of variation	df	Bulk weight reduction (%)	Soil cone index reduction (%)	Germination %	Germination rate index	Root yield	White sugar yield
Year (Y)	1	0.03^{ns}	0.04^{ns}	0.27^{ns}	0.01^{ns}	213.31^{ns}	26.22^{ns}
Error	4	0.09	0.03	0.45	0.01	166.38	20.75
Time (A)	1	1.54*	0.27*	765.77**	6.35**	7981.53**	997.625**
Y × A	1	0.01^{ns}	0.00^{ns}	0.01^{ns}	0.03*	6.17^{ns}	15.27*
Error *a*	4	0.08	0.01	1.92	0.01	17.64	4.210
Tillage treatment (B)	5	11.39**	1.71**	139.48**	2.29**	918.29**	110.79**
Y × B	5	0.00^{ns}	0.03^{ns}	0.10^{ns}	0.01^{ns}	56.28**	8.48*
B × A	5	0.22**	0.06**	71.32**	0.31**	76.34**	9.84*
A × B × Y	5	0.02^{ns}	0.01^{ns}	0.29^{ns}	0.01^{ns}	6.202^{ns}	3.22^{ns}
Error *b*	40	0.01	0.33	0.78	0.01	11.48	3.12
C.V.		12.97	10.84	11.02	12.80	13.44	14.05

*, ** and ns show significance at 5 and 1% probability level and non-significance, respectively.

sowing implements because the number of plants is an index of the number of seeds which has successfully germinated. It is used for evaluating the quality of seeds and seedbed. To determine the percentage of germinated plants, the number of germinated plants was daily counted in frames with the area of 0.5 m^2 which had been mounted in the middle of the plots after sowing. Then, germination rate index was calculated by Eq. (5).

$$ERI = \sum_{i=F}^{L} \frac{[\%D - \%(D-1)]}{D} \quad (5)$$

where *%D* is the percentage of germinated plants at the D^{th} day, *%(D-1)* is the percentage of germinated plants at the $(D-1)^{th}$ day, *D* is the number of days after sowing, *F* is the number of days after sowing in which the first plant germinated (the first counting day), and *L* is the number of days after sowing when germination completed (the last counting day).

Root yield, white sugar yield, and qualitative traits

At the end of the vegetative growth, four middle rows (18 m long covering an area of 36 m^2) were selected from each experimental plot after eliminating 0.5 m from both ends. Then, the number of roots was counted and the fresh weight was determined. Afterwards, 30 roots were randomly selected to prepare pulp sample and determine qualitative traits. Having root yield per unit area and sugar percentage, sugar yield was determined. The data were statistically analyzed by SAS software considering the fixed and random effects.

RESULTS AND DISCUSSION

The results of two-year combined analysis of variance of the soil bulk weight loss percentage, soil cone index loss percentage, germination percentage, germination rate index and root yield are presented in Table 3. Year had no significant effect on the measured variables and the experimental conditions were the same for both years. Time factor, i.e. soil preparation in autumn and spring, significantly affected soil bulk weight loss percentage and soil cone index loss percentage at 5% probability level and germination percentage, germination rate index, root yield and white sugar yield at 1% probability level. The application of tillage implements significantly influenced all the studied variables at 1% probability level. The interactions between experimental factors were significant for all measured variables. Combined analysis of variance of the qualitative traits is presented in Table 5 according to which the variables time, tillage implements and their interactions had no significant effects on qualitative traits.

Soil bulk weight and cone index

The greatest loss of soil bulk weight was obtained in A_1T_2 treatment (the application of moldboard plow + rototiller) in spring, but it did not have significant difference with A_1T_1 treatment (the application of moldboard plow + disking) (Table 4). It can be related to the application of secondary tillage implements. Given the fact that the loss of soil bulk weight results in the penetration of air and water in soil and the development of the roots, the type of elementary and secondary tillage implements and the time of the measurement of the parameters should be taken into account, too. As can be seed in Table 4, moldboard plow resulted in greater loss of soil bulk weight and cone index than chisel plot as did rototiller compared to disk which should be related to the performance of these implements and soil porosity. In total, the application of tillage implements in

Table 4. Grouping of means of combined treatments of time and tillage implement time on the measured variables in 2005-2006

Treatment	Parameter					
	Bulk weight reduction (%)	Soil cone index reduction (%)	Germination %	Germination rate index	Root yield (t ha^{-1})	White sugar yield (t ha^{-1})
A_1T_1	4.84 b	11.71 a	86.46 e	4.02 de	76.54 cd	8.09 cd
A_1T_2	5.08 a	11.70 a	91.20 bc	4.14 d	76.53 cd	9.23 c
A_1T_3	2.95 f	10.98 def	83.13 g	3.86 f	77.24 bcd	9.56 bcd
A_1T_4	3.34 e	10.76 fg	82.52 g	3.92 ef	76.26 d	9.50 bcd
A_1T_5	3.72 e	11.25 bc	77.37 i	3.22 h	77.55 bcd	9.96 bc
A_1T_6	4.69 b	11.42 b	80.35 h	3.29 h	77.78 bcd	10.28 bc
A_2T_1	4.18 d	10.53 g	90.63 c	4.28 c	79.19 abcd	10.66 ab
A_2T_2	4.20 d	1.65 g	91.76 b	4.52 b	80.77 ab	11.05 ab
A_2T_3	2.45 h	10.11 h	84.44 f	3.59 g	80.28 abc	9.95 bc
A_2T_4	2.80 g	10.01 h	87.94 d	3.87 f	82.69 a	10.24 bc
A_2T_5	4.36 c	11.01 de	90.98 bc	4.84 a	79.33 abcd	10.86 ab
A_2T_6	4.74 b	11.17 cd	94.42 a	4.93 a	81.81 a	11.84 a

Means in each column with similar letter(s) did not show statistically significant differences at 5% probability level (Duncan Test).

autumn reduced soil bulk weight to a lower level than their application in spring. This difference can be related to the fact that the farm is left to be be exposed to environmental parameters like precipitation for one season. In plots where soil bulk weight and cone index were measured in spring, these two parameters were measured immediately after tillage. But in plots where they were measured in autumn, this measurement was conducted in winter before sowing of the seeds. So, soil volume had been reduced in one season because of environmental parameters and consequently, its bulk weight and cone index had been reduced. Kyanmehr et al. (2008) reported similar results about the application of tillage implements and their effects on the measured variables. The results reported by Gyuricza et al. (1999) and Bialczyk *et al*. (2000) show their influence on reducing soil resistance and increasing the yield.

Germination percentage and germination rate index

Germination percentage and germination rate index were influenced by two factors of implement type and tillage time. In total, the treatments of tillage implements application in autumn increased germination percentage and germination rate index (Table 4). Also, moldboard plow vs. chisel plow and rototiller vs. disking are advantageous because of better turning of soil in the former and creating more uniform surface and tinier and more uniform aggregates in the latter. The results for soil bulk weight and cone index were similar to those for these two variables. No significant differences were observed between tillage implements and between tillage times in terms of germination percentage and germination rate index. However, there were slight differences between some treatments. Among treatments with similar tillage implements but different tillage time (autumn and spring), treatments of tillage in autumn produced higher germination percentage and germination rate index (Table 4). Gyuricza et al. (1999); Bialczyk et al. (2000) and Hao et al. (2000) reported the effect of tillage implement type and time on physical properties including the loss of soil resistance, the increase in sugar beet germination rate and finally, the increase in root

Table 5. Means squares of combined analysis of variance of the qualitative variables of sugar beets in 2005-2006

Source of variations	df	Sugar %	White sugar %	Raw juice purity (%)	Na	K	N	Molasses (%)
Year (Y)	1	29.01^{ns}	58.18^{ns}	1758.84**	9.23^{ns}	146.63**	0.36^{ns}	31.75**
Error	4	8.36	10.56	49.23	2.00	0.95	0.12	0.30
Time (A)	1	17.80^{ns}	21.34^{ns}	245.68^{ns}	4.40^{ns}	10.21^{ns}	0.12^{ns}	2.45^{ns}
Y × A	1	6.07^{ns}	29.06^{ns}	206.99*	2.02*	7.56^{ns}	0.20^{ns}	2.51^{ns}
Error *a*	4	1.29	8.91	23.05	0.19	1.08	0.04	0.53
Tillage treatment (B)	5	0.73^{ns}	6.68^{ns}	4.67^{ns}	0.22^{ns}	0.21^{ns}	0.02^{ns}	0.15^{ns}
Y × B	5	0.62^{ns}	8.19^{ns}	5.07^{ns}	0.36^{ns}	0.18^{ns}	0.05^{ns}	0.10^{ns}
B × A	5	0.92^{ns}	2.20^{ns}	9.10^{ns}	0.10^{ns}	0.96^{ns}	0.09^{ns}	0.18^{ns}
A × B × Y	5	0.57^{ns}	1.57^{ns}	7.12^{ns}	0.41^{ns}	0.51^{ns}	0.03^{ns}	0.11^{ns}
Error *b*	40	0.69	5.04	7.97	0.20	0.95	0.05	0.20
C.V.		4.94	17.52	3.58	22.71	13.81	18.61	15.71

*, ** and ns show significance at 5 and 1% probability level and non-significance, respectively.

yield.

The interaction between tillage time and tillage implement type was significant for root yield and white sugar yield at 1% and 5% probability levels, respectively. The interaction between year, tillage time and tillage implement type was not significant for the studied traits (Table 3). The highest root yields of 82.69, 81.81 and 80.77 t ha^{-1} were obtained in the treatments of A_2T_4, A_2T_2 and A_2T_6, respectively (Table 4). It can be concluded that time factor (seedbed preparation in autumn) increased germination percentage and germination rate index resulting in higher root yield because under these conditions, after the germination of the seeds, the seedlings grew on an optimum surface soil and developed effectively in fertile, deep soil. The highest white sugar yield was obtained under the application of tillage implements in autumn as compared to their application in spring (Table 4). The results imply that the tinier, more compact the surface soil is in sugar beet seedbed preparation and the more porous the deep soil is, the better form the roots will have given that roots play a crucial role in soil extraction process. Owing to complete turnover of soil, moldboard plow creates smaller aggregates and lighter soil than chisel plow. Out of the studied secondary tillage implements too, rototiller had better performance in creating these conditions than disk because in addition to breaking soil particles formed during the initial tillage, it compacts soil surface by its rear roller which is a very important practice to improve the contact between seed and soil and also, its rear fender levels the soil when it comes to contact with soil surface. These operations are not conducted by disk. The application of tillage implements in autumn, especially implements that produced high white sugar yield, provided the best conditions of seedbed preparation for the optimum growth of sugar beet roots. It should also be remembered that the energy used for seedbed preparation must be minimal. Results reported by Gemtos and Lellis (1997); Cooke and Scott (1993) and Bialczyk et al. (2000) indicated that such factors as manure, plant residue, and autumn plowing as well as physical factors like the decrease in soil resistance play role in increasing quantitative and qualitative yield.

Effect of tillage time and implement type on produced sugar beet

No significant differences were observed between tillage treatment in autumn and spring for raw juice purity and impurities of sugar beet roots (Table 5). Nonetheless, the highest coefficient of raw juice extraction (82.68%) was obtained under the treatment of moldboard plow and rototiller. In a study on the effect of the decomposition of wheat residue on sugar beet root purity percentage, Sims (2007) found that wheat residue, when mixed with soil, increased sugar beet root quality and decreased its impurities. Furthermore, Moor et al. (2009) concluded that the best practice for sugar beet seedbed preparation was the application of moldboard plow in September as compared to November because earlier mixing of residue with soil gave enough time for them to decompose and reduced N mobility in soil which resulted in lower application of fertilizers as well as lower impurities in roots.

Interaction between tillage time and implement type for root sugar percentage

The interaction between tillage time and implement type was not significant for root sugar percentage (Table 5). However, mean sugar percentage was higher under the treatment of tillage in autumn (A_2) than under that in spring (A_1) (17.16 vs. 16.17%). It can be concluded that plant residue (left from the cultivation of wheat) is decomposed better in autumn and winter providing better conditions for the growth of seedlings in spring. On the other hand, the roots were characterized by conical shape with the minimum crown and no branches under the treatment of tillage in autumn which are regarded as the features of high-quality roots. Cooke and Scott (1993) reported that autumn plow was one of the factors of the higher quality of the yield. In addition, Bialczyk et al. (2000) reported that the application of moldboard plow and rototiller was effective in increasing the yield and improving the root form of the sugar beets. It should be mentioned that the rototiller applied in the present study had the same performance as and higher quality than rotivator.

CONCLUSION

The results show that the factors tillage time, tillage implement type and tillage depth can influence the quantity and quality of sugar beet yield. The application of moldboard plow at the depth of 30-35 cm in autumn + rototiller (A_2T_2) increased germination percentage, germination rate index and quantitative yield (of root and white sugar) and this treatment is recommended for loamy soils.

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