

Application of tillage implements in different depths of soil on sugar beet (*Beta Vulgaris* L.) yield and some soil properties

ABSTRACT

Aim: This study was carried out to identify the optimal seedbed preparation with different tillage implements and their impacts on sugar beet yield and some soil properties in monogerm seeds.

Place and duration of study: The research was carried out in Darab Research Station of Fars province, Iran.

Study design: A randomized complet block design (RCBD) with three replications was used to conduct the experiment.

Methodology: Using monogerm seeds of sugar beet have increased among farmers due to reducing thinning costs. So, research on suitable tillage methods to prepare seedbed preparation for this type of seed is necessary. Experiment was conducted in Darab Research station of Fars province, Iran with six treatments in a loamy soil. Treatments were plowing with moldboard plow at a depth of 35-30 cm + disc harrow (T_1); plowing with moldboard plow at a depth of 35-30 cm + rototiller (T_2); plowing with chisel plow at a depth of 35-30 cm + disc harrow (T_3); plowing with chisel plow at a depth of 35-30 cm + rototiller (T_4), subsoiler at a depth of 30-35 cm + moldboard plow to a depth of 25-30 + disc harrow (T_5); subsoiler at a depth of 30-35 cm + moldboard plow to a depth of 25-30 + rototiller (T_6). Parameters such as soil bulk density, soil cone index, percentage of seed emergence, seed emergence rate, root yield and qualitative yield were measured. After conducting the experiments, collected data were analyzed using SAS statistical software and Duncan's multiple range test was used for comparing the treatments.

Results: Results demonstrated that the greatest and the lowest reduction in soil bulk density was observed in treatment T_6 and T_4 , respectively. The trend of enhancement and reduction of the soil cone index was consistent with the soil bulk density. Also, analysis of data showed that the type of tillage implement and the depth of tillage operation are important for seed emergence and seed emergence rate. The highest and the lowest value of these two parameters were in treatments T_2 and T_3 , respectively. Maximum amount of yield obtained from treatment T_6 and there was no significant difference between treatments T_5 and T_2 .

Conclusion:

The following conclusions deduces from this research:

1. For preparing seedbed of sugar beet, two points are important; first the tillage implements and then the depth of tillage operation.
2. To prepare suitable seedbed preparation for sugar beet with monogerm seed, moldboard plow in the depth of 30-35 cm and rototiller suggests instead of chisel plow and disk harrow.
3. By using moldboard plow and rototiller, soil bulk density and soil cone index reduced and seed emergence and seed emergence rate enhanced and eventually sugar beet yield increased.

Keywords: *Soil bulk density; soil Cone index; seed emergence rate; monogerm seed.*

1. INTRODUCTION

Seedbed preparation for sugar beet is important for producing high yield. The surface soil should be fine, slightly dense and smooth. In this condition, the germination of seed achieves fast and uniform. The physical properties of the soil, especially in heavy soils, is very important. No ventilation, inappropriate drainage and excessive soil compaction are very harmful for sugar beet growth. Root form plays an important role in the process of sugar extraction and depends on deep soil. Breeders have produced seeds that are simple and single-seeded or monogerm. This type of seeds have some advantages such as reducing the cost of thinning, decreasing the amount of seed up to 3-5 kilograms per hectare. But the use of monogerm seed requires a suitable seedbed, optimum moisture, and weed control [1]. The low seed quality and adverse conditions of the seedbed delay the emergence of seed and slow the rate of seed emergence and finally reduced the establishment of plants. The tillage methods are different in terms of type of tillage, time and numbers of tillage operations [2]. Therefore, research on different seedbed preparation methods is necessary. Principally, selecting suitable tillage implements and seedbed preparation operations for sugar beet sowing is important like seed selection. Koch et al. [3] reported that decreasing depth in tillage operation caused penetration resistance and dry bulk density and minimum tillage decreased sugar beet yield. They recommended that for producing high yield, the soil should be loosen down to 0.15-0.20 m depth. Results of a research by Laufer et al. [4] showed that strip tillage than reduced tillage could increase high yield in sugar beet. Also, penetration resistance and root length density have no relation to differences in yield. Arvidsson et al. [5] stated that with ploughless tillage in sugar beet, soil bulk density may be too high for optimal growth. In other experiment, chisel plow lowered yield compared with moldboard plowing. Soil bulk density decreased with tillage operations (conventional tillage) and reducing soil bulk density created good soil conditions for root growth and development [6]. Results of research by Koch [7] indicated that due to repeated wheeling, negatively affected penetration resistance on sugar beet yield. They recommended that reduction of tillage depth to 0.1 m is not good for high yielding sugar beet crops. Research on some crops like spring cereals, oilseed, potatoes and sugar beet showed that crop yield in shallow tillage was 1.8% lower than for moldboard plowing. For sugar beet alone, reduction in yield was 5-10% in shallow tillage. Also, in no-tillage, needs to improve to secure plant establishment and crop yield [8].

Primary tillage and the nature of soil is important for high yield in sugar beet and obtaining acceptable mean saturated hydraulic conductivity. Also, management in top soil is necessary in tillage operation [9]. An experiment based on meta-analysis showed that on average, deep tillage slightly increased yield (+6%). At sites with hard pan and root-restricting, crop yield responded to deep tillage 20% more than the sites without hard pan. The final results suggested that deep tillage prepare nutrients for plant in subsoil [10]. Crittenden et al. [11] reported that non-inversion tillage could apply for producing the sugar beet yield. In this method of tillage operation, there are high penetration resistance and low field-saturated hydraulic conductivity. However, they recommended that non-inversion tillage in sugar beet as a viable alternative for farms. Sugarbeet is a sensitive crop to soil compaction. Eleven sugarbeet genotypes were examined about the performance under different soil compaction levels. The compaction levels was up to 400 kPa. Results showed that low compaction pressure (less than 200 kPa) seems harmless for sugar beet and causes more crop yield [12]. Comparison of two tillage operations (conventional tillage and zero tillage) indicated that zero tillage systems offers financial benefits than

the conventional tillage, but the crop yield in zero tillage was low about 0-14.2% across all crops [13]. In a two-year experiment (2006-2007) on a sandy soil in Germany, ridge and flat cultivation compared. Results demonstrated that yield was higher in ridge cultivation and white sugar yield was increased by 8.4% compared to flat cultivation [14]. Direct drilling and using moldboard plow were tested on sugar beet yield. After six years of experimentation, the use of moldboard plow and disk harrow produced higher yield than direct drilling [15]. Datsenko et al. [16] reported that the depth of plowing had positive effect on seed emergence in sugar beet. Also, tillage on sugar beet rows had no significant difference compare to conventional tillage in sugar beet yield. The effect of moldboard plow on sugar beet yield after 5 years of experiment showed no significant difference than the no-tillage systems. Of course, a slight reduction was observed in the first two years of experiment [17]. Hao [18] stated that mean weight diameter (MWD) in conventional tillage (3.81 mm) was less than reduced tillage (6.52 mm) and the yield of sugar beet in conventional tillage was 25% more. Bialsic [19] stated that moldboard plow and rotivator caused the low soil penetration resistance than direct drilling in sugar beet. That was a reason for obtaining high yield and in shape for sugar beet crop. The main aim of this study was to determine the effects of using different types of tillage implements in different depths of a loamy soil on soil physical properties and quantitative and qualitative yield of sugar beet in monogerm seeds.

2. MATERIALS AND METHODS

The research was carried out in Darab Research Station of Fars province (250 KM south-east of Shiraz, Latitude 28°47' N, 57°17' E, and 1120 m above sea level with semi-arid climate condition), Iran. A randomized complet block design (RCBD) with three replications was used to conduct the experiment in a loamy soil with six treatments including plowing with moldboard plow at a depth of 35-30 cm + disc harrow (T_1); plowing with moldboard plow at a depth of 35-30 cm + rototiller (T_2); plowing with chisel plow at a depth of 35-30 cm + disc harrow (T_3); plowing with chisel plow at a depth of 35-30 cm + rototiller (T_4); subsoiler at a depth of 30-35 cm + moldboard plow to a depth of 25-30 + disc harrow (T_5); subsoiler at a depth of 30-35 cm + moldboard plow to a depth of 25-30 + rototiller (T_6). Dimensions of each plot was (20 m $\times$ 10 m) and at a distance of 6 m from each other in each replication and the distance between replications were considered 10 m for better traffic of tractor. Each experimental plot consisted 20 rows at a space of 0.5 m. Fertilizers based on soil analysis were added to the soil. Table 1 shows the soil characteristics of the tested farm.

Table 1. Soil specifications of the field used for study

Soil depth (cm)	Sand (%)	(%) Clay	Silt (%)	O.C (%)	pH	EC (dS m ⁻¹)	Soil texture
0-15	36.5	19.1	42.8	0.74	7.9	0.51	Loam
0-30	37.9	19.3	41.4	0.73	8.1	0.54	Loam

The genotype of Rasoul cultivar was planted (4 units ha⁻¹) with pneumatic planter and spaced at 5 cm from each other. Furrow Irrigation system was used for plots. Measurable parameters were: soil bulk density, soil cone index, percentage of seed emergence, seed emergence rate, root yield and qualitative yield. Bulk density in each plot was measured using the core sampler method. Intact soil core samples with a 5.4 cm diameter and 4 cm height were taken using a core sampler [20]. The samples were dried at 105 degrees centigrade for 24 hours in oven. The following equation was used to calculate the soil bulk density:

$$BD = \frac{W_d}{V} \quad (1)$$

where:

BD = soil bulk density (Mg m^{-3}),

W_d = sample dry weight (Mg), and

V = Sample total volume (m^3).

Cone penetration resistance (PR) was measured using a digital cone penetrometer (Model Rimik CP20, Agridry Rimik Ltd, Queensland, Australia). Penetration resistance was measured for the soil depth of up to 35 cm with the distance interval of one centimeter before and after tillage operation. The number of plants at full emergence was determined by counting the number of seedlings in two rows with the length of 1 m in each plot. Percentage of seeds emerged was calculated by the following equation:

$$SE = \frac{PPSM}{(SPSM)(P)(G)} \times 100 \quad (2)$$

Where SE is seed emergence (%), $PPSM$ is the number of emerged seed in 1 m^2 of each plot, $SPSM$ is the number of planted seeds in 1 m^2 of each plot, P is seed purity, and G is viability of seeds. Data collected from this study were analyzed using SAS software, [21], and Duncan's multiple range tests was used to compare the treatments means. Plant establishment is often considered as an evaluation of the performance of tillage and planting equipment. To determine the percentage of seed emergence, the number of emerged seed per day was counted from within the frames with area ($1 \text{ m} \times 1 \text{ m}$) in the middle of each plot. Then the seed emergence rate was calculated from the following equation:

$$ERI = \sum_{i=F}^L \frac{[\%D - \%(D-1)]}{D} \quad (3)$$

Where ERI is seed emergence rate (%), D is percentage of emerged seed in day of D , $D-1$, is percentage of emerged seed in the day of $D-1$, F is the number of days after planting, which is the first seed was emerged (the first day of counting) and L is the number of days after planting when the seed emergence is completed (the last day of counting). At the end of the planting season, root yield per area unit was harvested and Weighed for all treatments in different plots.

3. RESULTS AND DISCUSSION

3.1. Bulk density and penetration resistance

Comparison of means for using the tillage implements on soil bulk density and percent reduction in soil cone index are presented in table 2.

Table 2. Soil bulk density and cone index reduction in different treatments

Treatments	BD reduction (%)	Cone index reduction (%)
T_1	3.95 ^e	10.83 ^d

T ₂	4.53 ^b	11.08 ^c
T ₃	3.52 ^e	10.80 ^d
T ₄	2.88 ^d	10.74 ^d
T ₅	4.73 ^b	11.12 ^c
T ₆	5.91 ^a	12.71 ^a

Averages with different letters were statistically different at the confidence level of 95%.

T₁= Moldboard plow (30-35) + disk harrow.

T₂= Moldboard plow (30-35) + rototiller.

T₃= Chisel plow (30-35) + disk harrow.

T₄= Chisel plow (30-35) + rototiller.

T₅= Subsoiler (30-35) + Moldboard plow (25-30) + disk harrow.

T₆= Subsoiler (30-35) + Moldboard plow (25-30) + rototiller.

According to table 2, the greatest reduction in soil bulk density was observed in the use of subsoiler along with moldboard plow and rototiller (T₆) with 5.91%. This treatment showed a significant difference at 5% level with treatment T₅. With regard to the fact that in the these two treatments the subsoiler and moldboard plow are the same, a further reduction in soil bulk density in treatment T₆ is related to the use of rototiller. The use of rototiller than the tandem disk harrow causes more porosity in the soil and due to increasing of soil volume, the bulk density reduces in the soil. The lowest amount of soil bulk density is found in the chisel plow. There was no significant difference between treatments T₂ and T₅ at 5% level in percentage of soil bulk density. So, the use of secondary tillage equipment is also important. The trend of decreasing or increasing the percentage of the soil cone index is consistent with the soil bulk density. Because of increasing soil porosity, the amount of penetration increases and cone index decreases in the soil.

3.2. Seed emergence and seed emergence rate

As shown in table 3, the highest percentage of seed emergence was in the use of moldboard plow at the depth of 35-30 cm and rototiller with 92.81% (T₂). This treatment did not show a significant difference at 5% level with the treatment of subsoiler with moldboard plow and rototiller (T₆). Seed emergence in treatments T₁, T₄ and T₅ were 88.55%, 85.23% and 84.18%, respectively. The lowest emergence of sugar beet seeds observed in chisel plow along with disk harrow (T₃) with amount of 83.79%. Regarding the percentage of seed emergence, two points are important: type of tillage implement and the depth of tillage operation. As can be deduced from the data in Table 3, the moldboard plow with rototiller (T₂) has the highest seed emergence.

This treatment does not show a significant difference with the treatment of subsoiler with moldboard plow and rototiller (T₆). The percentage of seed emergence is a parameter that is considered at the beginning of plant growth and depends on the depth of planting. Sowing depth of seeds and seedbed preparation are important on emergence of sugar beet seeds. No significant difference between the two treatments (T₂ and T₆) and using moldboard plow in different depth (25-30 and 30-35) indicated that rototiller as secondary tillage implement is considerable for preparing suitable seedbed especially in the surface soil. In addition to the creation a uniform seedbed from the point of view of clod size in rototiller, this implement acts as a leveler due to having a cap. As already stated, the emergence rate index can be used as a parameter for plant establishment and evaluating the performance of tillage implements. The highest value of this index were 4.42 and 4.35 in the use of treatments

T₆ and T₅ with no significant difference at 5% level. These two treatments did not show any significant difference with the treatment T₂. The emergence rate index, like the percentage of seed emergence, is related to the optimal seedbed preparation, the beginning of plant growth and surface soil.

Table 3. Seed emergence rate and seed emergence in different treatments

Treatments	Seed emergence rate (%)	Seed emergence (%)
T ₁	4.15 ^b	88.55 ^b
T ₂	4.33 ^a	92.81 ^a
T ₃	3.40 ^d	83.79 ^c
T ₄	3.58 ^c	85.23 ^d
T ₅	4.35 ^a	84.18 ^c
T ₆	4.42 ^a	91.95 ^a

Averages with different letters were statistically different at the confidence level of 95%.

T₁= Moldboard plow (30-35) + disk harrow.

T₂= Moldboard plow (30-35) + rototiller.

T₃= Chisel plow (30-35) + disk harrow.

T₄= Chisel plow (30-35) + rototiller.

T₅= Subsoiler (30-35) + Moldboard plow (25-30) + disk harrow.

T₆= Subsoiler (30-35) + Moldboard plow (25-30) + rototiller.

3.3. Root yield

According to figure 1, there is a significant difference between using subsoiler along with moldboard plow and rototiller (T₆) with 71.50 t ha⁻¹ in comparison with the other treatments. After that, there are two treatments T₂ and T₅ with 67.75 and 66.49 t ha⁻¹ and no significant difference. One of the remarkable points about using the monogerm seed of sugar beet, is suitable seedbed preparation. Using moldboard plow produces the smaller clods and better soil inversion. These are happened in more depth (30-35 cm) than the depth of 20-25 cm. Therefore, the yield of sugar beet is more in the usage of this implement.

The chisel plow with disk harrow and rototiller (T₃ and T₄) produced the lowest amount of yield with 48.75 and 54.12, respectively. Based on the comparison of treatments, the performance of moldboard plow and rototiller were better than chisel plow and disk harrow in production of sugar beet root yield.

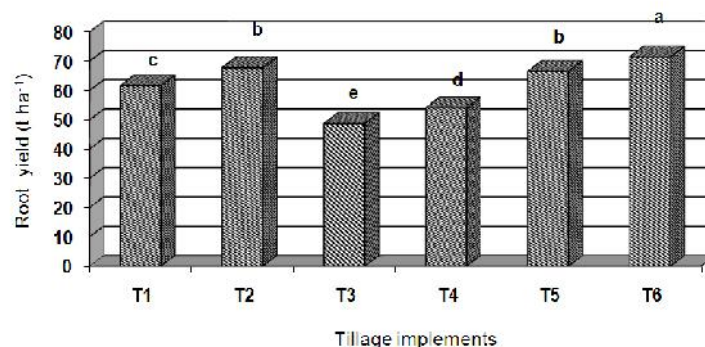


Fig 1. Sugar beet yield in different treatments

Averages with different letters were statistically different at the confidence level of 95%.

T_1 = Moldboard plow (30-35) + disk harrow.

T_2 = Moldboard plow (30-35) + rototiller.

T_3 = Chisel plow (30-35) + disk harrow.

T_4 = Chisel plow (30-35) + rototiller.

T_5 = Subsoiler (30-35) + Moldboard plow (25-30) + disk harrow.

T_6 = Subsoiler (30-35) + Moldboard plow (25-30) + rototiller.

3.4. Quantitative and qualitative yield of sugar beet

Regarding the performance of white sugar yield, treatments showed significant differences at 5% level. The highest yield of white sugar yield (9.6 t ha^{-1}) was related to the use of subsoiler and moldboard plow along with rototiller. The performance of white sugar in the treatment of using subsoiler with moldboard plow and disk harrow (T_5) was 8.82 t ha^{-1} . There was no significant difference in this treatment and subsoiler (30-35) + moldboard plow (25-30) + rototiller (Fig. 2). Also, treatments T_2 and T_5 did not show any significant difference.

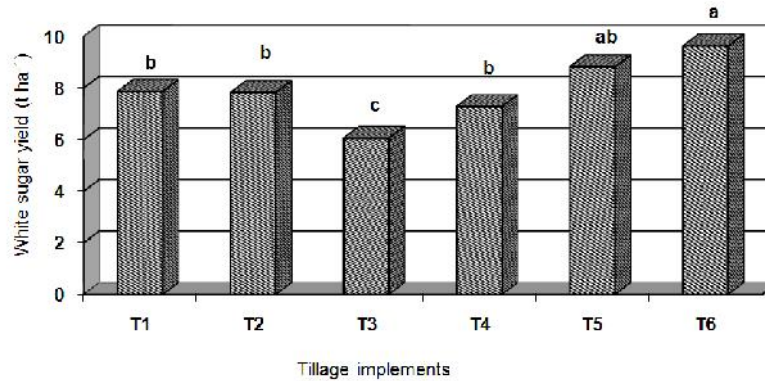


Fig 2. White sugar yield in different treatments

Averages with different letters were statistically different at the confidence level of 95%.

T_1 = Moldboard plow (30-35) + disk harrow.

T_2 = Moldboard plow (30-35) + rototiller.

T_3 = Chisel plow (30-35) + disk harrow.

T_4 = Chisel plow (30-35) + rototiller.

T_5 = Subsoiler (30-35) + Moldboard plow (25-30) + disk harrow.

T_6 = Subsoiler (30-35) + Moldboard plow (25-30) + rototiller.

So, usage of moldboard plow and rototiller affected on preparing suitable seedbed and root growth of sugar beet. In all treatments, relative superiority was observed in the application of moldboard plow than chisel plow and rototiller than tandem disk harrow. There are no significant difference at 5% level in treatments from the point of view sugar content, white sugar content, molasses sugar, purity raw juice and impurities (Na, P and Amino nitrogen) (table 4). The highest amount of purity raw juice was related to applying moldboard plow and rototiller (79.61%). The reduction of molasses sugar in this treatment increased purity raw juice. As seen in the table 4, with increasing in root yield, impurities such as potassium and amino nitrogen enhanced.

Table 4. Qualitative technological analysis of sugar beet

Treatments	Molasses sugar (%)	Impurities (meq.100g beet ⁻¹)			Purity raw juice (%)	White sugar content	Sugar content
		Amino nitrogen	P	Na			
T1	2.98 ^a	1.42 ^a	7.14 ^a	2.16 ^a	77.86 ^a	12.76 ^a	16.31 ^a
T2	2.69 ^a	1.34 ^a	6.86 ^a	1.86 ^a	79.61 ^a	11.54 ^a	16.48 ^a
T3	2.89 ^a	1.49 ^a	7.16 ^a	1.99 ^a	77.76 ^a	12.45 ^a	16.85 ^a
T4	2.89 ^a	1.44 ^a	6.96 ^a	1.87 ^a	79.04 ^a	13.47 ^a	16.89 ^a
T5	2.98 ^a	1.63 ^a	6.99 ^a	2.12 ^a	78.44 ^a	13.27 ^a	16.84 ^a
T6	2.83 ^a	1.66 ^a	7.22 ^a	1.86 ^a	79.27 ^a	13.45 ^a	16.87 ^a

Averages with different letters were statistically different at the confidence level of 95%.

T₁ = Moldboard plow (30-35) + disk harrow.

T₂ = Moldboard plow (30-35) + rototiller.

T₃ = Chisel plow (30-35) + disk harrow.

T₄ = Chisel plow (30-35) + rototiller.

T₅ = Subsoiler (30-35) + Moldboard plow (25-30) + disk harrow.

T₆ = Subsoiler (30-35) + Moldboard plow (25-30) + rototiller.

4. CONCLUSIONS

The following conclusions deduces from this research:

1. For preparing seedbed for sugar beet with monogerm seed, two points are important; first the tillage implements and then the depth of tillage operation.
2. Moldboard plow in the depth of 30-35 cm and rototiller suggests instead of chisel plow and disk harrow in seedbed preparation for sugar beet.
3. By using moldboard plow and rototiller, soil bulk density and soil cone index reduced and seed emergence and seed emergence rate enhanced and eventually sugar beet yield (root yield and white sugar yield) increased.

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