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Effect of subsoiling in condition of strip tillage on soil physical properties and sunflower yield

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This study was carried out to investigate the effect of using subsoiler for strip tillage on some soil physical properties and sunflower yield. The research was carried out in kabootar Abad Research Station (23 km southeast of Isfahan). The experiment was performed using complete randomized block design with 3 replications. The treatments were (T_1): strip tillage + flat planting and (T_2): subsoiling + strip tillage + flat planting. Cone index, Bulk density, infiltration rate, root length, plant height, stem diameter, sunflower head diameter, seed yield, thousand seed weight, plant dry weight and oil content were measured. The results indicated that bulk density and cone index values were not statistically different while water infiltration rate values in subsoiled land significantly were higher than those of unsubsoiled land. It was also found that Subsoiling did not affect sunflower yield, so from economical standpoint it is not recommended to use it in irrigated sunflower production in the area studied. Finally, it is concluded that subsoiling can be used when there is sever plow pan or hard pan within beneath soil layers witch causes to restrict root development.

Key words: sunflower, strip tillage, cone index, bulk density, subsoiler

Introduction

In the Isfahan region, sunflower is planted as a warm season crop after some products like wheat and barely. It is typically planted by the method of planting on flat land manually. According to the previous investigations, increasing irrigation productivity, improving use of water by plant, achieving better establishment of plant as well as preventing formation of big clods in

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condition of dried soil, are some principal challenges for this cultivation in the region.

Farmers in this region usually do not know where annual subsoiling is required in a field and required depth of subsoiling. Soil compaction is the main form of soil degradation, which affects 11% of the land area (Ahmad *et al*., 2007). It can have adverse effects upon plants by increasing field saturated hydraulic conductivity (Iqbal *et al*., 2005; Solhjou and Niazi Ardekani., 2001). Nevertheless high consumption of energy and cost to use subsoiling operation caused researchers to investigate concerning it. In clay soil conditions Shinners (1989) found that a Para plow operating at 1.1 ms−1 required 28 kW at 220 mm depth and 32 kW at 300 mm depth. Increasing the operating depth to 380 and 460 mm meant that the forward speed had to be decreased to 0.94 and 0.89 ms−1, respectively, to keep required power at about 32 kW. Marquéz Delgado (2001) working in different soils (sand and clay) at 300 mm depth, found that engine power increased by an average of 15% from about 26 kW per shank for a curved leg to about 34 kW per shank for a straight leg. Sometimes nevertheless there is very little to gain from tilling deeper than the compacted layer and in some causes it may be detrimental to till into the deep clay layer (Garner *et al*., 1989). Reeder *et al*. (1993) studied the effects of deep tillage on physical properties in silty clay loam and on crop yields. They found that two passes of a tractor re-compacted the soil by the time the first crop was planted. They advised that controlled traffic is essential to obtain long term benefits from subsoiling. Deep tillage increased soybean and corn yields (3.0–6.9% in 1991 and 1.5–3.0% in 1992) in areas not trafficked. Håkansson (1987) found that a disadvantage of subsoiling, even if it did alleviate compaction, was that it often mixed topsoil and humus-free subsoil. This may have a negative effect because high humus in the surface layer seems to be more beneficial than humus incorporated into a deeper layer. Raper *et al*. (1994) compared various cotton tillage systems on a sandy loam complex soil (Typic Hapludults), including annual subsoiling at 0.4 and 0.5 m depth. They found that the positive effects of controlling traffic were significant only when in-row subsoiling was not used as an annual tillage treatment. Considering the typical machinery complement on a farm in Argentina, agricultural soils receive about 20 mg km ha−1 of traffic intensity during seeding operations. This represents 20% of the total traffic of a conventional tillage system and occurs after primary and secondary tillage operations and just at the moment of minimum mechanical stability. In these conditions, machinery causes significant increases in soil compaction (Botta *et al*., 2006). High strengths build up naturally because of low organic matter(Pabin *et al*., 1998); strengths can also be increased by traffic(Busscher *et al*., 2002).Simeonov *et al*. (1984) studied impacts of tillage different systems for sunflower yield. In this investigation, moldboard plow, disk, cultivator, subsoiler and direct drill were used. Results shown that yield had no significant difference between used moldboard plow and used subsoiler treatments. In Romany, too, to increase tillage depth than 20 to 30cm and also to do subsoiling operation after tillage within 40cm depth had no significant effect on sunflower yield (Rusanpovschi *et al*., 1972).

Realizing that the subsoiling operation is expensive and it demands lots of energy, this research aimed to study the impacts of subsoiling on same soil physical properties as well as sunflower yield.

Materials and methods

This study was carried out with two treatments consisting (T_1): strip tillage + flat planting and (T_2): subsoiling + strip tillage + flat planting.

Some specifications of soil and water of experimental site are shown in Table 1. In the treatment having subsoiling operation, 10m length of undisturbed land was subsoiled to maximum depth at a moisture content of 9% w.b. (the average moisture content within 60 cm depth) and its profile was then examined to determine the critical depth (subsoiler working depth). Working depth of subsoiler less than determined critical depth was specified. Summary of the subsoiled land investigations are presented in Table 2. For strip tillage, subsoiler was used so that subsoiling depth was set in 20cm depth and in location of planting rows tillage practice was then done. Distance between strips was 60cm namely equal to distance between planting rows. In this situation, rupture width in soil surface was found to be 30-35cm. Fertilizer amounts were supplied based on soil fertilizer test in such a way 70kg/ha ammonium phosphate at time of tillage practice and 150kg/ha N fertilizer as dressing at 5 leaf stage before maturing grain were added.

Dimensions of each plot were considered as 3.5×20 m. The experimental design was planned as randomized complete block design in three replicates. After seedbed preparation in each plot 4 rows of sunflower seed was manually established with 60cm interval. Thinning operation was done after seed emergence so that plant interval was set to 20cm over each row. Hysun33 seed according to the region cropping pattern was used.

Water amount needed to each plot was calculated according to farshi *et al*. (1997) and by means of parshal flum, weir as well as time measurement was provided to each plot. Irrigation revolution was determined 10 days based on irrigation common in the examined region. Two soil samples per replicate were collected randomly from the 0-10, 10-20, 20-30, 30-40 and 40-50 layers of the soil for laboratory using 100mm×70mm cylindrical cores. Soil bulk density was determined from oven dried undisturbed cores as mass per volume of oven dried soil. Soil penetration resistance was measured from each plot in ten replications using a hand-held cone penetrometer till 50 cm depth. This penetrometer had a circular cone with an apex angle of 30° and base diameter of 12.83cm.This operation was done after first irrigation at reaching soil moisture content to 80-90% of field capacity.

In order to soil infiltration rate measurement and subsoiling impacts on it, dual rings method was used. For this purpose, before irrigation in three locations of both subsoiled and striply tilled plots, rings were installed and filled with water to predetermined level. Water heed loss after 150min was recorded.

Table 1. Some of soil and water characteristics in investigation station of Kabootar Abad.

Region	Soil texture	Average bulk density within 60cm depth (kg/m^3)	Moisture content in Field capacity (%)	Moisture content in Permanent depressing point (%)	Water EC (d.s/m)
Kabootar Abad	clay loam	1.41	23	12.5	2.23

Table 2. Some of soil characteristics after subsoiling.

Experiment place	Critical depth (cm)	Interruption width on soil surface (cm)	Interruption width up critical depth (cm)	Average moisture content within 60 cm depth (%)
Kabootar Abad	45	60	53.5	9

Mean of latest records in which infiltration rate was nearly constant were considered as base infiltration rate. In seed maturation stage two rows with length of 2 m in the middle of each plot were harvested ignoring lateral rows and sunflower heads were then threshed and seeds separated, after clearing were weighed.

Therefore yield parameters such as thousand seed weight, plant height, stem diameter, sunflower head diameter and plant dry weight were assigned. Of harvested seeds randomly samples were selected and oil content was determined by using sukcele method. In this method 2 gr of sunflower seed was accurately weighed and dried for 3 hours in on electrical dryer and was then milled. Sample prepared with 100ml of diethyl ether in a balloon for 6-8 hours was mildly heated. Oil solved in diethyl ether was remained of diethyl ether evaporation. The ration of oil weight to weight of sunflower seeds is denoted to oil content of seed .in order to root length measurement, 10 plant were eradicated from each plot and root length then measured.

Data collected were subjected to statistical analysis applying analysis of variance (ANOVA). The Student-t test based on paired observations was used to determine significant effects of two tillage treatments at a 5% level.

Results and discussion

In this study, effect of subsoiling on some soil properties and sunflower yield parameters was assessed.

Soil penetration resistance

Comparison of means related to soil penetration resistance is shown in Table 3. As can be seen from this table, no significant difference was found between cone index values within different treatments. Although subsoiling generally declines soil cone index, but this approach could not decrease the penetration resistance to less than 2 MPa within 35-45 depth. Then, it is essential that subsoiling operation can be done after strip tillage operation because tractor traffic after subsoiling can cause soil compaction (Reeder *et al*., 1993; Raper *et al*., 1994; and Botta *et al*., 2006). In a study, effect of subsoiling operation within 30-35 and 40-45 depths on soil cone index was investigated by Solhjoo and Niazi Ardekani (2001). They reported that there was no significant difference between subsoiled and unsubsoiled treatments.

Bulk density

The treatments, there was no marked difference between bulk density values as shown in Table 4. Frequent traffic of equipment, in order to crush the clods caused by subsoiling operation, had declined the suitable conditions for soil bulk density decrease in spite of subsoiling operation can increase soil porosity and decrease the compacted soil bulk density up to 3-4%. Similar results with what obtained in the current study were reported by Solhjoo and Niazi Ardekani (2001) who suggested that there was no significant difference in soil bulk density values between undisturbed soil and soil plowed to 20-25cm depth. It seems that impact of tillage practices as well as subsoiling on soil bulk density is mitigated with machineries traffics in secondary tillage (Reeder *et al*., 1993; Raper *et al*., 1994; and Botta *et al*., 2006). Note that rupturing the soil layers especially beneath plow pan can cause soil increase and result in relative decrease of soil bulk density. Eskandari & Hemmat (2003) reported that subsoiling operation in depth higher than 30 cm with 50 and 70 cm shank distances would significantly decrease soil bulk density.

Water infiltration rate

Based on the statistical analyses, infiltration rate in subsoiled land significantly is higher than that of unsubsoiled land (Fig 1). Subsoiling operation was found to improve the soil infiltration rate. Because use of subsoiler cause the hard pan to be ruptured and fit facilitates water infiltration rate which obtained 1.7-fold in subsoiled land compared to unsubsoiled land. This magnitude was reported by Solhjoo and Niazi Ardekani (2001) around 2.4.

Plant characteristics

Comparison of means of plant characteristics such as root length, plant height, stem diameter, sunflower head diameter, seed yield, thousand seed weight, plant dry weigh, and oil content are shown in table 5 & 6. Considering these tables, in all parameters, no significant difference was found between the treatments. Although subsoiling can help root distribution and improve root absorption but it had no marked effect on root length as well as other parameters of yield. It can be concluded that in irrigated cropping system, in which plant don't subject to stress, impact of subsoiling on soil moisture saving is not considerable, consequently such operation is not recommended in the examined circumstances. Similar results with what obtained in the current study were reported by Rusanpovschi *et al*. (1972) and Simeonov *et al*. (1984). Subsoiling can be used when there is sever plow pan or hard pan within beneath soil layers witch causes to restrict root development.

Table 3. Mean comparison of soil penetration resistance in the studied treatments.

Treatment	Soil depth(cm)									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
T_1	0.27a	0.57a	0.46a	0.43a	0.64a	1.10a	1.92a	2.62a	3.23a	3.61a
T_2	0.25a	0.51a	0.46a	0.48a	0.57a	1.05a	1.98a	2.43a	3.12a	3.51a

The means with minimum common letter are not significantly different ($P<0.05$) according to Student-t test.
Average soil moisture content within 50cm depth was about 19% when soil penetration resistance was measured.

Table 4. Mean comparison of soil bulk density in the studied treatments.

Treatment	Soil depth(cm)				
	0-10	10-20	20-30	30-40	40-50
T_1	1.23a	1.35a	1.51a	1.49a	1.47a
T_2	1.23a	1.43a	1.53a	1.49a	1.47a

The means with minimum common letter are not significantly different ($P<0.05$) according to Student-t test.

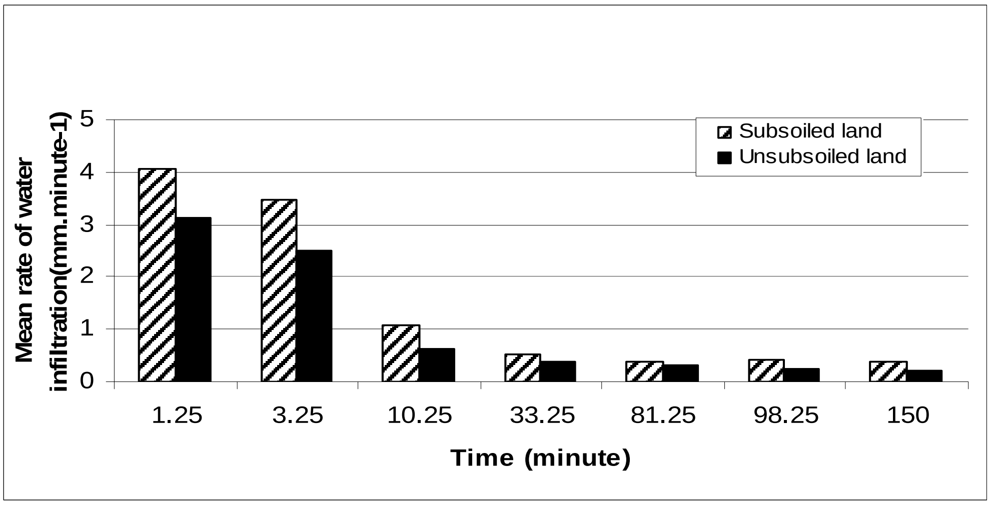

Fig. 1. Water infiltration rate**.**

Table 5. Mean comparison of sunflower plant parameters in the studied treatments.

Treatment	Root length (cm)	Plant high (cm)	Stem diameter (mm)	Head diameter (cm)
T_1	21.79a	179.05a	18.41a	13.56a
T_2	25.30a	182.56a	18.37a	13.65a

The means with minimum common letter are not significantly different ($P<0.05$) according to Student-t test.

Table 6. Mean comparison of sunflower yield parameters in the studied treatments.

Treatment	**Seed yield (kg/ha)**	**thousand seed weight (gr)**	**plant dry weigh (gr/m^2)**	**oil content (%)**
T_1	3776a	48.43a	1127a	38.84a
T_2	3664a	47.56a	1139a	39.37a

The means with minimum common letter are not significantly different ($P<0.05$) according to Student-t test.
Moisture content of sunflower seed was 9% when seed yield, thousand seed weigh and seed oil rate was measured.

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