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Effect of subsoiling on soil physical properties and sunflower yield under conditions of conventional tillage

M. Heidari Soltanabadi[1], *M. Miranzadeh*[1], *M. Karimi*[2]*, *M.Ghasemi Varnamkhasti*[2], *and A. Hemmat*[3]

[1]Agricultural and Natural Resources Research Center of Isfahan, Iran
[2]Department of Agricultural Machinery Engineering, Faculty of Biosystems Engineering, University of Tehran, Karaj, Iran
[3]Department of Farm Machinery, College of Agriculture, Isfahan University of Technology, Isfahan 84156, Iran

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A b s t r a c t. This study was carried out to investigate the effect of using a subsoiler for conventional tillage on some soil physical properties and sunflower yield. The research was carried out in the Kabootarabad Research Station (23 km south-east of Isfahan). The experiment was performed using randomised complete block design with 3 replications. The treatments were (T_1): conventional tillage + flat planting, and (T_2): subsoiling + conventional tillage + flat planting. Cone index, bulk density, infiltration rate, root length, plant height, stem diameter, sunflower head diameter, seed yield, thousand seed mass, plant dry mass 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 were significantly 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 plough pan or hard pan within underlying soil layers which causes restricted root development.

K e y w o r d s: sunflower, conventional tillage, cone index, bulk density, subsoiler

INTRODUCTION

In the Isfahan region, sunflower is planted as a warm season crop after some other crops like wheat and barely. It is typically planted by the method of planting on flat land manually. According to 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 the conditions 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, nor the 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 of using the subsoiling operation causes researchers to conduct relevant investigations. In clay soil conditions Shinners (1989) found that a Para plough operation at 1.1 m s^{-1} requires 28 kW at 22 cm depth and 32 kW at 30 cm depth. Increasing the working depth to 38 and 46 cm meant that the forward speed had to be decreased to 0.94 and 0.89 m s^{-1}, respectively, to keep the required power at about 32 kW. Sometimes, nevertheless, there is very little to gain from tilling deeper than the compacted layer and in some cases 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 soil 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 (3-6.9% in 1991 and 1.5-3% in 1992) in areas not trafficked. It has been stated 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

*Corresponding author's e-mail: mahm.karimi@gmail.com

at 40 and 50 cm 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. 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). In Romania, increasing tillage depth from 20 to 30 cm and also performing the subsoiling operation after tillage within 40 cm depth had no significant effect on sunflower yield (Rusanovski *et al*., 1972).

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

MATERIAL AND METHODS

This study was carried out with two treatments as follows, (T_1): conventional tillage + flat planting, and (T_2): subsoiling + conventional tillage + flat planting.

The investigated soil was derived of clay loam. The average bulk density within 60 cm depth was 1.41 g cm^{-3}. Moisture content at field capacity was 23% w.b. and at permanent wilting point was 12.5% w.b. Water electrical conductivity was 2.23 d S m^{-1}. In the treatment having the subsoiling operation, 10 m length of undisturbed land was subsoiled to maximum depth at a moisture content of 9% w.b. (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 the determined critical depth was specified. Soil characteristics after subsoiling were: critical depth – 45 cm, interruption width on soil surface – 60 cm, interruption width up critical depth – 53.5 cm, average moisture content within 60 cm depth – 9% w.b. In both treatments, mouldboard ploughing within 20-25 cm soil depth was performed at a moisture content of 8.5% w.b. (average moisture content within 25 cm depth). Tillage practices done and equipment specifications are shown in Table 1. In this study, a tractor (MF 399 Tabrize Manufacture, Iran) of total mass of 3 317 kg was used. Fertilizer amounts were supplied based on soil fertilizer test in such a way that 70 kg ha^{-1} ammonium phosphate at time of tillage practice and 150 kg ha^{-1} N fertilizer as dressing at 5 leaf stage before grain maturing were added.

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

Water amount needed for each plot was calculated according to Farshi *et al*. (1997) and by means of Parshal flume, weir as well as tine measurement was provided to each plot. Irrigation revolution was determined at 10 days, based on the irrigation common in the examined region. For laboratory testing, two soil samples per replicate were collected randomly from the 0-10, 10-20, 20-30, 30-40 and 40-50 cm layers of the soil, using 100 mm × 70 mm 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. The penetrometer had a circular cone with an apex angle of 30° and base diameter of 12.83 cm. This operation was done after the first irrigation, at reaching soil moisture content to 80-90% of field capacity.

In order to measure the soil infiltration rate and to determine subsoiling impacts on it, the dual rings method was used. For this purpose, before irrigation, in three locations of both subsoiled and commonly tilled plots, rings were installed and filled with water to a predetermined level. Water head loss after 150 min was recorded. 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, and after clearing they were weighed. Thereafter, yield parameters such as thousand seed mass, plant height, stem diameter, sunflower head diameter and plant dry mass were assigned. Of the harvested seeds,

T a b l e 1. Some specifications of implements produced by Khorasan Ahangaran Comp. used in the study

Implement	Treatment	Working width (cm)	Descriptions
Subsoiler	T_2	60	Mounted, single shank,
Moldboard plow	T_1, T_2	120	Mounted, triple shanks, working width: 39 cm
Disk	T_1, T_2	241	Mounted, Tandem, number of disk: 28, disk diameter: 46 cm
Leveler	T_1, T_2	300	Working width: 300 cm
Ridger	T_1, T_2	130	Mounted, furrow distance: 60 cm

T a b l e 2. Comparison of mean values of soil penetration resistance (MPa) 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	0.45a	0.41a	0.54a	0.89a	1.71a	2.46a	2.96a	3.27a	3.45a
T_2	0.28a	0.41a	0.34a	0.37a	0.72a	1.76a	2.27a	2.66a	2.93a	3.19a

The means with minimum common letter are not significantly different (P<0.05) according to Duncan's multiple ranges test. Average soil moisture content within 50 cm depth was about 19% when soil penetration resistance was measured.

T a b l e 3. Comparison of mean values of soil bulk density (g cm^{-3}) in the studied treatments

Treatment	Soil depth (cm)				
	0-10	10-20	20-30	30-40	40-50
T_1	1.23a	1.37a	1.38a	1.51a	1.47a
T_2	1.27a	1.34a	1.60a	1.44a	1.50a

Explanations as in Table 2.

random samples were selected and oil content was determined by using the Sukcele method. In this method, 2 g of sunflower seed was accurately weighed and dried for 3 h in an electrical dryer and then milled. Sample prepared with 100 ml of diethyl ether in a balloon for 6-8 h was mildly heated. Oil solved in diethyl ether remained after diethyl ether evaporation. The ratio of oil mass to mass of sunflower seeds was denoted as oil content of the seed. In order to measure root length, 10 plants were eradicated from each plot and root length was then measured.

Statistical analysis was done applying the analysis of variance. The F test was used to determine significant effects of tillage treatment, and the Duncan multiple range test was used to separate means at a 5% level of significance.

RESULTS AND DISCUSSION

Comparison of means related to soil penetration resistance is shown in Table 2. As can be seen from this Table, no significant difference was found among cone index values within different treatments. Although subsoiling generally declines soil cone index, 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 mouldboard ploughing, because tractor traffic after subsoiling can cause soil compaction (Botta *et al*., 2006; Raper *et al*., 1994; Reeder *et al*., 1993). In a study, the effect of subsoiling operation within 30-35 and 40-45 depths on soil cone index was investigated by Solhjou and Niazi Ardekani (2001). They reported that there was no significant difference between subsoiled and unsubsoiled treatments.

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

Comparison of means of plant characteristics such as root length, plant height, stem diameter, sunflower head diameter, seed yield, thousand seed mass, plant dry mass, and oil content are shown in Tables 4 and 5. Considering these Tables, in all the parameters no significant difference was found between the treatments. Although subsoiling can help root distribution and improve root absorption, 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 plants are not subjected to stress, the impact of

T a b l e 4. Comparison of mean values of sunflower plant parameters in the studied treatments

Treatment	Root length	Plant high	Stem diameter	Head diameter
	(cm)			
T_1	21.45a	178.13a	1.75a	13.30a
T_2	23.50a	177.01a	1.73a	13.03a

Explanations as in Table 2.

T a b l e 5. Comparison of mean sunflower yield parameters in the studied treatments

Treatment	Seed yield ($kg\ ha^{-1}$)	Thousand seed mass (g)	Plant dry mass ($g\ m^{-2}$)	Oil content (%)
T_1	4392a	48.46a	1325a	40.60a
T_2	4050a	45.20a	1212a	37.88a

Moisture content of sunflower seed was 9% when seed yield, thousand seed mass and seed oil rate was measured. Other explanations as in Table 2.

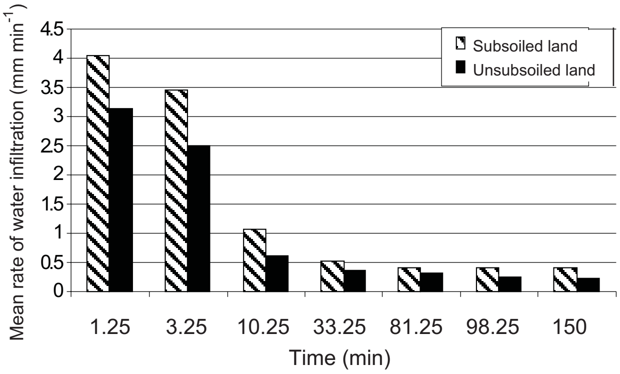

Fig. 1. Changes of water infiltration rate in time.

subsoiling on soil moisture saving is not considerable, consequently such operation is not recommended in the examined circumstances. Similar results to those obtained in the current study were reported by Rusanovski *et al.* (1972). Subsoiling can be used when there is sever plough pan or hard pan within the underlying soil layers, which causes restricted root development.

Based on the statistical analyses, infiltration rate in subsoiled land is significantly higher than that of conventional ploughing (Fig. 1). Subsoiling operation was found to improve the soil infiltration rate. Because the use of subsoiler causes the hard pan to be ruptured, it 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) as around 2.4.

CONCLUSIONS

1. No significant difference was found among cone index values within different treatments.
2. There was no marked difference among bulk density values.
3. Infiltration rate in subsoiled land is significantly higher than that of conventional ploughing.
4. In all the parameters no significant difference was found between the treatments.
5. Although subsoiling can help root distribution and improve root absorption, it had no marked effect on root length as well as other parameters of yield.
6. It can be concluded that in irrigated cropping system, in which plants are not subjected to stress, the impact of subsoiling on soil moisture saving is not considerable, consequently such operation is not recommended in the examined circumstances.

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