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Short Communication

Effect of Subsoiling on Soil Bulk Density, Penetration Resistance, and Cotton Yield in Northwest of Iran

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ABSTRACT

Cotton is highly susceptible to soil compaction. Subsoiling affectively alleviates compaction and recovers soil productivity. A study was conducted to evaluate the effect of subsoiling on soil physical properties as bulk density and penetration resistance as well as cotton yield. Three soil tillage treatments viz S_0: moldboard plow (conventional tillage), S_1: 30-35 cm subsoiling followed by moldboard plow, and S_2: 50-55 cm subsoiling followed by moldboard plow were randomized in complete block design with four replicates. Results indicated that subsoiling created significant effect on percentage of cone penetration decrease within depths of 10-20 and 20-50 cm ($P<0.01$). Highest average plant height was associated with 50-55 cm subsoiling treatments. Subsoiling resulted in yield increase within 9.7-13.5% and led to improvement of the soil physical properties.

Key Words: Cotton; Subsoiling; Tillage; Penetration resistance; Bulk density; Lint yield; Soil properties; Moghan region

INTRODUCTION

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), mechanical impedance to the growth of roots, altering the extent and configuration of the pore space (Tardieu, 1994). Soil compaction is also reported to aggravate root diseases by decreasing drainage and thus providing more favorable soil water conditions for early infection roots (Allmaras *et al.,* 1998). Associated with these changes are increased bulk density and soil resistance. In compacted layer, water, nutrients and airflow towards the plant roots are also restricted. These restrictions may reduce the crop growth and yield.

Cotton (*Gossypium hirsutum* L.) plants grow poorly when their roots are in soils of high strength. Lowry *et al.* (1970) concluded that reduced plant height and yield were associated with increased bulk density and penetration resistance (PR) and shallow hard pans. They linked the effects to an insufficient water supply due to limited rooting volume. In fields soil compaction as a problem, subsoiling (also called ripping, chiseling & aerating) has been found to help alleviate its negative influences. Subsoiling in severely compacted soil reduces soil resistance and provides increased rooting depth that helps plants withstand short-term drought conditions (Raper *et al*., 1998).

Taylor and Brar (1991) found no direct effect of soil compactness on root development. But they found its indirect effect on soil physical properties such as porosity, volumetric water content, soil hydraulic conductivity and gaseous diffusion of the soil. According to these authors root development is altered by changes in soil compactness and plant growth above the ground may be normal if the plant gets sufficient water and nutrients.

Akinci *et al*. (2004) reported that two-passes of subsoiling operation were more effective than subsoiling with one-pass for not only overcoming the soil compaction but also improving the soil physical characteristics. However, subsoiling treatments did not affect cotton yield in intensive and fully irrigated field conditions. A similar phenomenon was reported by Radford *et al.* (2000) for wheat and Raper *et al.* (2000a) for cotton. Present work was carried out to investigate the effect of subsoiling in 30-35 and 50-55 cm soil depths followed by moldboard plow compared with conventional soil tillage (use of moldboard plow) on both soil physical properties and cotton productivity.

MATERIALS AND METHODS

An experiment was conducted in Agricultural Research Field of Moghan located in Northwest of Iran (longitude: $47^o 23' - 42^o 39'$ N, latitude: $47^o 25' - 48^o 23'$ E). Environmental conditions of the region for the period of experiments and basic soil physical characteristics of the experimental cite are shown in Tables I and II. Three tillage treatments viz. moldboard plow (S_0), 30-35 cm deep

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Table I. Meteorological data of experimental site in Moghan during six months in 2006

Month	Temperature (°C)			Relative humidity (%)			Rainfall (mm)	Wind speed (m s^{-1})
	Min	Max	Mean	Min	Max	Mean		
April	4.4	14.8	10.5	54	94	73	44.2	3.11
May	12.7	24.3	18.5	52	92	72	44.4	3.6
June	17.1	30.8	24	41	85	63	1.8	4.3
July	20.4	32.7	26.6	40	82	61	1.5	4.1
August	22.2	34.6	28.4	43	82	69	0.7	4.5
September	18.4	28.9	23.7	47	88	67	3.2	3.6
October	14.3	23.2	18.7	57	92	74	7.9	2.2

Table II. Soil characteristics of the experimental field

Depth (cm)	Acidity of saturated soil (PH)	Hydraulic conductivity	Carbon (%)	Clay (%)	Silt (%)	Sand (%)	Soil texture
0-27	7.4	1	0.98	61	29	10	Clay
27-70	8.2	1.3	0.37	63	27	10	Clay
70-95	7.9	3.4	0.3	59	29	12	Clay

subsoiling followed by moldboard plow (S_1), and 50-55 cm deep subsoiling followed by moldboard plow (S_2) were employed to evaluate their comparative influence on crop yield, soil cone index and bulk density. Experiments consisted of 12 plots (3 treatments in four replications) with dimension of 30 m in length and 5 m in width each and organized as randomly complete block design. A heavy duty tractor 4560JD with the engine power of 103 kw was used for draft power needed to run subsoiler (manufactured by Khorasan Ahangari), with 3 shanks (L configuration), working width of 2.49 m, tool spacing of 0.83 m and having 2 depth adjusting wheels.

During October 2005, the field soil was sampled at a moisture content of 14.5% (the average moisture content of 60 cm depth) and subsoiling operation were carried out to achieve working depths of 30-35 and 50-55 cm for S_1 and S_2 treatments, respectively. The experiments were followed by moldboard plowing within 20-25 cm as depth per treatment. Secondary practices as two-pass disk harrow for uniform incorporation of distributed fertilizer and herbicide across the field for all treatments followed by leveling were accomplished. Seedbed preparation for sowing was also reached satisfactorily. During May 2006, cotton seeds were sown in 4 cm depth as row crop planting in 20×80 cm. In each treatment, soil cone index, bulk density, soil moisture content, lint yield and plant height were either measured or calculated. Soil penetration resistance was measured two times from each plot in three replications using a mechanical penetrometer up to 60 cm depth. This penetrometer has a circular cone with an apex angle of 30° and base diameter of 10 mm. For bulk density, undisturbed soil samples were taken by sampling cylinders of 100 cm^3 volume by Kopecky method at soil layers 0-20, 20-40 and 40-60 cm in three replicates from each plot.

The procedures stated above were carried out both before soil tillage operations and after tillage practice followed by irrigating the field. Four central rows in each plot were harvested to record lint yield. Prior to harvesting, 10 plants from each of the considered rows were randomly selected and plant height was determined. Data collected were subjected to statistical analysis applying analysis of variance (ANOVA). The F test was used to determine significant effects of three tillage treatments and the Duncan's multiple ranges test was used to separate means at a 5% level of significance.

RESULTS AND DISCUSSION

Penetration resistance or cone index (the insertion force divided by the cross-sectional area of the base of the cone) prior to tillage practices was within 0.68-2.69 MPa (Fig. 1). The ability of plant roots to penetrate soil is restricted as soil strength increases (Mason *et al.*, 1988) and ceases entirely at 2.5 MPa (Taylor, 1971). The inability of plant roots to penetrate compacted soil is reported elsewhere (Venezia *et al*., 1995; Laker, 2001). As the pressures exceeded 2 MPa root growth has been shown to be restricted to varying degrees (Aase *et al.*, 2001). 2 MPa was, therefore, considered as a measure in determination of soil hard pan layer and critical limit of penetration resistance restraining root distribution is within 40-50 cm soil depth and that subsoiling can reduce and provide increased rooting depth (Raper *et al*., 1998).

Percentage of penetration decrease did not vary within 0-10 cm depth. It was attributed to the fact that moldboard plow was used in all the plots. Percentage of penetration decrease associated with 10-50 depth was significant. Soil compaction increased from 30 to 40 cm depth and it finally reached to critical value within 40-50 cm depth (Fig. 1). No employment of subsoiler as well as continued use of moldboard plow led to increased soil resistance especially beneath plow pan; therefore necessitating use of subsoiler or any other implement. Mean comparison of percentage of soil resistance decrease are shown in Table III. The effect of tillage methods were also assessed within 0-60 cm soil depth. Results indicated that the highest percentage of penetration decrease was attributable to S_1 (38.37%) and S_2 (43.25%) the lowest one was in S_0 (24.62%). Subsoling increased favoring root distribution. Several authors (Sojka *et al.*, 1997; Raper *et al.*, 1998; Radford *et al.*, 2000; Raper *et al.*, 2000a) suggested that subsoiling severely compacted soil reduced soil resistance and provided increased rooting

Table III. Mean comparison of cone index decrease in different soil depth prior to subsoiling compared to after subsoiling operation

Treatment	0-10	10-20	20-30	30-40	40-50	50-60
S0	23.86ab	24.05b	11.24b	19.37	22.50b	44.17b
S1	31.03a	32.82a	37.07a	41.03b	40.77a	47.50ab
S2	21.51b	34.38a	40.13a	51.12a	55.89a	56.45a

The means with minimum common letter are not significantly different (P<0.05) according to Duncan's multiple ranges test

Table IV. Mean comparison of cotton performance parameters in the studied treatments

Subsoiling treatment	Cotton yield (ton ha^{-1})	Plant height (cm)
No subsoiling	3.63b	74.95b
Sunsoiling (35 cm)	4.18a	84.27a
Subsoiling (55 cm)	4.02a	86.27a

The means with minimum common letter are not significantly different (P<0.05) according to Duncan's multiple ranges test

depth that helped plants withstand short-term drought. No significant differences were observed for S_1 and S_2 within 40-50 cm depth (Table III) showing subsoiling depth did not influence percentage of penetration decrease that might be attributed to depth ranges.

Prior to tillage practices, the average bulk density values at soil layers of 0-20, 20-40, and 40-60 cm were 1.24, 1.48 and 1.65 g cm^{-1} respectively. The highest decrease in bulk density was observed in subsoiling treatments, while the least one was in conventional tillage (Fig. 2). Working depth did not create significant effect on soil bulk density. Bulk density decreased in subsoiling treatments compared to conventional tillage in 20-40 cm depth range showing compacted soil layer in this depth range. This observation is in close agreement with the results obtained on penetration resistance. Evans *et al.* (1996) reported that subsoiling performed in year 1 had a significant effect on soil bulk density and soil moisture content, while in later year, was not found marked influence on the latter parameters.

Subsoiling showed significant effect (P<0.01) on plant height that was attributed to moisture content available for plant growth. Subsoiling in 55 and 35 depth produced to 4.02 and 4.18 t ha^{-1} lint yield, respectively (Table IV) that was non-significant difference. The lowest cotton yield (3.63 t ha^{-1}) was recorded for S_0 treatment .Subsoiling had a marked effect on cotton yield but its depth has not significant effect on the yield. Subsoiling at depths greater than necessary requires significant additional tillage energy and may reduce crop yields, while covering excessive amounts of crop residue remaining on the soil surface. Also, loosening the soil to greater depths than necessary can promote future deeper compaction resulting from vehicle traffic (Raper, 2005). Considering the latter fact, subsoiling till 35 cm is preferred. Raper *et al.* (2000a & b) found that targeted depths of subsoiling in clay loam to the depth of compaction resulted in optimum yields, while deeper depths of subsoiling resulted in reduced yields. Percentage of yield increase in both subsoiling treatments in comparison to the

Fig. 1. Soil penetration resistance before subsoiling operation

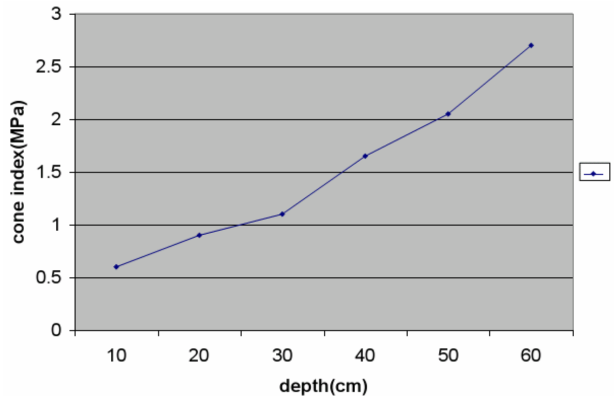
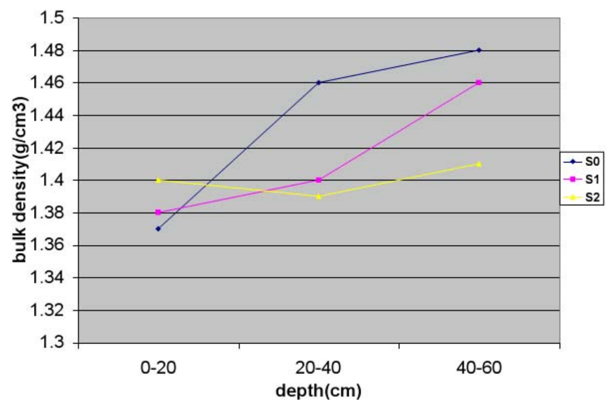


Fig. 2. Average bulk density values of the soil after subsoiling operation



conventional tillage was 9.7 and 13.5%, respectively (Table IV). It may be concluded that compaction affects plant growth and development most when there are no other limiting factors, such as soil water and nutrients. This agrees with findings of Bicki and Siemens (1990) and Schuler and Wood (1992). Clark *et al.* (1993) concluded that in moderately or severely eroded soils, subsoiling 30 cm deep should be done annually, even with precision traffic, to ensure minimizing the effect of soil compaction on crop growth.

It can be concluded that subsoiling not only increased cotton yield but also improved soil physical conditions such as bulk density and penetration resistance that such circumstances ensure convenient root propagation as well as more root aeration.

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