Subsoiler and its Effects on Soil Physical Conditions

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Abstract
Soil compaction has adverse effects on soil physical properties and hence on crop yield. It hinders crop root development, increases soil resistance and bulk density, and decreases pore space size and volume and finally infiltration rate of water into soil. Subsoilers are used primarily to break through and shatter the deep compacted layers.

Field experiments were conducted to evaluate the effects of using conventional subsoiler on soil physical properties as bulk density, cone index and water infiltration rate in Fars Agricultural Research Center. The texture of soil was clay loam with the moisture content of 10% dry basis in the working depth of 35 cm.

Results showed that subsoiling broke hard pan and plow pan successfully and caused reduction in the bulk density and soil cone index and increased the basic intake rate. But after heavy irrigation many of pore space will be closed and bad management in tillage causes making hard layer again. So the stability of suitable conditions depends on soil texture and good management.

Keyword: Subsoiler, Property, Bulk density, Infiltration, Penetration

Introduction
Soils are subsoiled to fracture the compacted layers in order to increase water infiltration and root growth for various crops. Engineering research has shown that plowing does not always return compacted topsoil to its original state. The most common variables used to assess soil strength in tillage studies are bulk density and penetrometer resistance. They are interrelated and the use of only one of these variables may lead to misleading results (Campbell and Henshall, 1991). Buader et al., (1981) investigated the effect of four continuous tillage systems on mechanical impedance of clay loam soil. They reported that increases in bulk density are correlated with increases in penetration resistance. Veihmeyer and Hendrickson (1948) reported that soil compaction reduces root growth. Such soil conditions can decrease crop yields, a result, which is certainly undesirable to farmers. Gameda et al., (1985) also found that plowing did not improve bulk density in the topsoil. On clay soil the bulk density in compacted plots was about 25% higher than in control plots. Even after plowing, the bulk density was still 10 to 12% higher. Farmers want to be productive by enhancing plant growth and maximizing yields. Philips and Kirkland (1962) and Morris (1975) reported that corn yield reduction was about 10 to 22 percent due to compaction. For each 1 kg/m³ increase in bulk density, a decrease in maize grain yields was 18% relative to the yield on a non-compactcd plot (Canarache et al., 1984). Increased soil compaction can reduce yields of potatoes up to 22 percent (Saini and Lantagne, 1974) and decrease wheat growth (Feldman and Domier, 1970). These results illustrate the potential for compaction to depress crop yields. Extremely dense soil impedes root growth and thereby limits water consumption of plants. Thus soil compaction must be managed in order to keep its detrimental effects to a minimum. The level of compaction which requires tillage for a given soil type is not well understood. No generally accepted rule of thumb is which states that certain bulk density or penetration strength limits plant productivity. However, some studies have been conducted which address these two parameters in predicting detrimental effects to plant growth. Bowen (1981) suggested a general rule
(with many exceptions) that bulk density measurements of 1.55, 1.65, 1.80 and 1.85 Mg/m$^3$ can impede root growth and thus will reduce crop yields on clay loams, silt loams, fine sandy loams, and loamy fine sands, respectively. Bulk density greater than 1.2 Mg/m$^3$ for clay soil, 1.6 Mg/m$^3$ for loam soil and 1.8 Mg/m$^3$ for sandy loam adversely affected the root growth of rice (Kar et al., 1976). Singh et al., (1992) proposed a bulk density less than or equal to 1.3 Mg/m$^3$ in any soil as non-limiting to crop growth. However Singh et al., (1992) stated that due to the lack of research literature, the maximum value of bulk density, which may be considered unusable by plants, is 2.1 Mg/m$^3$ in any type of soil. Subsoilers are used primarily to break through and shatter the deep compacted layers (Al-Adawi et al., 1996 and Black et al., 1986).

Soil strength is an indicator of how easily roots can penetrate soil. Cone index is a measure of soil strength and is measured using a Penetrometer. The magnitude of mechanical impedance to root penetration, which decreases plant growth, is also unknown. Penetration resistance will be increased with depth due to the increase in shaft friction. Yasin et al., (1993) found a cubic relationship between cone index and depth. Penetrometer values greater than 2MPa are generally reported to produce a significant root growth reduction (Atwell, 1993). Ehlers et al., (1983) stated that the Penetrometer resistance limiting to oats was 3.6MPa in tilled at horizon, but 4.6 to 5.1MPa in the untilled and in the subsoil. The limiting penetrometer resistance depends upon soil conditions and characteristics and the crop of interest. Ayers and Perumpral (1982) pointed out that dry density had a considerable influence on cone index at low moisture contents for soils containing a certain percentage of clay. Cone index became less dependent on dry density at higher moisture contents. Sojka et al., (1990) studied the effect of penetrometer resistance on sunflowers. A soil strength corresponding to a penetrometer resistance of 2MPa produces some root restriction and a resistance of 3MPa creates a total barrier to root elongation. A maximum root growth pressure for citrus is 1.5MPa. Murdock et al., (1995) suggested a penetrometer reading of 2.07MPa (300psi) as indicative of severe compaction for Kentucky soils. A penetrometer measurement of 2MPa generally regarded as sufficient to hinder the growth and development of crops. However, precise cone index levels, which limit plant growth for specific soil types, have been rarely documented. Schonning and Rasmussen (1987) subsoiled parts of their plots three years after compaction. On the sandy soil subsoiling significantly improved the penetration resistance from about 30 to 45 cm deep. However, subsoiling did not change cone penetrometer results on the sandy loam soil. The subsoiling prior to the fourth year did not affect yields in either soil, probably because yields in the compacted plots had already recovered to equal the control plots. Subsoilers are used to reduce soil cone penetration less than 2Mpa (Goddard et al., 1991).

Hakansson (1987) state that a disadvantage of subsoiling, even if it did alleviate compaction, is that the mixing of topsoil and humus-free subsoil may have a negative effect because high humus content in the surface layer seems to be more beneficial than humus incorporated into a deeper layer. A survey by Goddard et al., (1991) disclosed that soil amelioration by deep tilling improves water infiltration and often increases yield. Some of the interest is due to the reduction in pounding and run-off during the spring snowmelt. The ratio of depth to width of shank for critical depth should be considered. The critical depth is the depth of operation at which soil ceases to fail upward (crescent failure) and lateral failure starts to fail around the tool (Godwin and Spoor 1977). Subsoiler shank should work above of critical depth.
Materials and Methods
The study was conducted at the Fars Agricultural Research Center, located 35 km north of Shiraz, Iran. Soil texture for the entire depth (0-50 cm) was clay loam and moderately compacted. Soil bulk density varied from 1200 to 1600 g/cm³ as soil depth was increased from 20 to 50 cm. A single shank conventional subsoiler was used in three depths (25, 35 and 45 cm) and soil moisture content was about 10% dry bases in the depth of 35 cm. Soil physical conditions including cumulative water infiltration over 45 min, bulk density and cone index were measured and compared with before tillage conditions and control. The land had been used for wheat production for the last few years and was in a fallow phase and covered with wheat stubble prior to the tests. Experiments were conducted on 3-30 m plots arranged in a randomized complete block design with three replications. Tests were carried out in a total of 10 plots inclusive of control. The tractor forward speed was maintained at about 3km/h⁻¹ throughout all experiments. Before conducting the experiment soil bulk density of each plots, was measured by a core sampler at five different depth ranges 0-15, 15-25, 25-35, 35-45 and 45-55 cm. Measurements were replicated in three random locations in each plot. Cumulative infiltration over 45 min was measured before plowing at three different locations, using double ring infiltrometer (Bertrand 1965). Soil cone resistance was measured by sp1000 cone penetrometer. The cone had 12.83-mm diameter and 30 degree slop. Measurements were done at ten different locations in the depth of 0 to 50 cm. Similar measurements were performed after subsoiling and first irrigation in each plot and the percentage of variation of cone index, bulk density and water infiltration rate were calculated as ((before subsoiling – after subsoiling)/ before subsoiling )×100 for each treatments.

Results
Results showed that subsoiling broke hard pan and plow pan successfully and caused reduction in bulk density, soil cone index and increased the basic intake rate (Table 1). The analysis of variance for the depth range of 25 to 45 cm indicated that no significant decrease in soil bulk density, cone index and cumulative infiltration was obtained after first heavy irrigation, as the working depth was increased (Table 2).

Discussion
The first heavy field irrigation and traffic over the clay soils may be canceled out any gains made by subsoilers. So the stability of suitable conditions depends on soil texture and good management. As subsoiling could not decreased cone index less than 2MPa, in the depth of 30 to 45 cm, it might be worked in critical depth. Wing-type chisel points can increase critical depth and loose deep layer better, but needs more power. Fall is the best time to subsoil. Crops are removed, the soil usually is dry and evaporation rates are fairly low. Subsoiling dry soils, although requiring more energy provides better fracturing and heaving of the soil to break up compacted zones.

References
3- Ayers PD, Perumpral JV (1982). Moisture and Density Effect on Cone Index. Transactions of the ASAE.
4- Bertrand AR (1965). Rate of water intake in the field. In methods of soil analysis Part I. Agronomy monograph No. 9 ASA Madison. WI, USA. 197-209.

<table>
<thead>
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<th>Depth, cm</th>
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<th>Cone index reduction</th>
<th>Infiltration rate increase</th>
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<td>3.6b</td>
<td>1.9a</td>
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¶ Same letter means no significant difference, Duncan 5%

<table>
<thead>
<tr>
<th>Depth, cm</th>
<th>Bulk density, g/cm³</th>
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<th>Cone index 20-50 cm, kPa</th>
<th>Cumulative infiltration</th>
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