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Impact of Alleviation of Soil Compactness on Water Use and Yield of Cotton

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ABSTRACT

Sub-soil compaction, which may occur in lower depth of the soil and which usually leads to yield reduction, is often the result of surface / machinery traffic or natural sedimentation: the latter particularly so after rain run off or surface irrigation. The purpose of this research was to determine the effect of (a) different methods of sub-soiling, (b) the shape of sub-soilers on water use, and (c) soil compaction on the growth and yield of cotton under the field condition. The experiments were carried out on a silt clay loam soil, in a split plot design. A three parts experiment design with three treatments and three replications was conducted: (a) sub-soiling tillage methods as the main plots, (b) the shape of the sub-soilers as subplots, (c) plot with no sub-soiling treatments, were compared in three replications per treatments. Water use was increased by sub-soiling treatments relative to the mould board plough treatment. The water use in L shaped sub-soiling treatment was 15% higher than it was in the plot without sub-soiling treatment. Soil resistance decreased in the first 10 days after sub-soiling. However, after 165 days, all treatments had a higher resistance than they had at the beginning of the experiment with the exception of the L shaped sub-soiler. Soil resistance was un-stable both before and after sub-soiling. Root penetration and distribution varied in-significantly among different treatments. The cotton yield increased with C shaped sub-soiler, but it was statistically in-significant. The C shaped sub-soiler plot with lowest soil resistance had the highest yield.

Key Words: Compaction; Cotton; Sub-soil; Penetration resistance; Water use

INTRODUCTION

Some agricultural soils are naturally compact and surface machinery traffic can also increase their compaction. In both cases the compaction leads to soil structure degradation, i.e. the size and number of macrospores are reduced, which cause an increase in bulk density as well as in the soil strength, which may restrict root penetration (Coelho *et al.,* 2000). Restricting the root system means less water and nutrient available for uptake (Lowry *et al.,* 1970; Bennie *et al.,* 1981), so restricting the carbon fixation by the leaves (Greacen & Oh, 1972). USDA (1995) studied three different tillage methods (a) sub-soiling, (b) strip tillage and (c) no-tillage on a fine loam soil for corn yield over three years. The average yield and soil resistance were 5.34, 5.08, 5.07 tonha^{-1}, 2.51, 2.53 and 2.61 MPa for the three different methods, respectively which is statistically in-significant. There was no relationship between the depths of root penetration and the yield. According to Tupper *et al.* (1989) sub-soiling once every two produces a yield increase of 23 kg ha^{-1} and once every three years a yield increase of 98 kg ha^{-1}. Row sub-soiling at planting reduced pressure was reported and the lowest soil resistance was associated with the highest soybean yield (Vazquez *et al.,* 1989). A study of irrigation intervals and the soil compaction effect on the yield and the growth of cowpeas in the Nigerian Ultisol (Onofiok, 1989) showed that irrigation interval affected the yield and growth more than the compaction did. It was also concluded that the compaction did not had an effect on dry matter yield and tap root growth. Smith (1995) reported that sub-soiling dry clay soil will have a yield increase but one must remember that soil moisture content as a constraint for spring study of clay soil. Some soils in the South-eastern United States are severely degraded from excessive erosion and require intensive management including practices to alleviate soil compaction. Soils in the Tennessee Valley region of North Alabama have been found to respond positively to management practices that include a cover crop. Improved crop yields, improved soil tilth, reduced soil compaction, and reduced risk have been associated with experiments that have proven the benefits of cover crops (Raper *et al.,* 2000a; Raper *et al.,* 2000b; Schwab *et al.,* 2002). These same experiments have also shown benefits of conservation tillage practices that include either in-row sub-soiling or bent-leg sub-soiling. However, this tillage practice is expensive and time-consuming. Many producers would be interested in using this practice to alleviate their soil compaction problems using different methods of sub-soiling.

Tillage-induced changes in physical properties, such as bulk density (BD), penetration resistance, and aggregate stability are complicated and dependent on soil texture, water content at the time of tillage, and the time lags between tillage and physical properties measurements. There are reports that soil resistance measured by the cone index (CI) was not affected by the tillage method (Coelho *et al.,* 2000). However, an increase in soil resistance has been reported in the no-till system (Coelho *et al*., 2000). Parker *et al.* (1989) reported that in spite of large reductions in soil penetration resistance, the maximum depth of rooting was little affected by the loosening operation.

The purpose of this study was to characterise the effects of the methods of sub-soiling and shape of sub-soiler on the growth and the yield of cotton under field conditions. The objectives of this experiment were to study the effect of the shape and the direction of the sub-soiler on the soils' physical properties and the cotton yield, determine the stability of soil resistance: before sub-soiling, after the emergence and until harvest time and to study the effects of the tillage system (SL, SC, NS): on water use, growth and yield of the cotton plant.

MATERIALS AND METHODS

Experiments. The experiments were carried out in April 2001 at Hashem Abad experimental farm at the Gorgan cotton research institute, Iran (Latitude 54°, Longitude 36° N, Altitude 14 m). The soil was silt clay loam with an FAO standard. The previous crop was vegetable. There were two main plots: one with tillage parallel to the planted rows and the other with tillage vertical to the planted rows. The shapes of the sub-soilers as sub-plots were compared in a split plot experimental design with three replications per treatment. The main plot was 20 m x 46 m and the sub-plot was 20 x 7 m in size. After sub-soiling with SC, and SL, shape in the predetermined depth, the whole field was cultivated with a mould board plough in order to homogenize the top 20 cm of soil. The third treatment was a plot with no sub-soiling NS, only a mouldboard plough was used. This procedure allowed statistical comparisons of the same experimental site of cotton production under different treatments.

The cotton crop (Sahel cultivars) was planted on 27 April 2001. The same variety was planted in April 2002 after removing the crop residue of the previous experiment and tilling to a depth of 0.2 m with a mouldboard plough. In both treatments the plant rows were 0.80 m apart and the seed spacing was 200 mm. The plant population after thinning was 6 plants m^{-2}. The field was irrigated and fertilized as recommended. Before planting zinc sulphate, 50 kg ha^{-1}, iron sulphate, 100 kg ha^{-1}, and manganese sulphate, 50 kg ha^{-1} were dispersed on the field. Nitrogen fertilizer was added to the field as recommended @ 220 kg ha^{-1}, once before planting, 110 kg ha^{-1} and after planting at flowering, 110 kg ha^{-1}. P and K were not given to the soil. After the analysis of soil fertilizer, in 0 to 0.3 m and 0.3 to 0.6 m depths, P and K had a higher range than normal. The range was 23.3 pp m, 470 pp m and 19.6, 300 pp m, respectively. Microelement fertilizer (6 in 1000) was sprayed over the plant at the time of flowering.

The field was surface irrigated. Four irrigations were applied in 2001and rainfall during the cropping season was 151 mm. The water requirement was measured per hectare by determining the soil moisture.

Soil measurements. Soil physical characteristics were measured. The compacted subsoil layer was determined before sub-soiling by using a 30° cone, 12.83 mm diameter penetro-meter, coupled to a portable computer (Coelho *et al*., 2000). The penetration rate was approximately 0.03 ms^{-1} following standards of the American Society of Agricultural Engineers (1995). Resistance was recorded at 5 mm depth intervals at six points in each plot, three times during the growing seasons: before sub-soiling, 10 days after sub-soiling (10 DAS) and 165 days after sub-soiling (165 DAS).

The soil bulk density was measured in two locations within the central row: near the plant and at the root at two depths, 0 to 0.3 m and 0.3 to 0.6 m and in the same place as the soil resistance was measured.

Root measurement. Root morphology at the growing season was determined visually in the trench dug at the centre of each plot. Total of five plants per plot were analysed in 2001.

Water requirement. The water quantity during each interval was determined based on depth of irrigation and time of irrigation. Depth of irrigation was determined from the equation (1) based on measurement of soil moisture before irrigation.

$$I = (FC - SMD) * BD * Z \qquad (1)$$

Where I: depth of irrigation (mm)
FC: field capacity moisture content (mm)
SMD: soil moisture content before irrigation, (140 mm / m)
BD: bulk density
Z: depth of effective root (m)

The time of irrigation for each interval was determined from the following equation:

$$T = (I*A)/(60Q) \qquad (2)$$

Where T: time of irrigation (min)
A: the area, which irrigated by one siphon pipe (m^2)
Q: siphon flow rate

Plant measurements. Green bolls and open bolls per plant in the 2001 experiment were collected from 2-10 plants at different stages and weighed in different plot treatments. The cotton yield was collected from the central rows of each plot except for the first m at each end of the sub-plots and two m from the sides of the sub-plots. The harvesting dates were 10 September, 28 October, and 8 November 2001.

RESULTS AND DISCUSSION

Soil resistance to penetration and bulk density. SC treatment and SL treatments reduced the soil resistance more than NS. Fig. 1 shows the soil resistance before the L shaped treatment and 10 days after it. There was a reduction in soil resistance even 165 days after the treatments. So the L shaped sub-soiler can reduce soil resistance better than the C shaped sub-soiler. The C shaped sub-soiler reduces the soil resistance more in the first 10 days (Fig. 2), than the L shaped one. After 165 days, however, it was much higher than the L shaped one. From this, it is evident that the

Fig. 1. L shaped sub-soiler effect on soil resistance

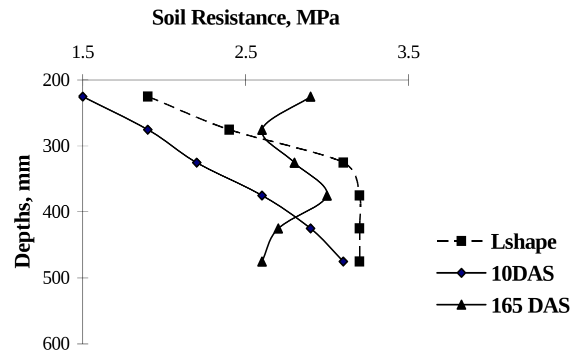


Fig. 2. C shaped sub-soiler effect on soil resistance

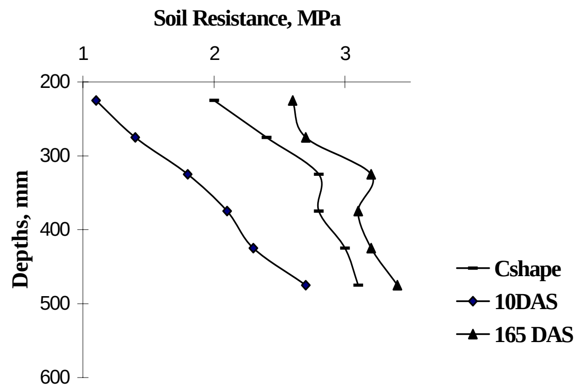


Fig. 3. NS and 165 DAS effects on soil resistance

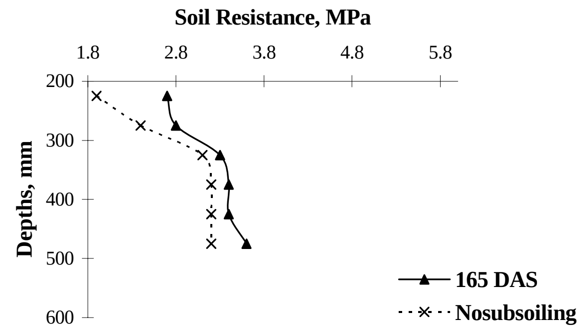
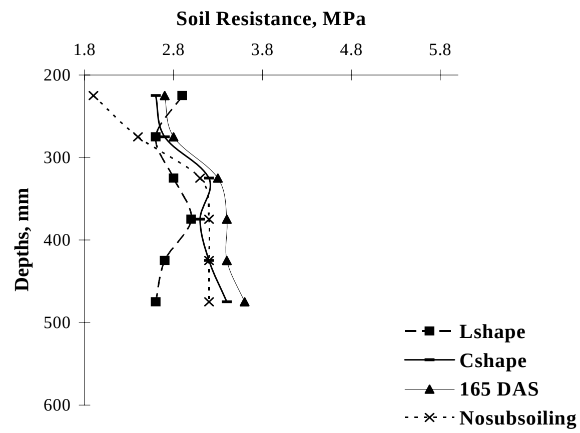


Fig. 4. Soil resistance comparisons before subsoiling and 165 days after subsoiling



smaller the soil particle size became the greater was the compaction in the lower depth of the soil and more settlement. Soil resistance increased in the mouldboard plough treatment, NS, from before sub-soiling (Fig. 3). Soil resistance was reduced only by the L shaped sub-soiling method after 165 days (Fig. 4), the other C and NS method increased soil resistance. The average soil moisture content in all treatments was about 15%, 165 days after sub-soiling to a 0.5 m depth.

The measured soil resistances with parallel and vertical sub-soiling to the rows methods were compared, at different dates, (Table I). The shape of the sub-soiling tool on soil resistance before sub-soiling and 165 days after sub-soiling in each method was in-significant ($p>0.05$). However, the resistance was higher in the mouldboard plough treatment. The treatment methods parallel to and perpendicular to the rows has no significant at all three dates. The soil resistance perpendicular to the rows method was lower than in the vertical method, although, it was in-significant ($p>0.05$). The horizontal method and the C shaped sub-soiler had a significant effect on soil resistance after 10 days of sub-soiling.

Average soil bulk density was 1.4 kg m^{-3} and 1.5 kg m^{-3} in 0 to 0.3 m and 0.3-0.6 m depth, respectively.

Water measurement. Water use was determined in all three cases (Fig. 5). The water use in mouldboard plough treatment was the lowest among the treatments. The C shaped sub-soiler treatment reduced the water intake relative to the no sub-soil. But the L shaped method increased water consumption by 15% relative to the NS method.

Plant measurements. The green bolls and cotton yield were weighed and found to be 5.2 g, 4.9 g. The yield was 2.4 and 2.7-ton ha^{-1} in the horizontal and vertical methods respectively (Table I). The cotton yield was higher at 2.7-ton ha^{-1} in the C shaped sub-soiler than in the other treatments. Cotton yield was higher (2.9 ton ha^{-1}) even in interactions of the method and shape for the C shaped sub-soiler. However, the methods and shape statistically were not significant on yield and green bolls. Many researchers have shown an increase in yield when fields have been sub-soiled, but the statistically significance was not discussed (Smith, 1995; Onofiok, 1989). The cotton yield increased by 7% and 14% with the C shaped sub-soiler in the vertical to planted rows and horizontal to planted rows relative to the no sub-soiling method but statistically not significant (Table II). The C shaped subsoil plot with the lowest soil

Table I. Methods and dates effect on the average soil resistance, MPa

Treatments	Dates		
Methods of Sub-soiling	Before sub-soiling, BS	10 days after Sub-soiling, DAS	165 DAS
Parallel to planted rows (H)	2.3	0.9	2.5
Perpendicular to planted rows (V)	2.3	1.2	2.3
Sub-soiling tool's shape and Mouldboard plough, NS			
SL•	2.4	1.8	2.2
SC	2.2	1.4	2.4
NS	2.3	2.3	2.5
Interactions			
H*SL	-	1.6^{b}	2.5^{ab}
H*SC	-	1.2^{c}	2.5^{a}
H*NS	-	2.4^{a}	2.5^{a}
V*SL	-	2.1^{a}	2.0^{b}
V*SC	-	1.7^{b}	2.3^{ab}
V*NS	-	2.3^{a}	2.5^{ab}

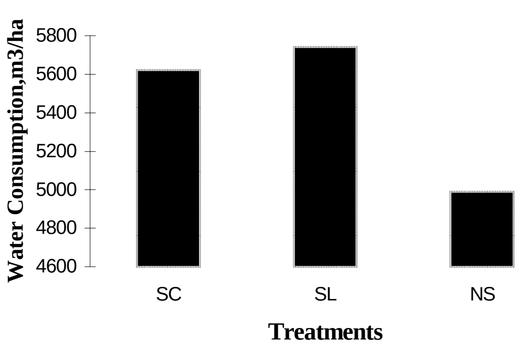
- SL: Subsoiling with L shaped SC: subsoiling with C shaped NS Mouldboard plough
- Directions H: Parallel to the rows V: Perpendicular to the rows

Table II. Cotton boll and yield in different treatments

Methods of Sub-soiling	Weight of boll, g	Cotton Yield, $tonha^{-1}$
Parallel to planted rows (H)	5.2*	2.4
Perpendicular to planted rows (V)	4.9	2.7
Subsoiling tool's shape and Mouldboard plough, NS		
SL •	4.9	2.5
SC	5.0	2.7
NS	5.2	2.5
Intersections		
H*SL	5.1^{ab}	2.4
H*SC	5.1^{ab}	2.5
H*NS	5.4	2.2
V*SL	4.7^{b}	2.6
V*SC	5.0^{ab}	2.9
V*NS	4.9^{ab}	2.7

- The rest were in class a.
- SL: Subsoiling with L shaped SC: subsoiling with C shaped NS Mouldboard plough
- Directions H: Parallel to the rows V: Perpendicular to the rows

Fig. 5. Water consumption in different treatments



penetration resistance had the highest yield and Vazaquez *et al.* (1989) has shown lower PR (soil resistance) highest soybean yield.

Observed root penetration and distribution in dug trenches showed no significant changes among the treatments. Parker (1989), unlike Coelho *et al.* (2000), also found result similar to this research, which may be true for fields with a very moderate compaction and bulk density of 1.5 gcc^{-1}.

CONCLUSIONS

L shaped sub-soiling keeps soil resistance lower than C shaped sub-soiling for longer periods.

The methods and shape interactions were not significantly ($p > 5\%$) effective on reducing soil resistance; however, the resistance was higher in mouldboard plough treatment.

The L shaped sub-soiler increased water use relative to the NS method. The methods and shapes of sub-soilers were not significantly effective on the yield and green bolls. The C shaped sub-soiler increased the yield slightly but not significantly. The C shaped sub-soiling plots with the lowest soil penetration resistance had the highest cotton yield.

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