Effect of Soil Manipulation and Other Field Parameters on Soil Physical Properties

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Abstract: The effects of tillage practice on soil physical properties (bulk density, air porosity, and infiltration rate) were investigated. The three tillage systems studied were: moldboard plowing; chisel plowing; and no tillage. Soil bulk density and air porosity were measured on cores obtained by a manually-operated tool. The collection of soil samples was replicated twice within each plot and at four depth increments of 10 cm each. Chisel and moldboard plowing significantly reduced bulk density of the upper 20 cm of the soil compared to no-till treatment while deeper levels were not affected. The amount of bulk density reduction in the chisel plowed plots was higher than the bulk density reduction in the moldboard plowed plots. The same tend was seen with the air porosity in the upper 10 cm of the soil; deeper levels were not significantly affected. Steady state water infiltration rate in the plow zone was higher in the chisel treatment than in the other two treatments.

1 Introduction

Soil compaction is a phenomenon that involves significant interrelationships between most recognized physical and biological properties of soils. Soil compaction is often measured in terms of soil density, water infiltration, or soil air porosity. One of the most frequently used measures of compaction is the bulk density of soil. Bulk density is found by determining the mass of dry soil that occupies a known volume. Ngunjiri and Siemens (1993) observed an increase in bulk density of the top soil from 0.96 to 1.31 g/cm^3 as a result of the first pass of a tire in a study of effects of multiple wheel traffic passes on soil compaction.

Hydraulic conductivity has been recognized as a potentially sensitive measure of compaction because deformations and small increases in bulk density often cause a very large decrease in hydraulic conductivity. Moore and Larson (1979) developed a system of routing water over a soil surface to estimate surface storage by use of point data originally measured to estimate random roughness produced by tillage or compaction. The total porosity of soils is the fraction of the volume not occupied by the oven dry solids. Danfors (1990) found higher air filled porosity as a result of lowering compactive effort.

Tillage treatments are expected to affect soil response and crop yield. Erbach *et al.* (1992) evaluated the effect of four tillage treatments - no till, chisel plow, moldboard plow, and para plow systems - on three soils (poorly drained, medium, and fine textured) in Iowa. Results showed that all tillage tools reduced bulk density and penetration resistance to the depth of tillage. However, after planting, only the soil tilled with the para plow remained less dense than before tillage.

2 Objectives

The objectives of this research study were to measure changes in soil physical properties (dry bulk density, infiltration rate, and air porosity) as affected by tillage system resulting from wheeled traffic on tilled soil in the Fall.

3 Materials and procedure

The experiment was initiated in the fall of 2000 on a clay loam soil (21% sand, 39% silt, 40% clay) at the northern part of Jordan. The following were the tillage trteatments:

N = No-tillage.

C = Chisel plowing, then disk harrow.

M = Moldboard plowing, then rotary tiller.

The experiment was arranged in a 194 m×50 m block representing two replications for each treatment. The entire block received primary tillage by chisel plowing in the fall of 1999 (a year before applying the traffic treatments) to a depth of approximately 15 cm. This was the only tillage done prior to the traffic treatments.

The three tillage treatments were applied to the specified plots. Next, conventional farming practices were then performed. All tillage and planting operations were performed by an 80-kW two-wheel drive KUBOTA M8030 tractor weighing 5 tons (front tires were 14.9R30 set to recommended level of 190 kPa and rear tires were 18.4R46 bias-ply set to recommended pressure of 110 kPa).

The dependent variables included soil bulk density, porosity, and infiltration rate. Soil bulk density was measured using samples obtained by a manually operated tool. These cores were 5 cm in diameter and approximately 5 cm in length and 100 cm^3 in volume (Blake & Hartge, 1986). The soil sampling was made at two locations in each treatment and at eight depths (5, 10, 15, 20, 25, 30, 35, and 40 cm) in each location. The data for each treatment were compiled and individual values were averaged for each 10 cm depth increment to a depth of 40 cm. Extra soil samples were taken to measure soil moisture content at specified depths. Soil water content (from the surface to 40-cm depth) at the time of compaction ranged from 8.2 to 17.3 kg kg^{-1}. Wet bulk density of soil sample was obtained by weighing the known volume of the core filled with soil and then subtracts the weight of the core itself.

Water infiltration rate in all treatments was measured using metal tubes used as soil samplers. It was inserted vertically into the soil leaving about 2 cm above the soil surface. A buplet was used to pour a known volume of water into the tube and, by using a stopwatch, the volume of water infiltrated into the soil was determined in a specific time interval. The volume of water obtained within a time interval was divided by the tube cross sectional area to give the depth of infiltration. The accumulated infiltration depth at any time interval was obtained by adding all depths of infiltration of the previous time intervals to the depth of infiltration at that time interval. This accumulated depth was plotted as a function of time on a log-log paper. The intercept and the slope of the resulting straight line were determined and the accumulated depth equation was obtained. The infiltration rate equation can be found as the derivative of the accumulated depth equation with respect to time.

Specific gravity of the experimental soil was measured in the soil mechanics lab according to the procedure described by Das (1990). After the moisture content evaluation, dry bulk density was calculated. Air porosity for each soil sample was measured using volume of solids and total sample volume. The sample was oven dried and then used for the determination of specific gravity. Total porosity values were found using the following equations:

$$V_S = M_S/(G_s*\gamma_w) \quad (1)$$

$$f_T = V_V / V_T = 1 - (V_S / V_T) \quad (2)$$

where:

V_S = volume of solids (cm^3)

M_S = mass of solids (g)

G_S = specific gravity of soil solids

γ_w = density of water (1 g/cm^3)

V_V = volume of voids (cm^3)

V_T = total volume of soil mass (cm^3)

f_T = total porosity

air porosity values were found using the following equation:

$$f_a = f_T - \theta \quad (3)$$

where:

f_a = air porosity

θ = volumetric moisture content

4 Results and discussion

Measured soil physical properties were averaged within the depth ranges of 0 to 10 cm; 10 to 20 cm; 20 to 30 cm; and 30 to 40 cm for comparison of tillage effects. Soil response to differences in tillage treatment are presented in Fig.1 for dry density, Fig.2 for air porosity, and Fig.3 for infiltration rate.

As shown in Fig.1, all plots that received no tillage had higher values of dry density compared to the tilled plots in the tillage zone. The averages of dry density at all depths show that the no-till treatment had the highest effect, followed by moldboard treatment while the chisel treatment had the lowest effect. It appears that tillage obliterated the effect of the axle load and tire inflation pressure on soil strength in the tilled layer. These results suggested that tire traffic followed by tillage might have a significant affect on the resulting soil physical properties. This is similar to the results obtained by Wood *et al.* (1993) who found that a 15.2 tons grain cart had a greater effect on soil properties in the plots that received no tillage compared to the tilled plots. Voorhees (1983) measured soil physical properties in the topsoil following normal farming operations using a tractor weighing 7.3 tons. He found that fall moldboard plowing decreased bulk density on the tilled layer to essentially the same level as in nontrafficked soil.

Air porosity measurements of less than 10% at field capacity moisture content represent soil conditions that make it difficult for roots to grow (Gupta *et al.*, 1990). The tillage significantly reduced air porosity to a depth of 40 cm for most treatments (Fig.2). Tilling did increase the air porosity of the soil at the tillage depth compared to no-till plots (Fig.2). Reeder *et al.* (1993) found that subsoiling increased the air porosity of the soil. Again, the no-till treatment caused the maximum percentage decrease of air porosity at the 0—10 cm depth, followed by the moldboard treatment and then chisel treatment. The difference between treatment and untrafficked value for each treatment decreased with increasing depth from 0—10 cm to 10—20 cm. These results were similar to the results obtained for the effect of investigated factors on soil bulk density. They reflect the ability of chisel plow to loosen the soil in the tilled layer more than the moldboard plow. In addition, chisel plow can be used in a conservation tillage system where some level of crop residue cover are required.

Fig.3 shows the effect of each treatment on steady state values of infiltration rate. All treatments had steady state infiltration rate values less than the untrafficked value. The no-till treatment caused the maximum decrease in infiltration rate and the chisel treatment had the lowest effect. Lowery and Schuler (1991) found that hydraulic conductivities of saturated cores were lower at the surface for increasing levels of compaction.

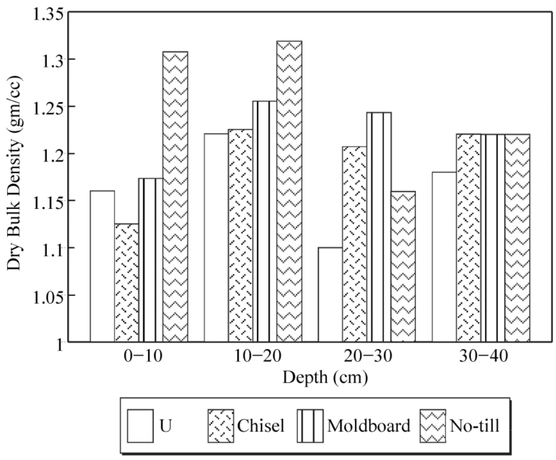

Fig. 1 The effect of tillage treatments on soil bulk density

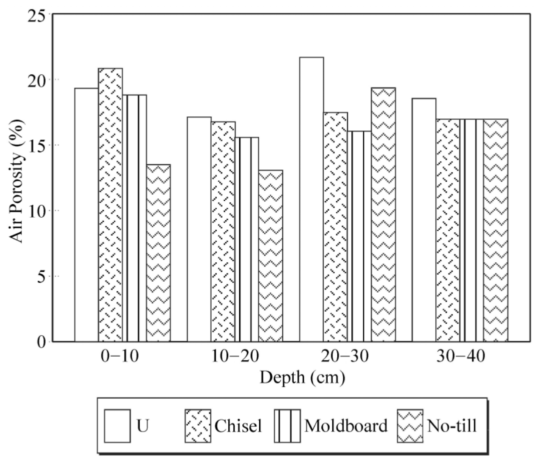

Fig. 2 The effect of tillage treatments on air porosity

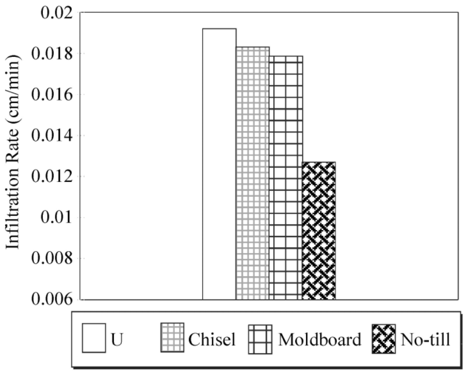

Fig. 3 The effect of tillage treatments on steady state infiltration rate

5 Conclusions

Based on the laboratory and field results of this study, the following conclusions were drawn:

(1) Soil bulk density was lower in the chisel-plowed plots than in the moldboard-plowed and no-till plots in the tilled layer.

(2) Air porosity was generally higher in the chisel-plowed plots than in moldboard-plowed and no-till plots in the tilled layer.

(3) Infiltration rate was higher in the chisel-plowed plots than in the moldboard-plowed and no-till plots.

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