



## EFFECT OF MACHINERY TRAFFIC ON SOME PHYSICAL CHARACTERISTICS OF CLAY LOAM SOIL

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### ABSTRACT

A field experiment was carried out to assess the effects of machinery traffic on some physical properties of a clay loam soil with four treatments i.e. Conventional tillage (CT), Minimum tillage (MT), Zero tillage (ZT) and Controlled traffic farming systems (CTF). The soil samples were taken from 0-15, 15-30 and 30-45 cm depths before and at the end of the experiment. Results showed that the dry bulk density and penetration resistance were significantly decreased ( $P < 0.05$ ) by conventional tillage system, followed by controlled traffic farming system at the depth of 0-15 cm. Contrarily, soil porosity and infiltration rate significantly increased ( $P < 0.05$ ) by conventional tillage system, followed by controlled traffic farming system at 0-15 cm depth. However, at lower depth (15-45 cm), the dry bulk density and penetration resistance were slightly decreased or remained consistent as well as soil porosity and infiltration rate were slightly increased or remained unchanged in almost all the treatments. It is concluded from the study that conventional and traffic farming systems are efficient tillage practices to decrease dry bulk density, reduce penetration resistance, increase soil porosity and infiltration rate as compared to minimum and zero tillage practices.

**Keywords:** Controlled traffic system, conventional tillage, dry bulk density, soil porosity, penetration resistance.

### INTRODUCTION

Soil compaction caused by machinery traffic in agriculture is a well-recognized problem in many parts of the world (Hamza and Anderson, 2005). It mainly depends on soil type, water content, traffic speed, number of passes and their interactions with cropping frequency and farming practices (Chamen *et al.*, 2003). Soil compaction adversely affects a number of key soil properties such as bulk density, porosity, penetration resistance, infiltration rate and hydraulic conductivity (Radford *et al.*, 2000; Hamza and Anderson, 2005), which ultimately

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reduce root development and crop yield as well (Kirkegaard *et al.* 1992; Passioura, 2002).

Compaction caused by conventional tillage systems is most serious, which particularly produces permanent destruction of soil structure (Hamza and Anderson, 2005). Recently conservation tillage has been widely adopted in Europe and in other parts of the world (Lahmar, 2010), however conservation tillage might not always be the most appropriate cultivation technique for all agro-ecosystems (Holland, 2004; Lahmar, 2010), as the excessive soil compaction has been observed owing to the long-term adoption of conservation tillage (Ferrerias *et al.*, 2000; Raper *et al.* 2000; Wiermann *et al.*, 2000; Munkholm *et al.*, 2003). Tillage induced soil compaction occurs more frequently than does traffic-induced soil compaction (West Europe the latter type of damage outweighs the former type) (Hakansson, 1994; Lipiec and Simota, 1994; Birkás, 2000; Tursi *et al.*, 2008). Although a limited amount of the compacted surface is favorable in the area planted seeds, because it supports better seed-soil contact and rapid seed germination as well as reduces the rate at which the soil dries; the excessive compactness of the soil surface leads to reduce crop productivity (Bicki and Siemens, 1991).

The study suggests that controlled traffic system should be introduced all over the world particularly in the soils, which are more susceptible to the soil compaction. The controlled traffic system provides a most favorable and conducive soil condition for the growth and development of plants mainly by restricting soil compaction to the traffic lanes (Braunack *et al.*, 1995) thus providing a firmed traffic lane and a loose rooting zone (Kayombo and Lal, 1993). Controlled traffic also helps for long-term management of traffic-induced soil compaction (Taylor, 1992), avoids machinery-induced soil compaction and allows optimization of soil conditions for both crops and tyres (Taylor, 1989). However, it is essential to remove any compacted layers prior to the implementation of controlled traffic system. In literature, a little information is available on the comparison of the effects of conventional tillage, zero tillage, reduced tillage and controlled traffic systems on the compaction of a clay loam soil. Therefore, the objective of this study was to assess the effects of controlled and uncontrolled traffic systems on soil compaction in a clay loam soil.

## **METHODOLOGY**

### **Experimental site**

A field experiment was designed and conducted at the experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam, during the year 2012 and 2013. A randomized complete block design (RCBD) was used with three replications. The experimental site was divided into twelve plots of 60 m x 20 m size. Three out of twelve plots were treated as conventional tillage (i.e. moldboard + cultivator (two passes)) (CT), three as minimum tillage (i.e. disk harrow (three passes)) (MT), three as zero tillage (i.e. direct drilling by seeder) (ZT) and three were treated as controlled traffic farming (i.e. cultivator

(two passes) (CTF). In controlled traffic farming system the tractor wheel base was 1.94 m and the implement width was 2.88 m. The traffic lanes were set with normal wheelbase of tractor without further modifications.

### Determination of soil physical and mechanical properties

Soil texture was determined by Bouyoucos hydrometer method (Bouyoucos, 1927) (Table 1), Penetration resistance was determined by cone penetrometer (CN-973), infiltration rate was determined by double ring infiltrometer (USDA Salinity Lab 1969), soil moisture content and dry bulk density were determined by gravimetric method (Blake and Hartge, 1986). Following formula was used to determine dry bulk density:

$$\text{Dry bulk density (P}_d\text{)} = \frac{\text{Dry weight of soil}}{\text{Total volume of soil}}$$

and soil porosity was determined by following formula:

$$n = 1 - \frac{P_d}{P_s} \times 100$$

where; n = soil porosity (%),  $P_d$  = dry bulk density (g/cm<sup>3</sup>) and  $P_s$  = particle density (g/cm<sup>3</sup>).

## RESULTS

The average values of particle size distribution and soil moisture content for conventional tillage, minimum tillage, zero tillage and controlled traffic at 0-15, 15-30 and 30-45 cm depths are shown in Table 1. The soil was clay loam in texture and maximum soil moisture content was retained under CT whereas minimum under ZT.

Table 1. Particle size distribution and soil moisture content under different tillage systems.

Tillage Method	Sand (%)	Silt (%)	Clay (%)	Texture Class (USDA)	Moisture content (%)					
					Before			After		
					0-15 (cm)	15-30 (cm)	30-45 (cm)	0-15 (cm)	15-30 (cm)	30-45 (cm)
T1(CT)	33.4	31.8	34.8	Clay loam	15.0	18.0	20.12	22.0	22.7	23.0
T2(MT)	31.4	31.8	36.8	Clay loam	14.5	17.2	18.3	20.7	21.0	22.5
T3(ZT)	30.4	31.8	37.8	Clay loam	13.2	15.3	16.2	19.0	19.2	20.0
T4(CTF)	33.0	32.0	35.0	Clay loam	14.0	16.5	18.2	20.5	21.0	22.3

LSD = 0.0261 at P<0.05

### Dry bulk density

The average values of dry bulk density of soil at 0-15, 15-30 and 30-45 cm depths before and after tillage operations are depicted in Figure 1. The results

indicate that dry bulk density significantly decreased under all systems at 0-15 cm depths, while at the depths of 15-30 cm, it decreased only under conventional tillage system and remained consistent under minimum tillage, zero tillage and controlled traffic farming systems. However, it slightly increased at the depths of 30-45 cm as compared to before tillage operations. The maximum decrease in dry bulk density was observed under conventional tillage system followed by controlled traffic farming system, minimum tillage and zero tillage systems at the depth of 0-15 cm.

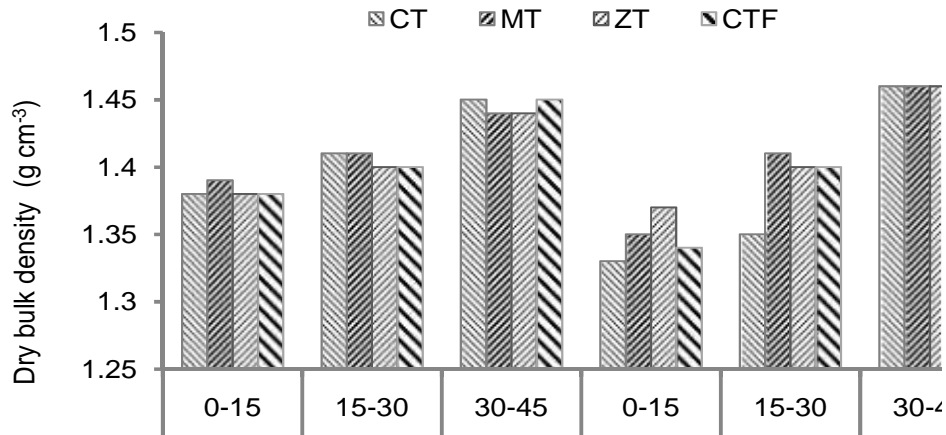


Figure 1. Average dry bulk density (gm cm<sup>-3</sup>) before and after different tillage operations LSD = 0.012 at P<0.05

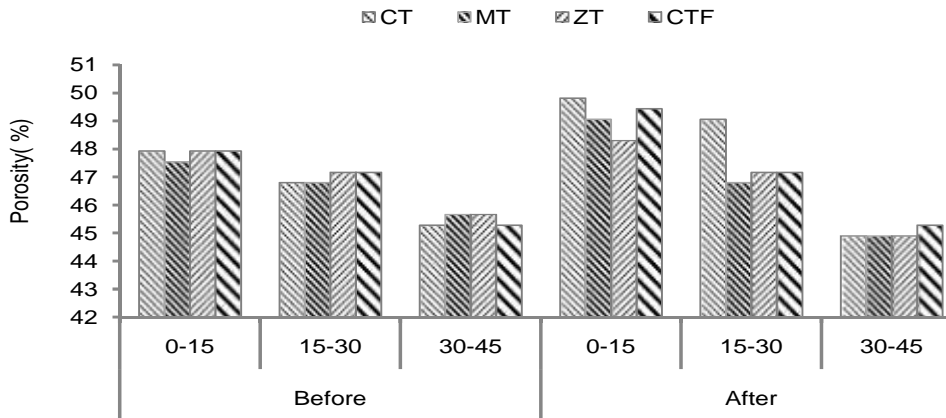


Figure 2. Average porosity (%) before and after different tillage operations LSD = 25.016 at P<0.05.

### Soil porosity

The values of average porosity for different tillage treatments are illustrated in Figure 2. The results show that soil porosity significantly increased under all systems at 0-30 cm depths, while at 30-45 cm depths it decreased or remained consistent under all traffic systems. The maximum soil porosity was observed under conventional tillage system followed by controlled traffic farming, minimum and zero tillage systems at the depth of 0-15 cm.

### Penetration resistance (Cone Index)

The average values of penetration resistance for different tillage treatments are portrayed in Figure 3. The results indicate that penetration resistance significantly decreased under conventional tillage, minimum tillage and controlled traffic systems at 0-15 cm depths, however under zero tillage, it slightly increased. At the depths of 30-45 cm, it slightly decreased or remained consistent under all systems. The maximum decrease was observed under conventional tillage system, followed by controlled traffic farming, minimum tillage systems at the depth of 15 cm.

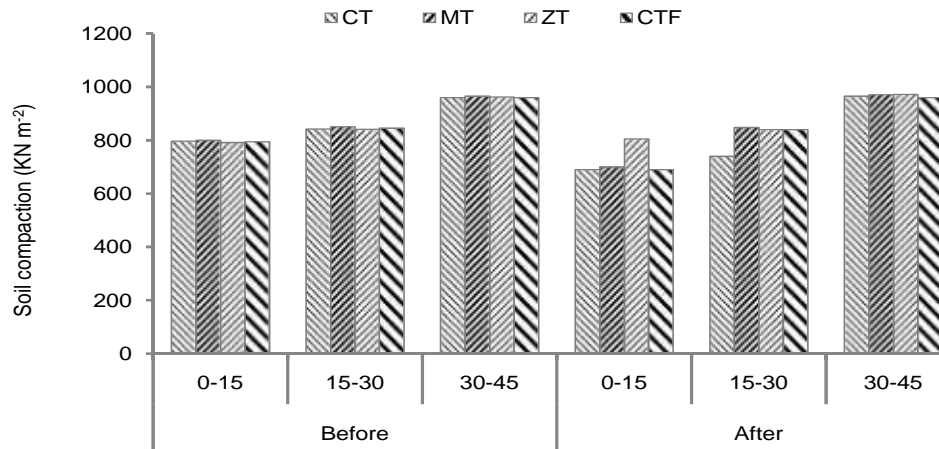


Figure 3. Average soil compaction (KN m<sup>-2</sup>) before and after different tillage operations LSD = 0.508 at P<0.05.

### Infiltration rate

The average values of infiltration rate for different tillage treatments are presented in Figure 4. The results indicate that infiltration rate significantly increased under all systems. The maximum increase in infiltration was observed under conventional tillage system, followed by controlled traffic farming, minimum tillage and zero tillage systems, while the lowest infiltration rate was observed under zero tillage treatment.

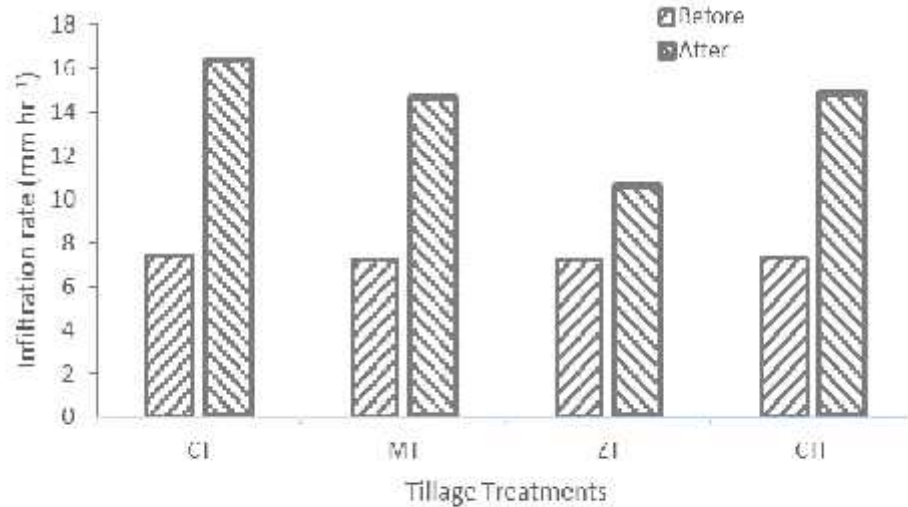


Figure 4. Average infiltration (mm hr<sup>-1</sup>) before and after different tillage operations.

## DISCUSSION

The statistical analysis of the data (ANOVA) showed that dry bulk density and penetration resistance significantly decreased ( $P < 0.05$ ); as well as soil porosity and infiltration rate were significantly increased ( $P < 0.05$ ) after tillage operations under conventional tillage system, followed by controlled traffic farming system at the depths of 0-15 cm. However, at the depths of 15-45 cm, the results on dry bulk density, penetration resistance, soil porosity and infiltration rate were non-significant ( $P > 0.05$ ). The findings of this study are in agreement with the previous studies which suggest that tillage is one of the most essential operations to decrease dry bulk density, increase porosity and infiltration rate and reduce the penetration resistance of the soil (Lio, 2006). According to Al-Adawi and Reeder (1996) and Voorhees *et al.* (1986), machinery loads also compact soil even for similar contact pressure between the machine and the soil. In a study, Filipovic *et al.* (2005) compared conventional tillage (CT), conservation tillage (CM), no-tillage system (NT), and the crop rotation in corn-wheat on the basis of soil compaction, bulk density and penetration resistance under these methods. They concluded that the bulk density and penetration resistance increased with depth and the greatest increase was observed in conventional tillage system. Similarly, Manea *et al.* (2009) monitored the effect of some unconventional soil tillage works (chisel, or simply disc) compared to classical tillage, on some physical features of the soil (bulk density, total and air porosity, structure etc.), on weed control and on yield level of two main crops i.e. wheat and maize. Bauder *et al.* (1981) observed that plowing inverts the soil that reduces soil compaction.

## CONCLUSION

The following conclusions were drawn from the study. The dry bulk density decreased under all systems at 0-15 cm depths, while at the depths of 15-30 cm, it decreased only under conventional tillage system and remained consistent under minimum tillage, zero tillage and controlled traffic farming systems. However it slightly increased at 30-45 cm depths as compared to before tillage operation. The maximum decrease in dry bulk density was observed under conventional tillage system, followed by controlled traffic farming, minimum tillage and zero tillage systems at the depth of 0-15 cm. The soil porosity increased under all systems at 0-30 cm depths, while at 30-45 cm depths, it decreased or remained consistent under all systems. The maximum soil porosity was observed under conventional tillage system followed by controlled traffic farming, minimum tillage and zero tillage systems. The penetration resistance significantly decreased under conventional tillage, minimum tillage and controlled traffic systems at 0-15 cm depths, however under zero tillage, it slightly increased. At the depths of 30-45 cm, it slightly decreased or remained consistent under all systems. The maximum decrease was observed under conventional tillage system followed by controlled traffic farming and minimum tillage systems. The infiltration rate was significantly increased in all treatments at 0-45 cm depth. The maximum increase in infiltration rate was observed under conventional tillage system followed by controlled traffic and minimum tillage. While the lowest infiltration rate was observed under zero tillage system.

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