Soil & Tillage Research 103 (2009) 381–386

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

# Effect of the number of tractor passes on soil rut depth and compaction in two tillage regimes

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ARTICLE INFO

*Article history:*
Received 18 August 2008
Received in revised form 7 December 2008
Accepted 10 December 2008

*Keywords:*
Repeated traffic
Soil bearing capacity
Soil compaction

ABSTRACT

The initially high level of soil compaction in some direct sowing systems might suggest that the impact of subsequent traffic would be minimal, but data have not been consistent. In the other hand on freshly tilled soils, traffic causes significant increments in soil compaction. The aim of this paper was to quantify the interaction of the soil cone index and rut depth induced by traffic of two different weight tractors in two tillage regimes: (a) soil with 10 years under direct sowing system and (b) soil historically worked in conventional tillage system. Treatments included five different traffic frequencies (0, 1, 3, 5 and 10 passes repeatedly on the same track). The work was performed in the South of the Rolling Pampa region, Buenos Aires State, Argentina at 34°55′S, 57°57′W. Variables measured were (1) cone index in the 0–600 mm depth profile and (2) rut depth. Tyre sizes and rut depth/tyre width ratio are particularly important respect to compaction produced in the soil for different number of passes. Until five passes of tractor (2WD), ground pressure is responsible of the topsoil compaction. Until five passes the tyre with low rut depth/tyre width ratio reduced topsoil compaction. Finally, the farmer should pay attention to the axle load, the tyre size and the soil water content at the traffic moment.



## 1. Introduction and literature review

In Argentina 16 million hectares cropped are grown under continuous direct sowing (DS) system, the rest, approximately 22 million hectares, are cultivated under conventional tillage (CT) system. Direct drilling systems usually have lower traffic intensities than those using conventional tillage, however, after several years of continuous direct drilling, yields tend to decrease. This could be the result of increased weed control problems and root diseases as well as a gradual increase in soil compaction due to agricultural traffic.

Highly compacted soil, particularly in the surface layers, generates inadequate soil physical conditions for seedling emergence. Therefore, the challenge is to attain a suitable seedbed while minimizing traffic-induced soil compaction, so that the soil physical properties do not diminish normal root growth (Botta et al., 2004). Strain force and compaction degrade soil by decreasing water infiltration and water holding capacity, increasing runoff and erosion, increasing crop production problems, thereby decreasing crop yields and profitability of farming systems (Way et al., 2005). The soil parameters usually identified as the most critical in over-compacted soils are aeration, bulk density and cone index (CI) (Håkansson et al., 1988).

The most obvious visual indicator of topsoil compaction is rut depth affected by agricultural tractor and machinery's traffic on the soil. That rut depth will be principally related with initial soil condition, inflation pressure, tyre width and number of passes (Botta et al., 2006). Davies et al. (1973) considered rut depth as the main indicator of compaction after trafficking. Chancellor (1976) reports that all the porosity reduction (measured with X-rays) in the soil, when applied superficial high load, was similar to the depression caused by traffic over the soil surface. The same author adjudicates a great importance to the relation between rut depth and tyre's width, for different loads, as an indicator of the compaction depth distribution. Low rut depth/tyre width ratio indicates that most of the compaction happens close to the topsoil where the soil is more affected not only by tyre's inflation pressures, but also by the pressure in the contact area. According to Raper et al. (1994), by increasing inflation pressure, the width ratio is decreased, but this has low effects on the ground pressure. The greater effect, according to the same authors, on the ground pressure is related to the tyre's load, because when it is increased there is a widening of the tyre at the same time that the soil is deformed, indicating that the greater pressure on the soil is in the centerline of the rut. Smith and Dickson (1992), on soil bin, found

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0167-1987/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2008.12.002

that compaction on the surface layer is determined by the ground pressure. However, for Håkansson et al. (1988) subsoil compaction is directly influenced by total load being independent of the ground pressure.

For the number of passes is known that the second and next passes of the tyre causes less compaction than the first one. However, this response to traffic is related to the initial level of soil compaction and the distribution in deep layers (Soane, 1980). Ljungars (1977) affirms that in some cases a lineal rise of the cone index may occur over the sixth pass, however, remarks the need for studying the response to repeated passes and initial soil condition where the traffic occurs. Raghavan and McKyes (1978) compared the compaction produced by the number of passes for different size of tyres with an approximate load of 14 kN. The 16.9–28 tyres produced an increase of the soil bulk density even after the fifth pass, exceeding this, the increase was lower. In the other hand 18.4–30 tyres produced a lineal rise of the cone index over the tenth pass.

In Argentina, soybean (*Glycine max* L.) is grown mainly on clayey soils (2.6 million ha). These soils are very susceptible to heavy traffic compaction. Narro Farias (1994) advises that soil cone index, in fine textured soil, should not exceed 1000 kPa, because higher values can harm root growth. Terminiello et al. (1998) found, in west Pampas region, that cone index values over 1150 kPa produced reduction, in the dry root weight, of cabbage crop (*Brassica oleracea* L.) in approximately 32%. Jorajuria et al. (1997) found in west pampas region that dry bulk density values over 0.937 Mg $m^{-3}$ at 0–300 mm depth range produced a decrease in pasture yield of approximately 76%.

Data from research that compare yield effects in the presence and absence of random traffic on no tillage soils are less extensive than those from conventional tillage systems. Campbell and Hunter (1986) working on imperfectly drained clay loam in Scotland showed that even with fairly modest wheel loads, no tillage yields were reduced when compared with not trafficked areas. However, this only occurred in the early years of no tillage and differences were absent by the fourth season despite no reduction in bulk density on the trafficked soil. In contrast, Botta et al. (2004) working with soybeans on clayey soil found that yields were reduced in 9.8%, 22.6% and 38% for 4, 6 and 8 passes respectively with a 39 kN tractor. Also, Botta et al. (2007), after 3 years of studies on clayey soil found that, comparing traffic intensities between 15.2 Mg $km^{-1}$ $ha^{-1}$ and 38.45 Mg $km^{-1}$ $ha^{-1}$ in soybean, yields reductions were approximately 23.5%. Soza et al. (2003) found, in the east Pampas region on a soil with high clay content, that cone index values >1200 kPa reduced wheat (*Triticum aestivum* L.) emergence by 26%. Also in Argentina, Ressia et al. (1998) advised that in clay soil, dry bulk density values >1.2 Mg $m^{-3}$ at 200 mm depth produced a 30% decrease in corn (*Zea mays* L.) yield.

The objective of the present work is to study the relation between rut depth and number of passes and the compaction caused by two different load tractors traffic on two soil mechanic conditions: (a) soil with 10 years under direct sowing system and (b) soil historically worked in conventional tillage system.

## 2. Equipment and test procedure

### 2.1. The site

The work was performed in the south of the Rolling Pampa region, Buenos Aires State, Argentina at 34°36′S, 58°40′W, altitude 14.8 m over sea level, slope type 1, gradient 0.5–1%, well drained, drainage class 4, no stony class 0. The soil was a fine clayey, illitic, thermic Typical Argiudol (Soil Conservation Service, 1994), with an organic matter content ranging from 3.4% (w/w) in the surface to 1.2 at 600 mm depth. Typical profile characteristics shown in Table 1. Previous history of soil management included, 10 years of a very usual regional alternative in crop rotation, wheat (*Triticum aestivum*) in winter, followed of a soybean (*G. max*), in summer.

Two tillage regimes were prepared: (a) conventional tillage, soil was moldboard ploughed at 200 mm depth after soybean harvesting, then harrowed with a light disk harrow (vertical load of 450 N/disk), to prepare the seedbed for wheat. After wheat harvesting, soil was chisel plowed to a depth of 280 mm and then tilled with a heavier disk harrow (vertical load of 850 N/disk), at an average depth of 150 mm, and then the soybean was seeded, (b) soil in direct sowing condition, soil with 10 years under direct sowing system.

### 2.2. Experimental treatments

Five treatments were imposed on plots 100 m long × 7 m wide (700 $m^2$) each one, where the experimental variable was traffic frequency of 0, 1, 3, 5 and 10 tractor passes in the same tracks, with 3 m wide buffer zones between plots to avoid interactions. Plots were in completely randomized blocks having three replications. Each experimental plot (CT and DS) were trafficked with 0, 1, 3, 5 and 10 passes of two 2WD tractors equipped with single rear tyres: Light (L) and Heavy (H) (Table 2), tractors speed was 5.5 km $h^{-1}$. No hitch load was applied to the tractors during the experiment. Statistical analyses were performed utilizing the Statgraf program 7.1. An analysis of variance (ANOVA) was carried out on the data and means were analyzed by Duncan's multiple range test. These tractors were models usually used on commercial farms in the experimental area. The numbers of passes were selected in order to

**Table 1**
Typical soil profile.

| HORIZONS | Ap | A12 | B1 | B21t | B22t | B23t | B3 | Cca |
|---|---|---|---|---|---|---|---|---|
| Depth range (cm) | 0–15 | 16–22 | 23–35 | 35–60 | 65–80 | 90–110 | 120–150 | 160–220 |
| Organic carbon (%) | 1.74 | 1.35 | 0.93 | 0.63 | 0.50 | 0.31 | 0.22 | 0.14 |
| Total nitrogen (%) | 0.24 | 0.14 | 0.10 | 0.085 | 0.075 | 0.058 | 0.042 | – |
| Clay (<2 μm) | 21.2 | 25.5 | 24.9 | 33.2 | 47.5 | 33.0 | 23.0 | 15.8 |
| Silt (2–20 μm) | 32.3 | 34.7 | 29.8 | 29.3 | 20.8 | 31.2 | 32.9 | 28.7 |
| Silt (2–50 μm) | 75.6 | 70.8 | 67.2 | 61.3 | 50.0 | 63.0 | 72.7 | 79.9 |
| Fine Sand (100–250 μm) | 0.3 | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 |
| pH | 5.4 | 5.3 | 5.5 | 5.5 | 5.8 | 6.0 | 6.0 | 7.5 |
| pH in $H_2O$ (1:2.5) | 5.8 | 5.8 | 6.0 | 6.2 | 6.5 | 6.4 | 6.4 | 7.9 |
| Cation exchange capacity (m.e. 100 $g^{-1}$) | | | | | | | | |
| $Ca^{2+}$ | 11.4 | 12.7 | 12.0 | 13.8 | 18.3 | 17.2 | 16.5 | – |
| $Mg^{2+}$ | 2.9 | 2.5 | 3.1 | 4.5 | 6.5 | 6.4 | 3.8 | – |
| $Na^{+}$ | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | 0.5 |
| $K^{+}$ | 1.4 | 1.0 | 0.9 | 1.3 | 2.3 | 2.4 | 2.3 | 2.4 |