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TILLAGE SYSTEMS WITH CONTROLLED TRAFFIC AND LIMITS TO MAIZE PRODUCTION

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Summary

Soil compaction can reduce the growth of crops, causing production losses even in soil conservation systems. In areas where controlled traffic is used, the wheeled rows are prone to show limiting conditions for corn growth and production. Determination of soil critical values limiting plant growth and corn grain productivity in areas with controlled traffic would be a valuable tool to adopt controlled traffic. Aiming the assessing of critical values to soil compaction an experiment was designed on a Rhodic Paleudult as random blocks in factorial scheme 2x4x5 (tillage x wheeling x soil layers), with three replications. Maize was sown with direct drilling (zero tillage) and reduced tillage (chiseling) system. A tractor with 3.8 Mg was used to compact soil in both systems (0, 1, 3 and 6 wheeling) prior to sowing. The soil density, macro porosity and field capacity were determined in undisturbed soil samples taken at 0-5; 5-10; 10-15; 15-20 and 20-25 cm dept layers. Soil penetration resistance (PR) was evaluated in the field as well. Regardless of tillage system, traffic increased agricultural soil density values even to the depth of 20 cm. The highest value of PR (1600 kPa) and soil density (1.67 Mg m^{-3}) were not limiting to maize growth and the productivity of corn grains increased on wheeled soil. Water content of the soil after wheeling, at field capacity, was increased by up to 0.1 m^3 m^{-3} and the macro porosity was reduced in 10%. The grain production of corn was higher in wheeled soil. The values of soil density and PR were not limiting to root growth. Wheeling the soil even up to six times with tractor, did not limit maize growth, and showed increases in grain productivity.

Key words: controlled traffic, soil resistance, soil density, maize production.

Introduction:

No-tillage system (NT) has been recognized as the most important soil management for sustainability of agro ecosystems. The agricultural area managed under NT in Brazil in 2013, was estimated to be about 35 million hectares. The adoption of NT in such a large scale was only possible due to the continuing development of technological solutions to overcome problems and difficulties related to the management of this system, as well as to improve it and adapt it to different regions. However, after almost 40 years of research and observations accumulated by producers, technicians and researchers, some problems still exist and need a better understanding. Among them,

we highlight the existence, in almost all areas under NT, of a soil layer of higher compaction, located 0.1 to 0.2 m depth (Franchini et al., 2011).
Modifications caused by soil compaction can reduce crop productivity, especially in dry years and/or with excess rainfall thus jeopardizing the sustainability of the NT. The main causes are the degradation of soil physical quality, decreasing root development and the availability of water, oxygen and nutrients to the plants.
The lack of a consistent response to the use of biological methods of recovery of compacted soils, in terms of improving the physical quality of the soil, has put at risk the sustainability of NT system and, often, deep chiseling has been indicated as an alternative to breakup of compacted layers of soil (Klein & Camara, 2007). Although chiseling is able to break up compacted soil layers immediately, its effects persist, in general, for a period equal to or less ephemeral, one year, since this operation does not eliminate the cause of soil compaction, but only their symptoms (Franchini et al., 2011). In addition, the susceptibility of soil to subsurface compaction is increased, mainly by agricultural machinery traffic, and can even decrease crop productivity (Debiasi, 2008).
Improvements in soil management system, to alleviate soil compaction in agricultural areas involve preventive practices, such as the increase in load-bearing capacity of the soil, the controlled traffic, and preventive/corrective, as the increase in soil organic matter content and the opening of bio pores by roots and the soil meso and macro fauna (Debiasi, 2008). The use of controlled traffic consists of wheeled traffic concentration on the same site, associated with the use of coulters and fertilizer depositing shafts working at depths greater than 0.10 m, which can speed up the recovery of soil and minimize the negative effects of compaction on summer crops (Debiasi, 2008).

Material and methods

The field experiment is located in the Agricultural Experimental Station of the Federal University of Rio Grande do Sul, in the municipality of Eldorado do Sul on a Rhodic Paleudult with sandy clay texture (250, 200 and 550 g kg-1 clay, silt and sand, respectively). Plots measuring 15 x 3.2 m, are being used since 2008, using crop rotation with clover and ryegrass in winter and maize in summer, with controlled traffic farming machines, in different tillage systems.
The design was of randomized blocks with three replications in factorial 2 x 4 (tillage methods x traffic intensity) with three repetitions. Tillage methods consist of: (i) no-tillage system; (ii) reduced tillage with soil scarification done in 2008 and repeated in 2013, before agricultural traffic. The traffic intensity factor consisted of areas (i) without traffic; or (ii) with one pass of a tractor; (iii) with three passes and; (iv) with six passes of a John Deere tractor, model 5600, with a mass of 3.8 t, with front tires 12.4-24 R1 and rear 18.4-30 R1, inflated to 95 and 110 kPa, respectively. The tire-ground contact area was 514 cm2 (front) and 1,018 cm2 (rear). The contact pressure of the front and rear tires with the soil were in the range of 115 and 120 kPa.
Soil penetrometer resistance (PR) was determined in transect with 5 points in each plot, using a penetrometer, with electronic measurement system and data recording system (ASAE, 2004). The PR measured at 1 cm intervals to the depth of 25 cm. After data collection PR was calculated to layers of 0-5, 5-10, 10-15, 15-20 and 20-25 cm. This determination was accomplished with the soil water content at field capacity.

Soil density was taken at the 5 to 12.5 cm depth layer. Maize was planted to 60.000 plants per ha and grain was harvested 140 days after planting. The results were submitted to analysis of variance ($p < 0.05$).

Results and discussion:

Physical variables (soil density, total porosity, macro porosity, field capacity), only presented interactive effect ($p < 0.05$) between the levels of traffic and the layers of soil and between traffic levels and soil preparations. However, the soil resistance to penetration (RP) presented triple interaction (tillage, traffic levels and layer. Traffic with the tractor changed the compression level of the soil to the depth of 20 cm, as noted on the data of soil density (Figure 1a). Six traffic passes show tractor transmission of pressure to depths of up to 20 cm, where the highest values of soil density were attained. The increase in the level of soil compaction on traffic function was quadratic for all layers (0-5; 5-10, 10-15 and 15-20 cm) up to the depth of 20 cm (Figure 1b). In the layer of 20-25 cm no change in the level of soil compaction due to traffic was detected.

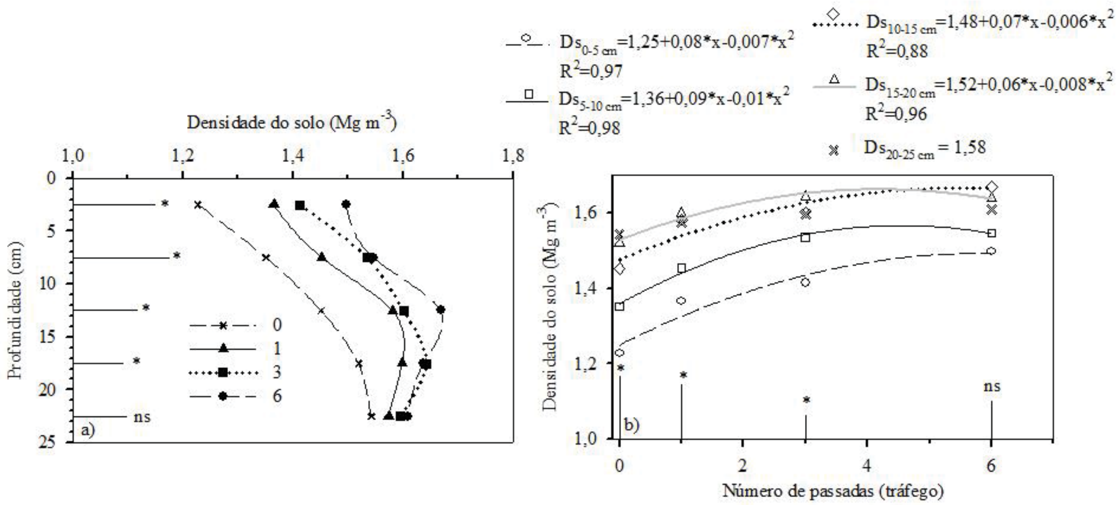

Figure 1: Soil density as influenced by traffic and soil layer depths.

[ns] Non significant at F-test (p<0,05).

Regardless of the tillage (reduced tillage with scarification and NT) the level of soil compaction increased due to the higher traffic intensity. After one single pass soil density in reduced tillage system reached the same densities attained under NT system. This indicates that the effects of reduction of Ds by soil scarification are eliminated already in the first passage of the tractor.

In reduced tillage, the increase in soil compaction was linear in the layers of 0-5; 5-10 and 10-15 cm, as a function of traffic increase (Figure 2). At the layers of 15-20 and 20-25 cm, the increase in the values of PR was described by a quadratic equation on the basis of the number of passed from the tractor. However modification of the RP values in NT can be described by a quadratic curve until the depth of 15 cm (layers of 0-5; 5-10 and 10-15 cm). In the soil deeper than r 15 cm, under NT, no change in the level of soil compaction as a function of tractor passes was detected. This indicates that the highest values of PR occurred when the soil was wheeled up to three times (further traffic showed no evidence of soil RP increases).

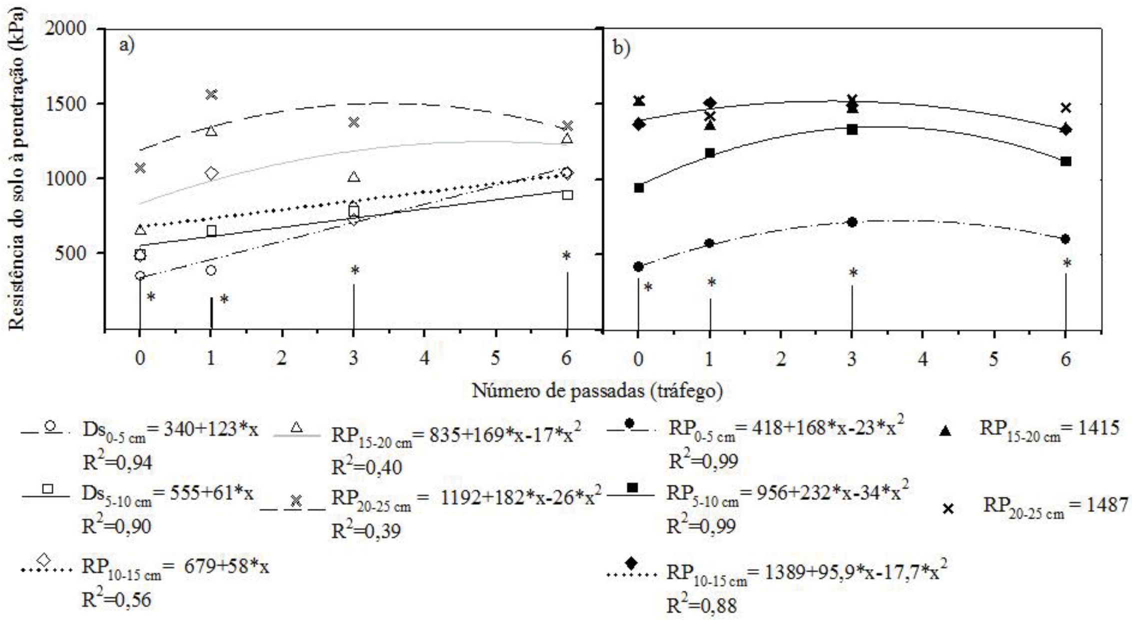

Figure 2. Soil penetration resistance related to number of tractor wheeling: in chiseled soil (a) and under No Tillage system(b).

[ns] Non significant at F-test (p<0,05).

The water content at field capacity, regardless of soil preparation, changed along the soil profile depending on the level of traffic (Figure 3). Traffic increased the amount of water stored in the soilmainly in the layer to 10 cm. In 0-5 cm layer, the water content at field capacity in the area without traffic increased from 0.26 to 0.35 m^3 m^{-3}, after one pass with the tractor. This indicates that agricultural traffic favors increments in the available water content in the soil in layers of 0-10 cm, mainly after the first passed from a tractor with 3.8 Mg and tire contact pressure of 120 kPa soil. However, as the soil is wheeled more times, water content at field capacity starts to decrease in relation to the sites without traffic.

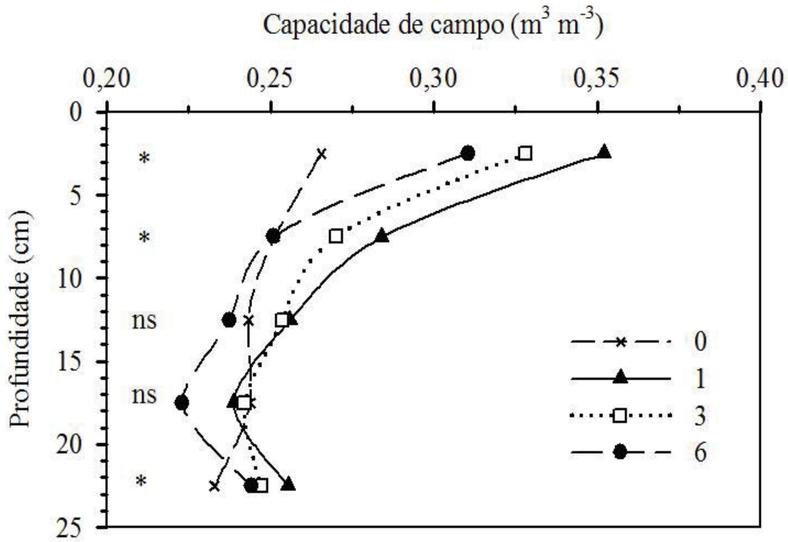

Figure 3: Water content at field capacity as a function of tractor passes.

[ns] Non significant at F-test (p<0,05).

Modifications in soil water content at field capacity is influenced mainly by soil pore size redistribution. After the traffic, there was a reduction in the volume of soil macropores in all layers to 25 cm (Figure 4). Agricultural traffic induced redistribution of soil pore size, reducing the amount of Macropores favoring increments in volume of pores that store water in the soil (micro pores).

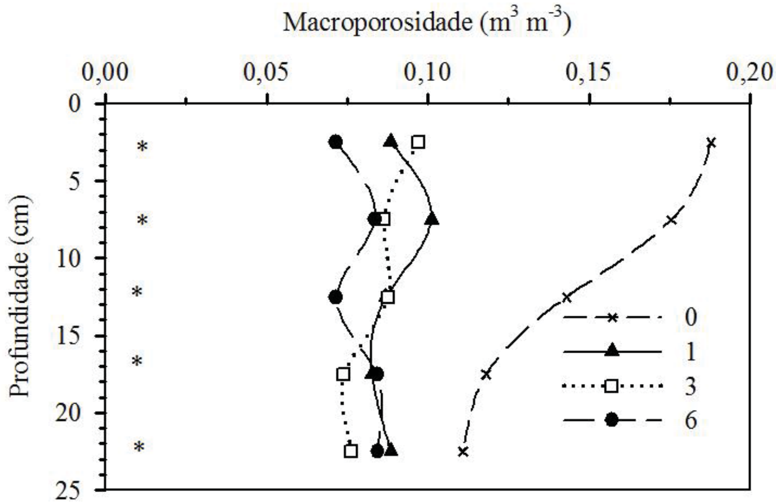

Figure 4: Soil macro porosity as a function of tractor passes.

[ns] *Non significant at F-test ($p<0,05$).*

Tillage systems and traffic levels did not alter the morphological parameters of the shoot (culm diameter, plant height, dry mass of aerial part) and culture root of corn (green mass, dry mass, volume, surface area, diameter, and root length). This indicates that the observed values of soil density (Figure 1) has not limited the plant growth nor the root of maize. The increase in the density of the soil, not reaching the critical limits of plant growth, may favor physical improvements to increase soil water storage that will be important in periods with reduced rain precipitation. The maximum value of soil density (1.66 Mg m-3) was observed in 10-15 cm layer in places with six tractor passes; however, this value of soil density was not limiting to the root growth of maize.

As an indicator of overall performance, maize grain production was increased by tractor wheeling irrespective to tillage system used. No difference was found in relation to the amount of wheeling (Figure 5).

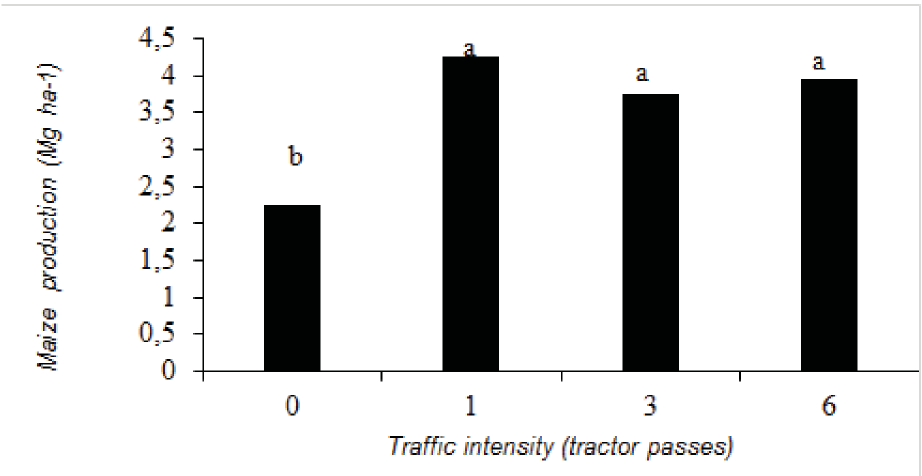

Figure 5. Maize grain production in a Rhodic Paleudult under wheeled soil.

Soil density and penetrometer resistance were increased, and the compaction by up to six passes with a 3.8 t tractor did show significant difference in maize production. This is probably due the increase of soil water content at field capacity due to tractor wheeling with soil tire relatively low contact pressure (120 kPa). Maize plant did not show any detrimental effects due to the amount of soil compaction.

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