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REGULAR ARTICLE

Soil compaction in progressive agricultural tractor treads

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Abstract

Soil compaction is one of the main problems in world agriculture. It is known that, even in soil conservation management, such as in no-till, the transit of agricultural machinery damages the soil structure, therefore, it is essential to better understand the compaction processes and ways to alleviate the problem. In soils that have traditional tillage management, just one machine pass can damage the physical structure. This research aimed to evaluate the levels of compaction as a function of different passages of an agricultural tractor, considering the hypothesis that, during agricultural operations, a machine transits several times through the same place in the crop. The experiment was carried out on plowed and harrowed agricultural soil in the state of São Paulo. Resistance to soil penetration at different depths was evaluated, and the averages were correlated as a function of the number of steps taken by the tractor. Results showed that approximately 60% of the total soil compaction occurs in the first passes of the agricultural tractor, and above five passes the increase in compaction is minimal. At depths of 20 to 30 cm, the largest RSPs were found. It is concluded that a good planning of machinery traffic is essential, because in the case of a motor-mechanized set moving out of its predestined route, the soil structure is permanently affected.

Keywords

Mechanization; Soil density; Cone index.

Introduction

Soil compaction is one main productivity limiting factors in most agricultural crops, as it directly affects root growth and nutrient absorption (Olubanjo and Yessoufou, 2019; Ungureanu, Vladut and Cujbescu, 2019; Hargreaves et al. 2019). Compaction can be understood as the reduction of soil porosity and permeability, which causes a lower availability of water and nutrients for plants (Alaoui and Diserens, 2018). Compaction always has an anthropic character, unlike the densification that occurs by natural causes. Inadequate soil management produces short-term effects such as surface compaction, reduced productivity, subsurface disaggregation, among others, while in the long term it provides permanent degrading effects and environmental problems (Molina Jr., 2017; Horn, 2015).

In agriculture, the main causes of soil compaction are agricultural tractors and their implements and accessory machines. As over the years the machines have gotten bigger and bigger, due to the high demand for power, the pressure on the ground has grown to considerable levels. However, this problem can be reduced by better planning the use of machines and their components, such as the implementation of controlled traffic and the use of different types of wheels (Camargo and Alleoni, 2019).

Colombi and Keller (2019), studying the relationship between root growth and soil compaction, stated that, in compacted soils, root elongation was the process that suffered the most delay, causing losses in the absorption of water and nutrients by the plants, making them more susceptible to periods of drought.

Martins et al. (2018) state that agricultural machinery traffic is the main factor causing compaction in agriculture. The authors state that the compaction intensity will depend on the equipment used in the operation, the type of soil and the number of passes of the mechanized systems.

Machines often travel over agricultural areas throughout the crop production cycle. The amount of ground damage depends directly on the applied load and the number of passes the machine passes through the ground. This research aimed to evaluate the effect of different passages of an agricultural tractor on the same site in a newly prepared agricultural soil in a conventional system.

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Materials and methods

The experiment was carried at the University of São Paulo State - UNESP/Botucatu. The soil of the experimental area was classified according to Embrapa (2018) as Argisol type Red Yellow. For conventional soil preparation, plowing and harrowing operations were carried out to decompact the subsurface layer until reaching 0.3 m in depth. During the tests, the soil had an average moisture content of 21%.

In the compaction evaluations, a John Deere tractor, 4x2 TDA traction with 80.9kW of engine power, total mass of 6050kg, distributed 65% on the rear axle and 35% on the front axle was used. The tractor had bias-ply pneumatic wheels measures/(pressure) in the front 14.9-26/(137kPa) and 23.1-30/(124kPa) rear.

The treatments consisted of progressive tractor passes, with synchronous collection of soil penetration resistance. The treatments were: T1 – one tractor pass; T2 – five tractor passes; T3 – ten tractor passes, and T4 – Zero tractor passes (control), with four replications for each treatment. The collections were carried out in the center of the machine's traffic lane in the agricultural area at random points along a lane with 100 meters of prepared soil.

The soil penetration resistance (RSP) data were collected with the aid of a mechanical analog penetrograph of the brand Soilcompact® and the graphs and cone indices were prepared in an electronic spreadsheet of the Microsoft Excel 365 software. The data underwent normality tests, analysis of variance, and when applicable Tukey at 95% significance. RSP linear regression tests were applied at each soil depth. All statistical analyzes were performed using Minitab Software v.16

Results and discussion

The resistance to soil penetration as a function of different tractor passes can be observed by the cone index graph, through the median curves between the values of the repetitions of each treatment (Figure 1). The increase in penetration resistance as a function of different machine passes collaborates with the results obtained by Arcoverde et al. (2020), Valicheski et al. (2012), and Bergamin et al. (2010).

The results of the work showed that critical compaction occurs with greater intensity in the soil in the first passes of the tractor, but after the fifth pass of the machine on the ground the response and the increase in compaction occurred in a decelerated way.

Observing the cone index at different depths, the increase in RSP is verified up to a depth of 25 cm, which indicates the effective action depth of the plow and harrow tools. After the soil preparation and in the passages of the machine, the soil was progressively re-accommodated according to the passages of the tractor.

At a depth of 5cm, the prepared soil presented penetration resistance of 0.2MPa, with one pass of the RSP tractor it was increased by 450%; with five and ten passes, the percentage increase in RSP was 825 and 950%, respectively. Similar percentages of increase occur in the other depths up to 35 cm, where there is a balance between the RSP of all treatments.

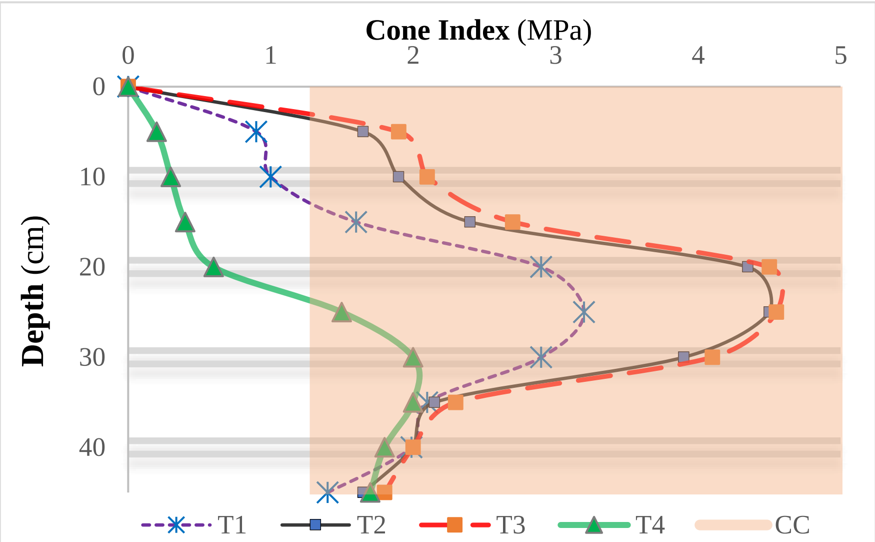

Figure 1. Soil penetration resistance (RSP) indices for treatments T1 (one tractor pass); T2 (5 tractor passes); T3 (10 tractor passes) and T4 (zero tractor passes, soil after preparation).

Olubanjo and Yessoufou (2019) obtained a reduction of 18.8% in corn productivity in compacted soil, with compaction negatively influencing the uptake of nutrients by the crop. The authors stated that corn should not be grown in soils with penetration resistance greater than 2MPa. In our research, the reference value CC was reached in the first pass of the tractor from 15 cm in depth. As vegetable crops intensively exploit this strip of soil, the results indicate losses in crop development already in first machine pass.

When we consider in general terms the percentage of RSP that the first pass of the tractor reached in relation to 10 passes (T3) on average, the first pass of the tractor increased by 60% of the maximum RSP reached.

The tractor was not ballasted at its maximum capacity, but compaction reached high levels that could be harmful to the root development of vegetable crops (Table 1).

Table 1. Results of the average test for soil penetration resistance (MPa) as a function of cone penetration depth (cm); SD: Standard Deviation.

Depth (cm)		5			10			20			30			40		
	C.V(%)	mean		S.D	mean		S.D	mean		S.D	mean		S.D	mean		S.D
T1	18,4	0,77	**b**	0,16	0,82	**b**	0,12	2,37	**b**	0,58	2,87	**ab**	0,37	1,17	**b**	0,22
T2	14,9	1,55	**a**	0,10	1,90	**a**	0,23	4,10	**a**	0,73	3,50	**ab**	0,47	2,22	**a**	0,55
T3	15,3	1,87	**a**	0,28	2,22	**a**	0,25	4,30	**a**	0,64	3,75	**a**	0,52	2,02	**a**	0,43
T4	32,2	0,12	**c**	0,05	0,22	**c**	0,09	0,40	**c**	0,2	2,67	**b**	0,23	1,20	**b**	0,24

*Means with the same letters do not differ statistically between treatments according to the Tukey test at 5%.

The result of the average comparison test proves a statistical difference between the passages, depending on the different soil depths. It is interesting to note that in T4 the lowest values represent the mobilized area and an initial critical compaction from 30 cm, that is, the conventional soil preparation was not able to decompact the soil in the subsurface.

Ungureanu, Vladut and Cujbescu (2019) found critical compaction after passing an agricultural sprayer in orchards and stated that, to reduce soil compaction, the ideal situation was to decrease tire inflation pressure, which increases tire deformation and the tire/ground contact area, attenuating the compaction process. The authors stated that tires with higher inflation pressure have smaller contact areas with the ground and compaction reaches greater depths in the ground. In this research we worked with the pressure recommended by the tire manufacturer, however the reduction of the internal pressure of the tire could have mitigated the impact on the ground. Further investigations may address this issue in the future.

Compaction at 30 and 40 cm showed no significant difference between treatments T1 and T4; T3 and T2 respectively, a fact that may have been due to the initial compaction found in the control treatment, and to the high coefficient of variation found. It is important to emphasize that between treatments T2 and T3 there was no statistical difference at any of the depths, which indicates that the soil reached its maximum compaction point as a function of the applied load after the five passes of the machine, not representing differences in the levels of penetration resistance after this procedure.

Arcoverde et al. (2020), in an analysis of soil compaction as a function of different tractor passes, did not find limiting factors of compaction for the no-tillage system, which makes it possible to infer that soil cover affects the response to compaction.

It is not just the tractor and machines that cause soil compaction, animal production can have negative effects on crop productivity. Hargreaves et al. (2019) evaluated the impact of animal trampling and the traffic of tractors in a silage production area, where they found a 19% reduction in the productivity of the first cut in the area where animals entered, and of 37.7% in the area where it occurred. traffic with agricultural tractor, demonstrating that the intensity of soil compaction directly affects the productivity of the vegetable crop.

Colombi and Keller (2019), studying the relationship between root growth and soil compaction, stated that, in compacted soils, root elongation was the process that suffered the most delay, causing losses in the absorption of water and nutrients by the plants. plants, making them more susceptible to periods of drought.

Figure 2 demonstrates the regression of median soil penetration resistance data at each depth evaluated as a function of tractor passages over the soil. There are adjustments with a high correlation between the increase in RSP as a function of the increase in tractor passes. The highest angular coefficient was obtained at a depth of 20 cm, precisely at the depth at which the maximum RSP occurred between treatments.

Knowing the exact location of soil compaction, it is possible to determine methods and ways of mitigating the problem. Our methodological application can be implemented to control soil compaction in commercial agricultural units.

Moraes et al. (2020) in a study relating soybean yield to soil compaction, obtained the best yield results in no-tillage (DPT) systems, without soil disturbance, with higher grain yields compared to areas that were subsoiled. According to the authors, subsoiling increased the number of macro pores, increased root elongation, but made the crop more sensitive to water stress, with a negative impact on productivity.

Esteban et al. (2019) found an increase of 17.9% and 18.5% in the dry mass of sugarcane roots in alternating single and double spacing, respectively, when the traffic direction and control system was used in the field. The authors stated that the implementation of controlled traffic provided gains in the final productivity of sugarcane. Traffic control is a way to avoid the damage caused to the ground by the first passes of the machines, as evidenced in this research.

Conclusions

The greatest intensity soil compaction (60%) occurs in the first passage of the tractor over the soil, after five passes of the tractor the soil does not present a significant increase in compaction.

At depths of 20 to 30 cm, the largest RSPs were found. Considering that, after one pass of the machine, the soil becomes compacted, it is important to establish exclusive transit areas in agricultural areas, under penalty of permanent deformation of the soil in the first agricultural operations.

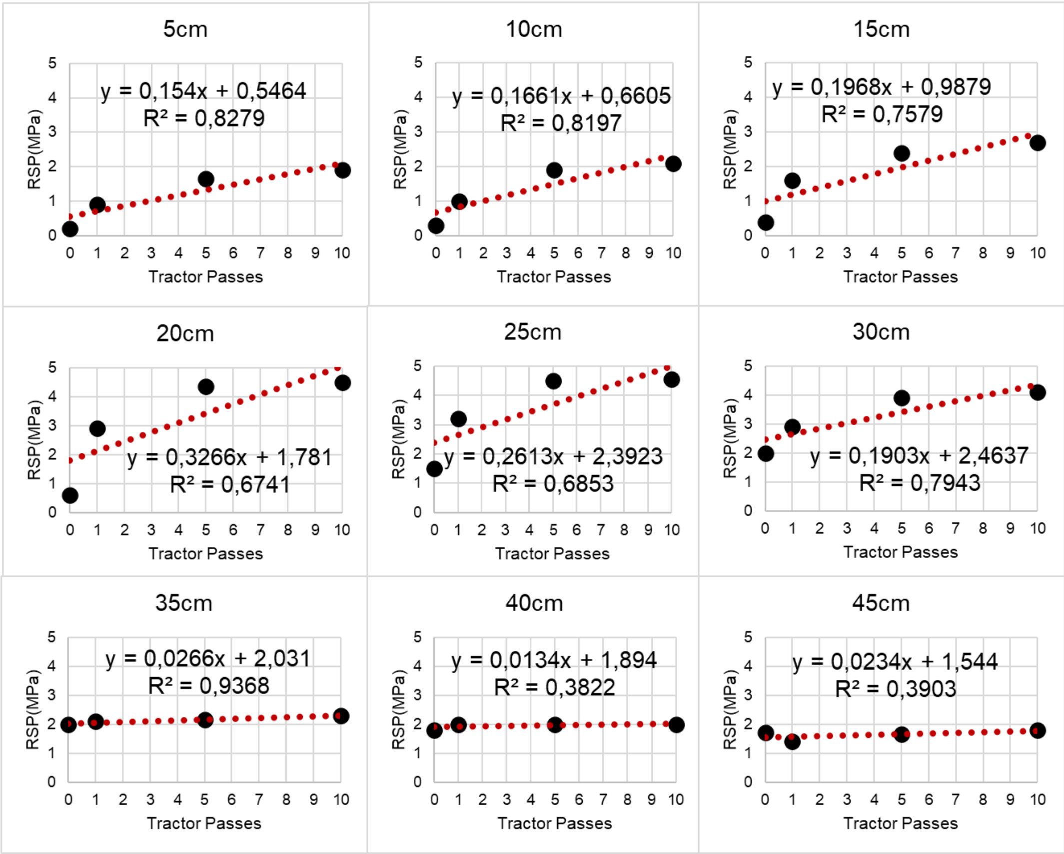

Figure 2. Regression coefficient between RSP at each depth as a function of agricultural tractor passes.

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