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ORIGINAL ARTICLE

Preconsolidation of Ultisol subjected to the traffic of agricultural tractors

Pressão de preconsolidação de um Argissolo Vermelho-Amarelo submetido ao tráfego de trator agrícola

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ABSTRACT: The objective of this study was to evaluate the preconsolidation pressures and the coefficient of compressibility of the soil caused by the traffic of agricultural 4 × 2 tractors in yellow red argisol. For the uniaxial compression tests, three undisturbed 0-15 cm deep soil samples were randomly collected for the following situations: natural soil condition; after one and two wheel passes of a Valtra BM 120 4 × 2 TDA® tractor with 7100 kg total weight, with diagonal 14.4-24 R1 front tires with 82.74 kpa inflation pressure and 18.9-24 rl rear tires with 96.53 kpa inflation pressure, with tire-ground contact areas of 0.11 and 0.13 m^2, respectively, at the speed of 8 km h^{-1}. Soil samples were subjected to the uniaxial compression at pressures ranging from 25, 50, 100, 200, 400 and 800 kpa for 30 min. The tractor traffic increased the preconsolidation pressure of the soil. Tractor traffic influenced soil compression, thus emphasizing the need for strict control in decision-making regarding the number of wheel passes of machinery in agricultural areas in the studied soil.

RESUMO: *O objetivo deste trabalho foi avaliar as pressões de preconsolidação assim como o coeficiente de compressibilidade do solo provocado pelo tráfego de um trator agrícola 4 × 2 TDA sob um Argissolo Vermelho-Amarelo. Para os ensaios de compressão uniaxial, foram coletadas aleatoriamente três amostras com estrutura preservada do solo na profundidade de 0-0,20 m, para as seguintes situações: sem tráfego, uma passada e duas passadas de um trator, modelo VALTRA BM 120 4 × 2 TDA®, com peso total de 7.100 kg, pneus diagonais com dianteiros do tipo 14.9-24 R1 com pressão de inflação de 82,74 kPa, e pneus traseiros do tipo 18.4-30 R1 com pressão de inflação de 96,53 kPa; a área de contato pneu-solo apresentou valores de 0,11 e 0,13 m^2, respectivamente, para o pneu dianteiro e o pneu traseiro, com velocidade no momento das passadas de 2,22 m s^{-1}. As amostras de solo foram submetidas ao ensaio de compressão uniaxial com pressões que variaram entre 25, 50, 100, 200, 400 e 800 kPa, durante 30 min. O tráfego do trator contribuiu para o aumento da pressão de preconsolidação. O aumento da trafegabilidade de tratores agrícolas contribuiu para tornar o solo menos susceptível à compactação.*

KEYWORDS
Preconsolidation
Coefficient of compressibility
Additional compression

PALAVRAS-CHAVE
Preconsolidação
Coeficiente de compressibilidade
Compactação adicional

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1 Introduction

The need to obtain increased production per area unit has led researchers to develop techniques aiming at greater crop yields, which considerably increases the practice of mechanized farming that can cause soil compaction and harm its structure.

Soil compaction caused by agricultural machinery and equipment occurs mainly due to the pressure exerted by the wheelsets and the managing system (PINTO FILHO; DANTAS; PEREIRA, 2009). The rolling of tires on the ground generates stresses perpendicular and tangential to the surface. These stresses, also named normal stress and shear stress, are transmitted to the soil mass by the wheelset-soil contact area (BARBOSA et al., 2004).

Pressures applied on the soil with magnitude greater than its resistance tend to deform it plastically, increasing density and reducing porosity and the soil void ratio. According to Mosaddeghi et al. (2007), the change in volume can be expressed by the soil void ratio (the ratio between the volume of void space, or pores, and the volume of solid substance), porosity, or density of soil. These ratios depend on the soil characteristics and the history of stresses suffered by it; they are generically expressed by the soil compaction curve (KELLER et al., 2004a). Soil compressibility refers to the reduction in volume per unit of compressional energy. Soil porosity reduction occurs through the expelling of air and water and, optionally, under high pressure, through water compression and the deformation of solids (KELLER et al., 2004b). The relations between pressure and deformation are complex and differ greatly among soils, and vary with humidity within the same soil (GREGORY et al., 2006).

The process of soil compaction can be better assessed by the soil compaction curves, which are graphically represented by the relationship between a parameter related to soil structure (void ratio or soil density) and the logarithm of the pressure applied, allowing to estimate the changes that may occur in the soil structure (SILVA, 2008). Based on the soil compaction curve, it is possible to determine the preconsolidation pressure, which is the maximum pressure that the soil can withstand, as well as the compression coefficient, an indicator of the susceptibility of soil to compaction that represents the reduction of porosity in relation to the increased pressure applied (SILVA; CABEDA, 2006). This study was carried out in order to assess the soil compressibility parameters – preconsolidation pressure and coefficient of compressibility – with or without the traffic of front-wheel-assist farm tractors on Red-yellow Argisol.

2 Materials and Methods

The study was carried out on an experimental area of the ‘Pici’ campus of the Agricultural Engineering Department, Federal University of Ceará (UFC), Fortaleza, Ceará state, Brazil. According to Köppen’s classification, the region presents tropical rainy climate, Aw’ type, with average annual temperature of 28 °C and average annual rainfall of 900 mm. The area is located at the following georeferenced coordinates: 3° 44’ S and 38° 34’ 51’’ W, 26 m above sea level in average. The area had been in fallow for six months with growth of natural vegetation. The soil studied is classified as Red-yellow Argisol (EMBRAPA, 2006). In order to determine the physical characteristics of the soil, three samples with preserved structure were collected at random in the study area from the 0-20 cm deep layer with the aid of an Uhland soil sampler; the samples were then taken to the Laboratory so that soil density could be determined. Soon after, the samples were crumbled for determining particle density, physical limits (liquid limit, plastic limit and consistency limit), and granulometry, according to the methodology described by EMBRAPA (2006) (Table 1).

The experimental design was completely randomized with three treatments and three replicates. The following treatments were studied regarding the intensity of farm tractors traffic: a) no traffic (NT); b) one tractor roll (1R); and c) two tractor rolls (2R). The farm tractor used presented the following characteristics: VALTRA manufactured, model BM 120 4 × 2 front-wheel-assist®; total weight 7,100 kg; diagonal front tires 14.9-24 R1 type, with inflating pressure of 82.74 kPa; rear tires 18.4-24 R1 type, with inflating pressure of 96.53 kPa; tire-soil contact area of 0.11 and 0.13 m^2, for front and rear tires respectively; 2.22 m s^{-1} rolling speed. Nine soil samples with preserved structure were collected, three for each treatment, for uniaxial compression tests. Sampling was performed with the use of metal rings with 11 cm diameter and 9.5 cm height in the 0 to 20 cm layer. After collection, the samples were sealed with cotton cloth and paraffin to keep the humidity and history of stress found in the field. The soil samples were subjected to uniaxial compression testing according to the NBR-12007/90 norm (ABNT, 1990), in a densification hydraulic press, Solotest manufactured, sequentially applying static loads of 25, 50, 100, 200, 400 and 800 kPa, for 30 min each. After the uniaxial compression tests, a soil compaction curve was obtained, which represented graphically the relationship between the soil void ratio and the pressure applied, at the end of the load application period. The methodology developed by Casagrande (1936) was used for determining the preconsolidation pressure (σp) and the coefficient of compressibility (Cc). The data were submitted

Table 1. Physical characteristics of Red-yellow Argisol from the 0-0.20 m deep layer of the experimental area.

Textural classification	Sandy loam	Liquid limit	13.47
Particle density (g cm^{-3})	2.72	Plastic limit	NP
Soil density (g cm^{-3})	1.68	Shrinkage limit	NC
Porosity (cm^3 cm^{-3})	0.3623	Clay (g kg^{-1})	106.2
Initial saturation	62.13	Sand (g kg^{-1})	829.1
Sample unit	10.35	Silt (g kg^{-1})	64.6

to analysis of variance with the application of the Tukey's test at 5% probability level, for comparison of means. The analyses were performed using the statistical software ASSISTAT 7.6 BETA®.

3 Results and Discussion

The soil compaction curves are shown in Figure 1 for soils NT, 1R and 2R, presenting reduction of the soil void ratio with the increased logarithm of the pressure applied to soil surface. The greatest tractor traffic impact on the preconsolidation pressure occurred with two tractor rolls, which presented the highest value, corroborating Silva et al. (2003), who verified that the traffic of a farm tractor wheelset influenced the preconsolidation pressure, soil density and porosity of Dystrophic Red Latosol, considering that, as a rule, the roll of the rear wheelset contributed the most to the increased values on soil surface (0-20 cm), indicating the structural degradation of this soil. The values of preconsolidation pressure, in turn, increased with the number of rolls (Table 2). The mean values of gravimetric humidity, preconsolidation pressure, coefficient of compressibility, and porosity of the area subjected to different intensities of tractor traffic, obtained by the compressibility assays, are shown in Table 2. The preconsolidation pressure values increased 11.76 and 28.57% with the increase in the number of tractor rolls. An increase in the preconsolidation pressure, as a soil compaction indicator, was also verified by Silva, Reinert and Reichert (2002), who found that preconsolidation pressure values increased from 68 to 164 kPa when soil density increased from 1.3 to 1.6 cm^{-3} in Red-yellow Argisol. Increased preconsolidation pressure provides lower risk of additional compaction processes, since it makes the soil more resistant to plastic deformation when external pressures are applied (OLIVEIRA et al., 2011). Rena and Guimarães (2000) reported that soils with high mechanical resistance might favor machinery trafficability; however, they may severely alter the growth of the root system and the absorption of water and nutrients by the roots. The compression coefficient, as reported by Peng et al. (2004), reflects the decrease in the void ratio per unit increase in the logarithm of the compression coefficient, that is, the greater the compression coefficient, the more compressible the soil (LARSON; GRUPTA; USECHE, 1980). No significant difference was noticed in this parameter among the treatments (Table 2). The preconsolidation pressure and the coefficient of compressibility were inversely proportional (Table 2), which was also verified by Carpenedo (1994), when analyzing Dark-red Argisol. This shows that the soil resistance to compression increases as the preconsolidation pressure increases.

In sandy soils, there is predominance of macropores, which are responsible for aeration and water infiltration in the soil. According to Dexter (2004), in the process of soil compaction by machinery traffic, there are changes in the continuity and distribution of pores, and volume reduction of macropores, which undergo size reduction reaching micropore size, therefore making the soil more efficient in retaining water (SILVA et al., 2009); however, in this study, the total porosity after different traffic intensities did not differ statistically.

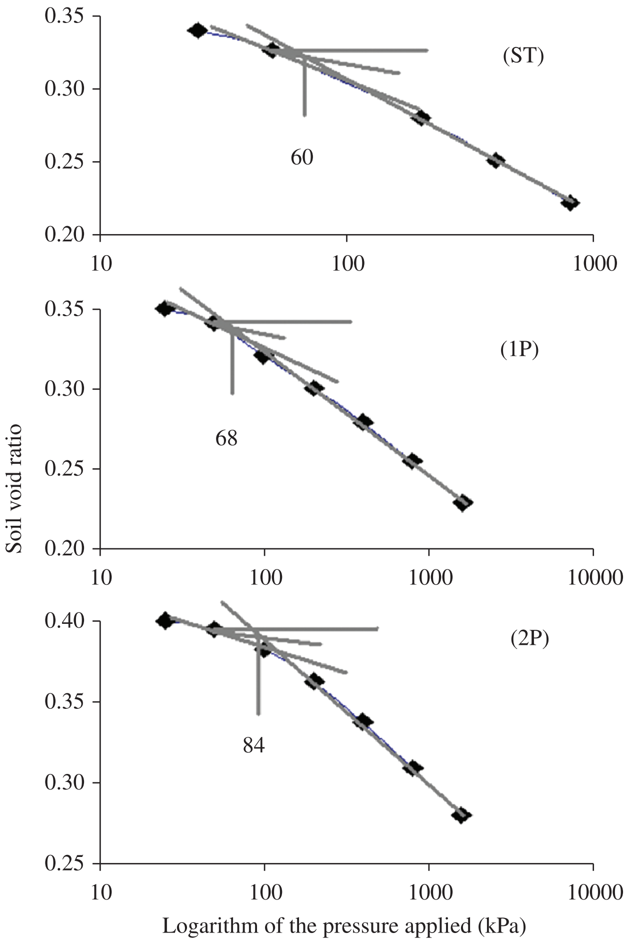

Figure 1. Soil compaction curves with no traffic (NT), one tractor roll (1R) and tow tractor rolls (2R).

Table 2. Humidity, preconsolidation pressure, coefficient of compressibility (Cc) and total porosity of a Red-yellow Argisol with means test for the levels of tractor rolls.

Treatments	Humidity (kg kg^{-1})	Preconsolidation pressure (kPa)	Coefficient of compressibility (Cc)	Total porosity(m^3 m^{-3})
No traffic	0.11	60 b	0.118 a	0,.4 a
One roll	0.11	68 ab	0.091 a	0.37 a
Two rolls	0.12	84 a	0.082 a	0.38 a

Means followed by different letters in the same column are significantly different at 5% probability level ($p \leq 0.05$).

4 Conclusions

The increase of agricultural machinery traffic contributed to the increased values of preconsolidation pressure. With the increased traffic of farm tractors on the area, the soil has become less susceptible to additional compaction.

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