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ORIGINAL ARTICLE

Elivânia Maria Sousa Nascimento[1*]
Marcelo Queiroz Amorim[1]
Karla Lúcia Batista Araújo[1]
Thereza Rhayane Barbosa Cavalcante[1]
Carlos Alessandro Chioderoli[1]

Shear strength and preconsolidation Red Yellow Acrisol from Northeast semiarid under conventional and no-tillage management

Pressão de preconsolidação e resistência ao cisalhamento de Argissolo Vermelho amarelo do semiárido nordestino sob manejo convencional e plantio direto

[1]Universidade Federal do Ceará – UFC, Av. Mister Hull, s/n, Campus do Pici, Bloco 804, 60450-760, Fortaleza, CE, Brasil
***Corresponding Author:**
E-mail: elivaniaufc@gmail.com

ABSTRACT: Currently the bigger limitation of the agricultural production and the quality of the environment of the mechanized areas is the compaction. The objective of this work was to evaluate the shear strength and the preconsolidation of a Red yellow Acrisol soil of the northeast semiarid, under conventional and no-tillage management. The soil samples were subject to uniaxial compression test where static loads of 25, 50, 100, 200, 400 and 800 were applied during 30 minutes. The tests of direct shear were realized with applying loads of 50, 100 and 200 kPa. The results showed that the maximum deformation, independent of management system, occurred in the three first minutes, of the application of the load. The shear stress increased as far as the normal tension was applied to the soil. The conventional management was more susceptible to pressures applied in the soil when compared to no-tillage system.

KEYWORDS
Machinery
Cohesion
Compaction

RESUMO: *Atualmente, um limitador da produção agrícola e da qualidade do solo das áreas mecanizadas é a compactação. O objetivo deste trabalho foi avaliar a preconsolidação e a resistência ao cisalhamento em Argissolo Vermelho amarelo do semiárido nordestino sob manejo convencional e plantio direto. As amostras de solo foram submetidas ao ensaio de compressão uniaxial utilizando cargas estáticas de 25, 50, 100, 200, 400 e 800 durante 30 minutos. Os ensaios de cisalhamento direto foram realizados aplicando-se cargas de 50, 100 e 200 kPa. Os resultados mostraram que a deformação máxima do solo, independente do sistema de manejo, ocorreu nos três primeiros minutos. A tensão de cisalhamento aumentou à medida que a tensão normal era aplicada ao solo. O manejo convencional foi mais susceptível as pressões aplicadas no solo quando comparado ao plantio direto.*

PALAVRAS-CHAVE
Máquinas agrícolas
Coesão
Compactação

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1 Introduction

Comparative studies of natural and agricultural environments have shown physical and mechanical degradation of soil properties under intense cultivation (Iori et al., 2012). Currently the bigger limitation of the agricultural production and the quality of the environment of the mechanized areas is the compaction (Gontijo et al., 2007). The principals causes of the compaction of the soil are the intensive use of the machines and agricultural implements and the animal trampling resulting in the increase of the density of the soil and reduction of the total porosity and of the macroporosity of the soil (Stone et al., 2002; Bortoluzzi et al., 2008) of this way increasing the resistance of growing of the roots, decreasing the potential of water and increasing the lack of oxygen in the soil. Soil compaction often prevents the growth of plant roots, and therefore the absorption of water and nutrients (Way et al., 2009), negatively affecting crop growth and resulting in low productivity (Patel & Mani, 2011).

The management system can exert great influence in the parameters of compaction and compressibility of the soil (Silva & Cabeda, 2006) what can reflect in changes in his capacity of load bearing support. The agricultural soils well managed are sufficiently porous, with the structural space containing macropores unsaturated and with heterogeneous distribution of nominal diameter of particles.

In the conventional management the superficial layer of the soil is resolved through plowing and harrowing, what increases the porosity of the soil in this layer (Bortoluzzi et al., 2008). In the no-tillage system, is more hard to remove the compaction of the soil, because the mechanical mobilization, is not recommended practice, only in the sowing row.

As from tests as experiments of uniaxial compression is possible derive, for example, the compressibility, the pressure of pre consolidation, compression index, and as from tests of shearing, derives the cohesion and the angle of intern friction of the soil, and shear strength (Arvidsson & Keller, 2004). Dexter et al. (2007) in their studies verified that when a pressure compressive is applied on the soil, the principals' effects occur due to reduction of the porous space, especially of macropores.

The curve of compression of the soil, that relates the deformation with the applied load, allows estimate parameters that will serves to analyze the compaction of the soil, as from this analysis we get the pressure of pre consolidation, that is the estimate of the capacity of load bearing of the soil (Dias Junior et al., 2005) and the coefficient of compressibility that is an indicative of susceptibility of the soil to compaction. In according Mion et al. (2013) 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.

The compression curve has been determined with loads that last 5 min (Braida et al., 2008), 7 min (Silva & Cabeda, 2006), 30 min (Veiga et al., 2007) and 2 h (Canarache et al., 2000). They also argue that the times of application of each pressure were necessary for that the soil reach approximately 98% of the maximum deformation, however, few works have determined the curve of compression of the soil applying short times (0.5 a 1.0 min) of loads in the test of uniaxial compression, simulating the time of compression of the soil imposed for agricultural machines in the activities of cultivation (Kutilek et al., 2006).

The resistance of the soil to shear can be used as an indicator of compaction of the soil, usually the most compressed soils presents more resistance to shear (Secco, 2003), by means of smaller distance between the particles, conferring consequently smaller empty index and larger effort to prepare them to cultivation. The resistance of a soil to shear is determined for the cohesions and frictional characteristics between the particles of the soil, defined as the maximum shear stress that the soil can suffer without rupture (Pinto, 2000). In accord with Silva & Cabeda (2005) in soils of sandy texture the shear strength depends basically of the friction between the particles, whose angle of intern friction depends of the form of the grains, distribution of the grains and level of compaction of the soil.

Through the above, it was objectified with this study to evaluate the compressibility and shear strength in Red yellow Acrisol the northeastern semiarid region under conventional tillage and no-tillage.

2 Material and Methods

The experiment was conducted in the experimental area from University Federal of Ceara, in the city of Fortaleza, state of Ceará, situated in the geographic coordinates 3° 44'45" S and 38° 34'55" W and with 19.5 m above of the medium level of the sea. The climate is part of the second classification by Koppen as Aw', wet tropical, with average annual temperature of 28 °C and precipitation of 900 mm.

The soil of the area was classified as Red Yellow Acrisol (EMBRAPA, 2013). The area with conventional management was cultivated with spontaneous vegetation and had been fallow for six months and the area of no-tillage was in fallow to implantation of sesame, previously, the area was being managed by the sunflower crop. For determination of the physical properties of the soil (Table 1) undeformed samples of soil were collected randomly at 0-0.20 m depth, using a Uhland-type sampler, after the samples were took to Laboratory of Soil Analysis, Federal University of Ceará, for determination of particle density, bulk density and granulometry according to the methodology of EMBRAPA (2011).

For the tests of uniaxial compression and direct shear three samples were collected in order aleatory, in box of 0.50 × 0.50 × 0.50 m, in each area, where trenches were

Table 1. Physics characteristics of the soil area evaluated.

Tabela 1. Características físicas do solo da área avaliada.

Characteristics	Area	
	Conventional	No-tillage
Texture classification	Sandy-loam	Sandy-loam
Particle density (g cm^{-3})	2.72	2.62
Soil density (g cm^{-3})	1.68	1.72
Porosity (m^3 m^{-3})	0.35	0.36
Initial saturation	48.54	62.13
Sample moisture (g kg^{-1})	0.08	0.15
Clay (%)	10.62	11.20
Sand (%)	82.91	82.40
Silt (%)	6.46	6.54

opened to realization of data collection in the depth of 0-0.20 m, after the samples were waterproofed using paper film and paraffin, objectifying keep the moisture, which at the time in collection is was 0.08 and 0.15 $m^3 m^{-3}$, respectively, conventional management and no-tillage. The determination of these attributes allowed does a current evaluation of the effect of management above the structure of the soil.

To determinate the values of the attributes of the soil, the test samples were submitted to tests of compressibility, using an odometer. The soil samples were submitted to uniaxial compression tests following the standard NBR-12007/90 (ABNT, 1990), in a press densification from Solotest1 brand, where static loads of 25, 50, 100, 200, 400 and 800 kPa were applied during 30 min (Figure 1).

From uniaxial test was obtained the compression curve of the soil that represents graphically the relation between the logarithm of the applied pressure and the void index (Casagrande, 1936). For determination of the precompression stress (σp) and of the coefficient of compressibility (Cc) used the method proposed for Pacheco & Silva, described NBR-12007/90 (Abnt, 1990). The Cc corresponded to tangent of the angle of inclination of the virgin compression line, determined in accord with the same standard.

The tests of direct shear were realized applying loads of 50, 100 and 200 kPa suggested by Brandt (2005) when treating a Red Yellow Acrisol. In each loading there was a period of stabilization of 10 min before begin the data collection. After the realization of the tests it plotted the values of normal tension versus shear stress getting a line whose inclination represents the angle in internal friction and the point of intersection of this line with the ordinate axis define the cohesion of the soil. The speed used in the test was 2.25 m s^{-1} realized in table of direct shear from Pavitest (L-1073) brand with load cell type "Z" an capacity to 500 kgf belong Laboratory of Mechanic of the Soils and Paving of the Course of Civil Engineering of the UFC.

3 Results and Discussions

With the increase of the applied pressure, there was a reduction in the empty index (Figure 2A and 2B) mainly no-tillage system, where the empty index varied of 0.31 to 0.16, while in the, conventional management this variation was of 0.53 to 0.31. The pressure of pre consolidation was of 42 and 50 kPa, respective, conventional management and no-tillage. Notice that the compressibility of the soil accentuates when the pressure exceeds the load of pre consolidation. The management system interfered in the pressure of preconsolidation of the soil, the maintenance of the crop residues in the surface of the soil afforded the increase of pressure of pre consolidation causing a bigger protection of the soil against the direct impact of the applied forces in the surface in relation to his incorporation through conventional system.

The compression index was of 0.13 and 0.09 for conventional management and no-tillage, and reflects the decrease in the empty index per unit increase in the logarithm of the pressure of compression (Figure 2A and 2B). How much smaller the compressions index of the soil bigger the aggregation of these soils. Mion et al. (2014) working with Alfissol in the conventional system found coefficient of compressibility in the layer de 0-0.20 m of 0.11, 0.09 and 0.082, respectively, after traffic, one and two passes of a tractor.

In the Figure 3A and 3B, shows the curves of shear stress versus horizontal displacement obtained in the direct shear tests of samples collected in the conventional system and direct

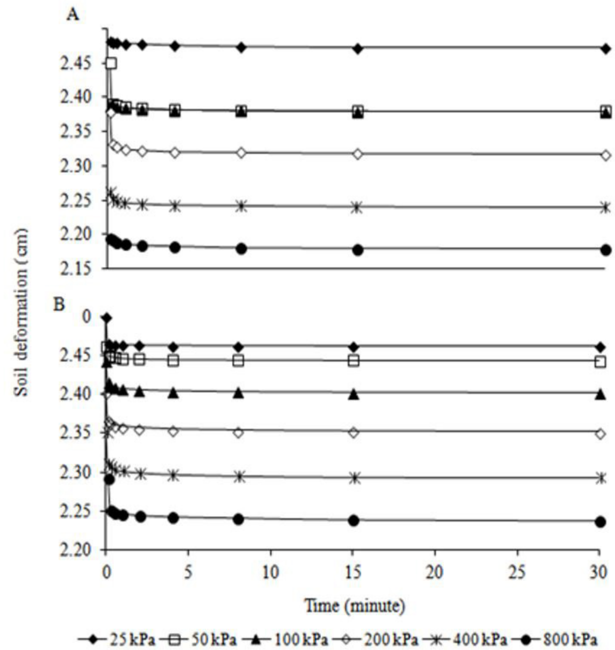

Figure 1. Soil deformation versus time of load application to conventional management (A) and no-tillage (B).

Figura 1. Deformação horizontal versus carga aplicada no manejo convencional (A) e sistema de plantio direto (B).

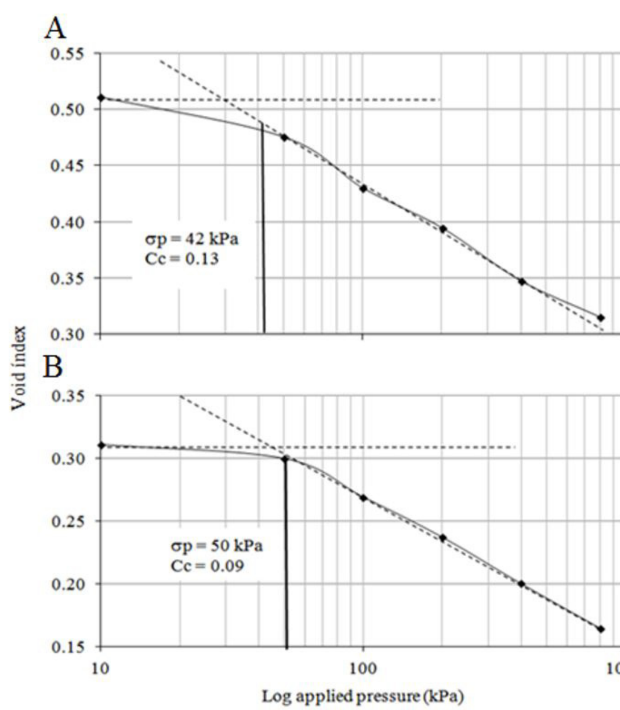

Figure 2. Empty index versus decimal logarithm of the applied pressure in the conventional tillage (A) and no-tillage (B).

Figura 2. Índice de vazios versus logaritmo da pressão aplicada no manejo convencional (A) e sistema plantio direto (B).

non-tillage management of the soil in the period 1 min. It is observed that with increasing normal stress was increased shear stress with reduced horizontal displacement. Conventional soil system showed shear stress below the tillage system. Silva et al. (2009) also observed that soil shear strength increased with the applied normal stress, resulting in greater contact between soil particles and greater internal friction angle.

The shear stress versus the normal tension evaluated in the depth of 0-0.020 m it is shows in Figure 4, for which verify that the shear stress increase as the normal tension is applied on the soil. The disruption of the soil of the area in the conventional management occurred with a shear stress of 82 kPa. The soil of no-tillage area was ruptured with a shear stress of 103.5 kPa, while the normal tension was 200 kPa. The angle of intern friction was 22.19° and 27.24°, respectively, conventional and no-tillage management. The soils didn't present cohesion between the particles. Silva et al. (2004) and Carvalho et al. (2010) verified that soil use and management can influence cohesion intercept, internal friction angle and, therefore, shear stress.

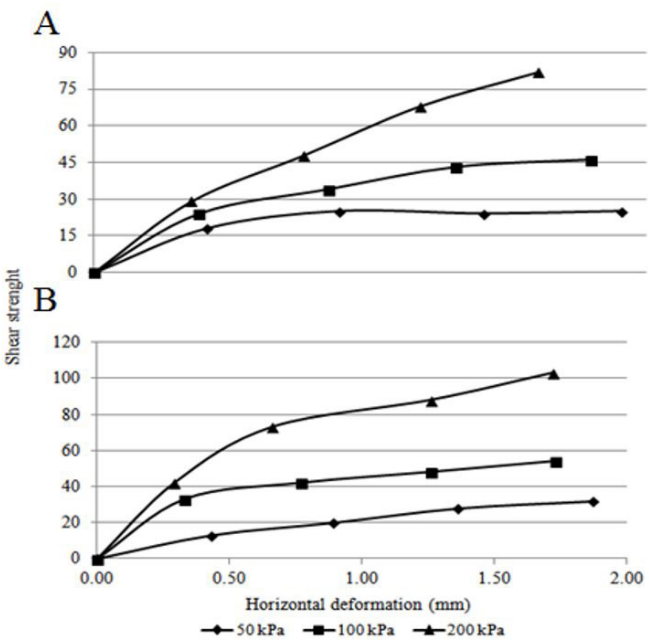

Figure 3. Shear strenght versus horizontal deformation soil submitted pressure 50, 100 and 200 kPa in the conventional tillage (A) and no-tillage (B).

Figura 3. Tensão de cisalhamento versus deformação horizontal do solo submetido às pressões de 50, 100 e 200 kPa no manejo convencional (A) e plantio direto (B).

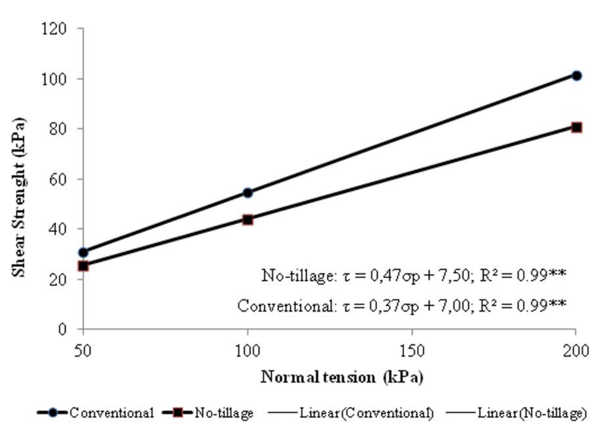

Figure 4. Shear stronght (τ) *versus* normal tension (σp) of the soil in the conventional tillage and no-tillage.

Figura 4. Tensão de cisalhamento (τ) versus tensão normal (σp) do solo no manejo convencional e plantio direto.

With the increase of loading occurred the decrease of empty index, consequently, the increase of the angle of intern friction. When use loads smaller than value of shear stress, the soil keeps intact. However, when pressures bigger than that are applied occurs ruptures. This value was smaller than the normal tension that was 200 kPa. This happened because in these soil the aggregation is weak, especially is his superficial layer, that contains nearly of 83% of sand is due to lack of cohesion of the soil that provides reduction of shear stress (Rosa, 2007).

In their studies with system of management of soils, Silva & Cabeda (2005), rainfed type, and costal tableland found an angle of intern friction of 39° and 32°, however, Secco (2003) found medium values of angle of friction to depths of 0-0.05, 0.7-0.12 and 0.20-0.25 m, were, respectively, 26, 28 and 29, without significant difference, and the general average was 28°, in a Red Latosol. Showing the difference of these values according to soil texture, since these parameters are intrinsic characteristics of the soil, because are dependents of other properties and characteristics. Lima (2004) affirm that the friction between the particles is bigger than sandy soils, what difficult the movement of the solid particles and the deformation of the soil. The wrappers of shear strength for all studied tensions present a constant inclination along of range of pressures used.

4 Conclusions

The conventional management was more susceptible to pressures applied in the soil when compared to no-tillage system, consequently, showed increment in the compress index.

The shear strength was higher in the conventional management when compared to the no-tillage system.

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