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STRUCTURAL POROSITY AS RATIO OF SOIL COMPACTION IN NO-TILLAGE AND MINIMUM TILLAGE SYSTEM

ABSTRACT

SUMMARY: Soil tillage systems and traffic of machines modify the soil structural porosity leading to serious changes in the soil compaction, making them still difficult to characterize. Soil conservationist management system creates favorable conditions to the development of the cultures, making possible appropriate conservation of the soil and of the water. Modifications in the soil structure need studies to determine the best management, improving its productivity making its resources naturals economically sustainable. Soil structural porosity was analyzed at no tillage (NT) and minimum tillage (MT) systems, in experimental area in Foz do Iguaçu, Western of Paraná, whose production has been carried out during five years under NT system, at an Alfisol soil. The samples were collected before wheat seeding and after its crop harvest for determination of particles density, soil bulk density, textural density and soil organic carbon content from depths 0.00-0.05, 0.05-0.10, 0.10-0.15 and 0.15-0.20m. No tillage system favored greater structural porosity in the layer depth from 0 to 0.05 m. The structural porosity is altered when this is compared before the seeding and after its crop harvest in the minimum tillage system.

Key words: tillage system, textural density, machine traffic.

POROSIDADE ESTRUTURAL COMO INDICE DE COMPACTAÇÃO DO SOLO EM SISTEMA DE PLANTIO DIRETO E CULTIVO MINIMO

RESUMO

Sistemas de cultivos do solo e trafego de máquinas modificam a porosidade estrutural do solo conduzindo a sérias mudanças na compactação do solo, tornando-as ainda difíceis de caracterizar. O manejo conservacionista do solo cria condições favoráveis ao desenvolvimento das

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culturas, possibilitando adequada conservação do solo e da água. As modificações na estrutura do solo necessitam de estudos para determinar o manejo mais adequado, melhorando a produtividade e proporcionar a sustentabilidade do solo. A porosidade estrutural do solo foi avaliada em sistemas de plantio direto (PD) e cultivo mínimo (CM), em área experimental no município de Foz do Iguaçu, Oeste do Paraná, com histórico de cinco anos sob PD, sendo o solo classificado como NITOSSOLO. As amostras foram coletadas antes da semeadura e após a colheita do trigo para determinação de densidade de partículas, densidade do solo, densidade textural e teor de carbono orgânico do solo nas profundidades de 0,00-0,05; 0,05-0;10; 0,10-0,15 e 0,15-0,20 m. O sistema de plantio direto propiciou maior porosidade estrutural na camada de 0 a 0,05 m de profundidade. A porosidade estrutural é alterada quando esta é comparada antes da semeadura e após a colheita de trigo no sistema de cultivo mínimo.

Palavras-Chaves: tráfego de maquinas, densidade textural, mudança estrutural.

INTRODUÇÃO

The soil structural quality is important in studies of soil management, seeding emergence, root development and soil compaction. Soil compaction reduces the aeration and the infiltration of the water in the soil, which increases the risk of erosion and threatens the quality of the agricultural soil (Soane & Van Ouwerkerk, 1995).

In addition, environmental degradation results from soil compaction and includes the losses of the air quality of the atmosphere and of the water of the soil due to changes of the use and soil management, specifically, in agricultural activities (Beriss et al. 2012).

Soil compaction reduces the structural porosity responsible for the soil aeration, a dynamic process that consists of the exchange of gases between the atmosphere and the air produced by aerobic respiration by the roots of the plants and microorganism (Stepnieweki et al., 1994). The aeration is dynamic because the oxygen consumption depends on the temperature, on the availability of organic matter for oxidation, on the composition of the soil air and on the structural pores volume.

Soil organic matter is viewed as the most important factor in evaluation soil management systems affecting soil quality and therefore agricultural sustainability (Sollins et al., 1996 and Salinas-Garcia et al., 1997). However, the effects of the tillage methods on decomposition rates of organic matter are dependent on soil type, mainly texture and mineralogy (Bayer et al. 2000). In a clay (680 g kg-1) Oxisol, Bayer (1996) from Southern Brazil, did not detect difference between the effect of tillage method on soil organic matter decomposition rates (k = 0,014 per year under conventional tillage and 0,012 per year under no-tillage).

Several researches have been showing that the risks of the soil compaction reduce significantly with the direct drilling system and report the incorporation of the organic matter of the soil and the residues of culture in the soil surface like principal responsible (Richard, et al., 2001, Pereira et al., 2007).

Structural porosity is the best indication of the structural condition of the soil because it is associated with the aeration of the soil.

To understand and to quantify the impact of the land use and management on soil physical quality are basic requirements in order to develop agricultural sustainable systems (Dexter and Youngs, 1992).

The objective of this work was to value the effect of the direct drilling and minimum tillage system in the changes at the soil structural porosity as affected by the soil compaction.

MATERIAL AND METHODS

The experimental site, is located at the Agricultural Farm near Foz do Iguaçu, in Paraná (25°26’ S, 54°29’W) and the sampling was carried out in 2004/2005 with an area of 0,2 ha. The soil (Nitossolo , Brazilian classification EMBRAPA, 1999; Alfisol, FAO – UNESCO, 1975) is clayey averaging 630, 220, and 150 g kg^{-1} for clay, silt and sand, respectively. According to Koppen’s system the climate is classified as Cfb (mesothermic, wet with a mean annual precipitation and temperature of 1955 mm and 23 °C, respectively.

The area was used during five years with no tillage. Previously the conventional system was used, with tillage successive of wheat in the winter and soybean in the summer, without rotation of crops. Before the drilling the wheat, the samples were collected for determination of the soil bulk density, particles density, textural density and organic matter of the soil. The minimum tillage was carried out by the mobilization of the soil with scarification to 20 cm of depth.

Sampling Procedures

Undisturbed samples were collected from the 0 – 5, 5 – 10, 10 – 15 and 15 - 20 cm layer of each plot of each management system before sowing and after the harvest for determination of the soil bulk density at four locations at each sampling site. It was used a steel cylindrical sampler (24 mm of height with 70 mm of internal diameter) with four repetitions. Disturbed samples were collected for organic matter and mechanical analysis. Soil bulk density was obtained from gravimetric weights of cores before and after oven-drying, and the volume of the core

Texture and soil organic matter determination

Samples were collected and treated with hydrogen peroxide to eliminate organic components. Sedimentation and densimeter methods were used to determine soil texture, after dispersion with sodium hexametaphosfate. Soil organic matter was also determined following loss on ignition method Raij et al. (2001). The results were expressed as (g dm^{-3}) mass of carbon for dry mass of soil.

Soil textural and structural porosity measurements

We determined porosity according to Monnier et al. (1973) as a function of pore origin. Soil porosity can be thought of as the sum of (i) macropores (structural pores) that result from tillage, traffic, weather and biological activity, and (ii) micropores (textural pores) that result from the arrangement of soil elementary particles. Structural pores are subjected to short-term variations such as compaction by wheeling, whereas compaction does not affect the textural porosity (Bruand & Cousin, 1995).

We can write:

$$e = e_t + e_s \quad (1)$$

where e is the total void ratio, e_t is the textural void ratio, and e_s is the structural void ratio.

The total void ratio can be calculated by:

$$e = \rho_s/\rho_d - 1 \quad (2)$$

where ρ_s is the soil particle density and ρ_d is the soil bulk density. We determined particle density by pycnometry (four replicates per soil). The textural void ratio was measured as a function of soil moisture on the aggregate fraction 2–3.15 mm using the kerosene method (Monnier et al., 1973). Therefore, we first calculated the total void ratio using Equation (2), and then calculated the structural void ratio using Equation (1).

Statistical analysis

It was used a factorial design 2 x 4 (two management systems and four depth), 0 - 5cm, 5 - 10cm, 10 - 15cm and 15 - 20cm with four repetitions. All statistical analyses were done using procedures of SISVAR version 5.0 (Ferreira, 2003).

RESULTS AND DISCUSSION

Results of the physics and organic properties of the soil before sowing are considered standard to compare the same properties after the harvest at management system because the soil at the last five years were working with no tillage system (table 1).

Soil carbon and bulk density

In the no-tillage system, the organic matter decreased significantly with the increase of depth of soil layer (table 1). In the minimum tillage system it was noticed a decrease significantly between the layers of 0 – 5, 5 – 10 and 10 – 15 cm. When we compare the two management systems we can notice that in the organic carbon level was on the average significantly higher under no-tillage (NT) than under minimum tillage (MT) only at soil layer of depth 15 - 20 cm. At no-tillage and minimum tillage system the average values of carbon were more uniform in layers 0 - 5 and 5 -10 cm showing little variation on carbon content. Our results are in accordance with Bayer (1996) what did not detect difference significant in soil with similar clay content. Pereira et al (2007) had encountered higher carbon level under no-tillage than under superficial tillage in a silty soil, reinforcing that the effects of the tillage methods on decomposition rates of organic matter are dependent on soil type, mainly texture and mineralogy (Bayer et al. 2000).

Table 1. Physics and structural soil characteristics under the treatments given as means. Means with the same letters small within each line and big within each column are not significantly different at P = 0.05.

Soil properties	**Period of sampling**	**Depth of soil layer (cm)**			
		0 - 5	**5 - 10**	**10 - 15**	**15 - 20**
C (g dm^{-3})	**Before sowing**	22.85aA	16.71bA	14.06cA	10.31dA
	AHNT	22.36aA	17.87bA	16.71cA	19.61dB
	AHMT	21.67aA	18.99bA	15.08cA	15.51cC
ρ_d (g cm^{-3})	**Before sowing**	1.10aA	1.37bA	1.37bA	1.31cA
	AHNT	1.12aA	1.28bB	1.32cB	1.28bA
	AHMT	1.43aB	1.49bC	1.32cB	1.16dB
e_s (%)	**Before sowing**	0.769aA	0.373bA	0.373bA	0.461cA
	AHNT	0.730aA	0.497bB	0.444cB	0.509bB
	AHMT	0.264aB	0.232bC	0.444cB	0.726dC
ρ_s (g cm^{-3})		2.41	2.41	2.57	2.68
ρ_t (g cm^{-3})		1.70	1.74	1.71	1.69

AHNT, after harvest no-tillage system; AHMT, after harvest minimum tillage system.

Soil bulk density in the depth layer from 0 - 5 and 5 - 10 cm was significantly lower for no-tillage than minimum tillage system (table 1). For depth layer from 15 – 20 cm, the no-tillage system had significantly higher bulk density (1.28 g cm^{-3} no-tillage and 1.16 g cm^{-3} minimum tillage). There was no difference significant between bulk density at no-tillage system in the depth layer from 0 – 5 cm, before sowing and after harvest;

however, the bulk density was significantly lower after harvest than before sowing in the depth layer 5 - 10 and 10 - 15 cm. Tillage practice significantly changed soil bulk density. Within the superficial layer 0 - 10 cm, soils under no-tillage had lower bulk density than those with minimum tilled, whereas only at soil depth layer from 15 – 20 cm soil under minimum tillage had bulk density lower than no-tillage. As expected, at no-tillage system, soil stubble improves the physical quality by activity of the microorganisms and roots of plants acting in the formation of the pores volume. Soil bulk density is influenced by management system. Stirring up the soil increases oxidation of the organic compounds that lose its action cementing of aggregation inducing the reduction of the porosity as result of the subdivision of coarse aggregates. With supportive results from this research and other published data (Dam et al., 2005; Li et al., 2011), we can conclude that, after more than 5 years of no-tillage, the lower soil bulk density was likely due to reduced tillage and crop residues maintained on the soil surface. Our results were opposite those obtained for Horn (2004), reporting an increase in bulk density from 1.40 Mg m^{-3} to 1.65 Mg m^{-3} after 7 years of conservation tillage.

Soil structural porosity

Analysis of pore attributes, and directly related properties, provided further evidence of effects of tillage on soil structure. Concomitant with smaller bulk densities, the structural void ratio and associated small textural density (□t) tend to be largest in no-tillage soil in topsoil layer and minimum tillage soil in layer after 15 cm (table 1, figure 1).

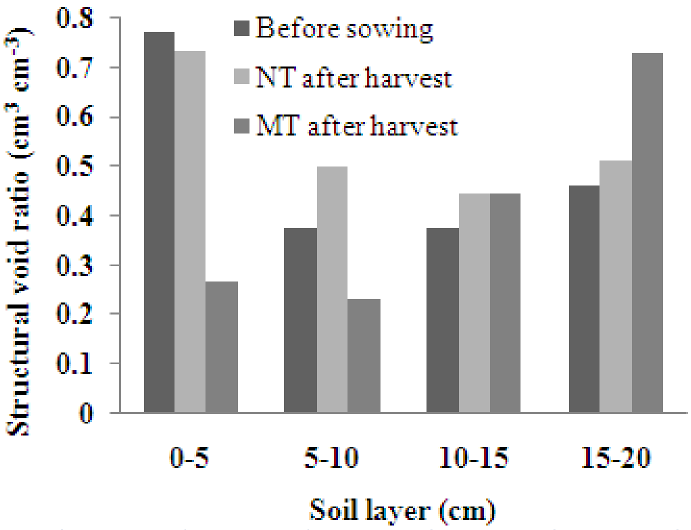

Figure 1. Structural void ratio in function of soil depth layer in management system.

After 5 years at no-tillage the structural void ratio decreases significantly till depth layer from 10 - 15 cm with value larger in the depth layer from 0 to 5 cm (table 1, figure 1). There was an increase significant of the structural void ratio in no-tillage from period before sowing until after harvest on depth layer from 5 - 10 cm until 15 - 20 cm. The structural void ratio was smaller in minimum tillage system than no-tillage on depth from 0 – 5cm and 5 – 10 cm. Our results give information about the impact of no-tillage system and minimum tillage on soil structure change. Two factors contributed for increase of the structural void ratio into the topsoil surface (0 to 5 cm and 5 to 10 cm) in the no-tillage, the large carbon content with reflex direct in the low soil bulk density. Compaction by passage of wheels in the minimum tillage at superficial layer (0 - 5 and 5 - 10 cm) manifested itself primarily as a loss of structural pores which probably resulted in poorer aeration. Our results show that stirring up the soil in the minimum tillage system did not increase the porosity at soil superficial layer, contrasting those obtained for Stone and Silveira (2001).Using wide tyres, low profile tyres or bed systems can reduce soil compaction under arable soil (Ball et al., 1997). However, Coulomb et al, (1990) affirm that structural state at the time of operation is an important factor to analyze on its result.

CONCLUSIONS

The following conclusions were drawn from this study:

- At no-tillage and minimum tillage system the average values of carbon were more uniform in layers 0 - 5 and 5 -10 cm showing little variation on carbon content.
- Soil bulk density was significantly lower after harvest than before sowing in the depth layer 5 - 10 and 10 - 15 cm on no-tillage system. Tillage practice significantly changed soil bulk density.
- Soil bulk density is influenced by management system showing that stirring up the soil increases oxidation of the organic compounds that lose its action cementing of aggregation inducing the reduction of the porosity as result of the subdivision of coarse aggregates.

- Compaction by passage of wheels in the minimum tillage at superficial layer (0 - 5 and 5 - 10 cm) manifested itself primarily as a loss of structural pores which probably resulted in poorer aeration, whose results of this research show that stirring up the soil in the minimum tillage system did not increase the porosity at soil superficial layer

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