Soil macroporosity and saturated hydraulic conductivity and soybean and black beans yield in response to the degree of compactness

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1. Introduction

The ”degree of compactness” refers to as the current bulk density to some reference state or of maximum bulk density, is an alternative to compare the compaction in different soils. The reference state or maximum dry bulk density may be obtained by a static pressure of 200 kPa in the uniaxial compression test (Hakansson, 1990) or by the Proctor test (Carter, 1990; Twerdoff et al., 1999), in both tests using disturbed samples. Hakansson (1990) defined the “degree of compactness” for soil annually disturbed by tillage. However, Suzuki (2005) studied different managements under no-tillage in six soils of different particle sizes and proposed the load of 1600 kPa in the uniaxial compression test using undisturbed samples to obtain the reference bulk density. Klein et al. (2004) observed that the degree of compactness of the soil depends on the tillage system and it is a good parameter to indicate the soil physical quality. This study aimed to evaluate the influence of degree of compactness on soil macroporosity and saturated hydraulic conductivity and soybean and black beans height and yield in two different soils.

2. Material and methods

Several experiments were distributed in completely randomized blocks, in a Rhodic Hapludox (654 g kg^{-1} of clay and 260 g kg^{-1} of silt content in the depth of 0-0.30 m) and in aRhodic Paleudalf (92 g kg^{-1} of clay and 247 g kg^{-1} of silt content in the depth of 0-0.30 m). The treatments were:

(a) Rhodic Hapludox (Oxisol): Treatments: NT: no-tillage since the year of 1998; CP: no-tillage + chisel plough in december 2003; NTC: no-tillage + compaction by 4 passes of machine of approximately 10 Mg in december 2003. Soybean (*Glycine max*) was sown in december 2003 and soil physical parameters and crop yield were evaluated in the first semester of 2004.

(b) Rhodic Paleudalf (Alfisol): *Experiment 1*: NT: no-tillage since the year of 1989; CP: no-tillage + chisel plough in December of 2004; NTC: no-tillage + 4 passes of machine of approximately 10 Mg in the agricultural year 2001/2002 and 2002/2003. *Experiment 2*: NT: no-tillage since the year of 1989; CP: no-tillage + chisel plough in 2002 and february 2004; NTC: no-tillage + 4 passes of machine of approximately 10 Mg in the agricultural year 2001/2002. *Experiment 3*: NT: no-tillage since the year of 1989; CP: no-tillage + chisel plough in December of 2004; NTC: no-tillage + 4 passes of machine of approximately 10 Mg in the agricultural year 2002/2003.

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In *experiment 1* soybean and in the *experiments 2* and *3* black bean (*Phaseolus vulgaris*) were cropped. These crops were sown in December 2004 and in the first semester of 2005 were evaluated soil physical parameters and crops yield.

For both soils the macroporosity and degree of compactness, and height and crop yield were evaluated. Whereas the hydraulic conductivity using a permeameter of constant load was evaluated only for the Rhodic Paleudalf. The degree of compactness (DC) was calculated as: DC = 100 BD/BDref where, BD is the current bulk density and BDref is the bulk density of the same soil in a reference state obtained in the laboratory. The degree of compactness is expressed in percentage. To determine the current bulk density, soil cores were collected in six depth increments ranging from 0-0,30 m. Soil cores were oven-dried at 105°C and weight to obtain dry bulk density. To obtain the reference bulk density, soil cores were collected in the depth of 0.08 - 0.13 m, equilibrated at a tension of 33 kPa and submitted to the uniaxial compression test, applying sequential loading (0, 12,5, 25, 50, 100, 200, 400, 800 and 1600 kPa) on the same sample. The bulk density obtained in the end of the uniaxial compression test was considered as BDref, following procedure of Suzuki (2005).

3. Results and discussion

A decrease in soil macroporosity was observed with increase of degree of compactness (Figs. 1a, 1b). Lipiec et al. (1991) verified that the range of matric water potential in which air-filled porosity and penetration resistance are not restrictive for plant growth becomes narrower as the degree of compactness increases. Considering a macroporosity minimium of 0.10 $m^3 m^{-3}$ for the satisfactory growth and development of plants (Vomocil & Flocker, 1966), it corresponds to a degree of compactness of approximately 76% for the Rhodic Hapludox (Fig. 1a) and 86% for the Rhodic Paleudalf (Fig. 1b). Suzuki (2005) observed a degree of compactness of 75% for soils with 30-70% of clay and 89% for soils with 10% of clay, when considering the limit of 0.10 $m^3 m^{-3}$ of macroporosity. According to Hakansson & Lipiec (2000) when the degree of compactness is lower than approximately 85%, soil aeration and penetration resistance are not critical within the 10-1500 kPa tension range. Carter (1990) determined that 0.10 $m^3 m^{-3}$ of macroporosity corresponds to a degree of compactness of 89% for Ap horizon of two soils with, respectively, 12 and 7% of clay and 30 and 29% of silt (fine sandy loam). The hydraulic conductivity in the Rhodic Paleudalf decreased with an increase in the degree of compactness up to a limit of 91%, when the conductivity was nearly constant (0.1- 10 mm h^{-1}) (Fig. 1c). Soybean plants, in the Rhodic Hapludox, were tallest and showed highest yield in notillage with a degree of compactness of 85.6% (Figs. 2a, 2b). In the Rhodic Paleudalf tallest plants and the highest soybean yield were verified in no-tillage with a degree of compactness of 92.7% (Figs. 2c, 2d). This degree of compactness (92.7%) seems to be high for soybean crop, possibly suggesting that a smaller degree of compactness could present higher yield. Suzuki (2005) observed higher soybean yield with degree of compactness approximately 82% for Oxisols and 85% for Alfisols. Beutler et al. (2004) verified that the optimum degree of compactness to the soybean is 80% in an Oxisol of medium texture. Lipiec et al. (1991) observed for two soils with respectively 6 and 7% of clay and 68 and 15% of silt, that the barley yield decreased when degree of compactness in the plough layer exceeded values of approximately 88 and 91%, respectively for both soils. Carter (1990) verified that a degree of compactness among 77.5-84% presented a relative yield larger or equal to 95%. Hakansson (1990) on various types of soils verified the maximum barley yield with degree of compactness around 87%. These results obtained for other studies reinforce the possibility that this degree of compactness is high for soybean crop.

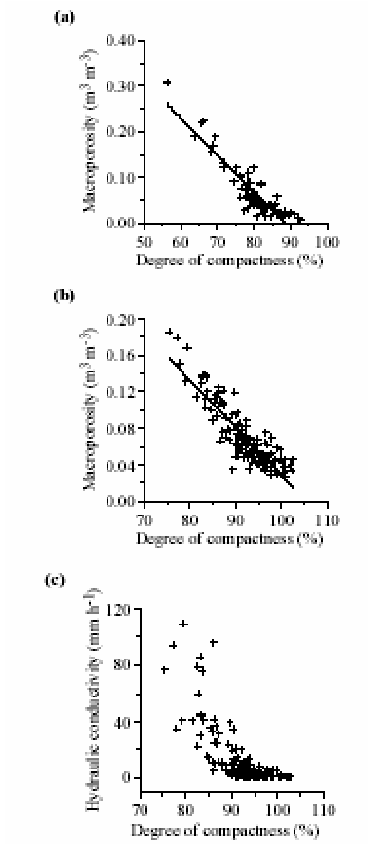

Fig. 1. Degree of compactness and macroporosity for the Rhodic Hapludox (a) and Rhodic Paleudalf (b), and hydraulic conductivity for the Rhodic Paleudalf (c).

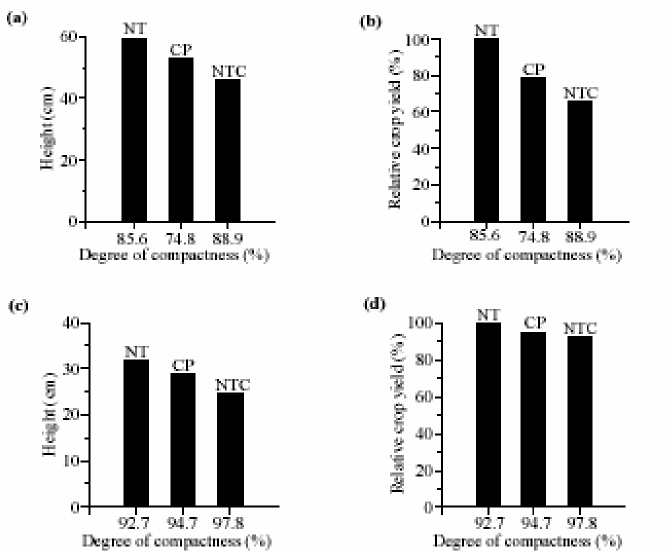

Fig. 2. Soybean plant height and yield for the Rhodic Hapludox (a, b) and Rhodic Paleudalf - *experiment* 1 (c, d).

Black bean crop, in both *experiments*, was taller with low degree of compactness (90.9-92.2%) (Figs. 3a, 3c), but the highest yields were obtained with intermediate degree of compactness (93.7-93.8%) (Figs. 3b, 3d). Differently from soybean crop, which seems to produce the highest yields with a degree of compactness around 80-90%, for black beans the highest yields were obtained with a degree of compactness up to 90%. Arvidsson & Hakansson (1991) state that the optimal degree of compactness differs between crop species; for instance, barley, wheat and sugar beet require a high degree of compactness, oats and peas require intermediate levels and potato a lower level.

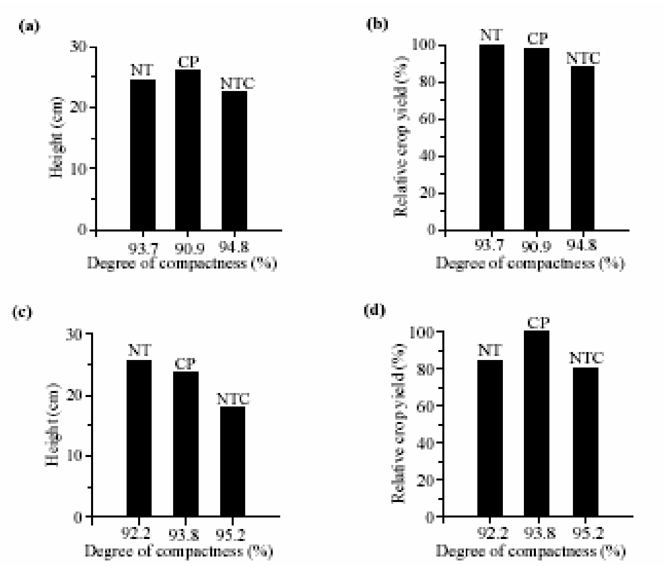

Fig. 3. Black bean plant height and yield in *experiment 2* (a, b) and *experiment 3* (c, d) for the Rhodic Paleudalf.

4. Conclusions

An increase in the degree of compactness caused a linear decrease in macroporosity and increase in penetration resistance, and an exponential decrease of the soil saturated hydraulic conductivity, showing satisfactory relation between these parameters and degree of compactness. The macroporosity of 0,10 m^3 m^{-3}, value considered minimum for the satisfactory growth and development of plants, corresponded to a degree of compactness of 76% for the Rhodic Hapludox and 86% for the Rhodic Paleudalf, representing an increase in the degree of compactness with decrease of clay content. Soil saturated hydraulic conductivity presented minimum values (0.1-10 mm h^{-1}) with degree of compactness up to a limit of 91%, which may be associated to a decrease in macroporosity when degree of compactness was 86%. The optimum degree of compactness for maximum yield of black bean was higher (94%) than for soybean (86% in the Rhodic Hapludox and 93% in the Rhodic Paleudalf), showing that the optimum degree of compactness is different between crops, being necessary its study for other crops.

Acknowledgment

To CNPq, CAPES and FAPERGS for financial and fellowship support.

References

Arvidsson, J., Hakansson, I., 1991. A model for estimating crop yield losses caused by soil compaction. Soil Tillage Res. 20, 319-332.

Beutler, A.N., Centurion, J.F., Roque, C.G, Ferraz, M.V., 2004. Densidade relativa de Latossolos e produtividade de soja. In: Manejo: Integrando a Ciência do Solo na Produção de Alimentos. In: Anais da Reunião Brasileira de Manejo e Conservação do Solo e da Água, 15, Santa Maria, Brasil, 25-30 julho. (CD-ROM)

Carter, M.R., 1990. Relative measures of soil bulk density to characterize compaction in tillage studies on fine sandy loams. Can. J. Soil Sci.70, 425-433.

Hakansson, I., 1990. A method for characterizing the state of compactness of the plough layer. Soil Tillage Res. 16, 105-120.

Hakansson, I., Lipiec, J., 2000. A review of the usefulness of relative bulk density values in studies of soil structure and compaction. Soil Tillage Res. 53, 71-85.

Klein, V.A., Massing, J.P., Câmara, R.K., Biasuz Júnior, I.J., Simon, M.A., 2004. Densidade máxima e relativa de solos sob plantio direto. In: Manejo: Integrando a Ciência do Solo na Produção de Alimentos. In: Anais da Reunião Brasileira de Manejo e Conservação do Solo e da Água, 15, Santa Maria, Brasil, 25-30 julho. (CD-ROM)

Lipiec, J., Hakansson, I., Tarkiewicz, S., Kossowski, J., 1991. Soil physical properties and growth of spring barley related to the degree of compactness of two soils. Soil Tillage Res. 19, 307-317.

Suzuki, L.E.A.S. Compactação do solo e sua influência nas propriedades físicas do solo e crescimento e rendimento de culturas. 2005. 149f. Dissertação (Mestrado em Ciência do Solo) – Universidade Federal de Santa Maria, Santa Maria, 2005. (in Portuguese with English abstract).

Twedorff, D.A., Chanasyk, D.S., Mapfumo, E., Naeth, M.A., Baron, V.S., 1999. Impacts of forage grazing and cultivation on near-surface relative compaction. Can. J. Soil Sci.79, 465-471.

Vomocil, J.A., Flocker, W.J., 1966. Effect of soil compaction on storage and movement of soil, air and water. Trans. Am. Soc. Agric. Eng. 4, 242-246.