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CHEMICAL AND PHYSICAL FRACTIONS OF THE ORGANIC CARBON OF A CAMBISOL AFTER 21 YEARS UNDER DIFFERENT TILLAGE

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ABSTRACT

Soil organic carbon is used as an indicator of soil quality. The objective of this study was to evaluate chemical and physical fractions of the organic carbon in a Humic Cambisol under different tillage for 21 years. The treatments were conventional tillage (CT) and no-tillage (NT). As reference area, a native grassland (NF), next to the experiment, was evaluated. Samples were collected at three depths. Total (TOC) and particulate organic carbon (POC) concentrations and stocks and humic substances (HS) were evaluated. The TOC and POC were higher in the NF than in the crop systems. NT has more carbon than CT in the humin and humic acid fractions in the surface soil. Physical fractions of organic carbon are similar between the management systems. NT has a greater organic carbon stock than CT 15 years after its development and shows greater potential for carbon conservation in the surface soil. Thus, long-term experiments are important to monitor soil behavior under different management conditions.

Keywords: Soil use, organic matter, humic substances

FRACIONAMENTO QUÍMICO E FÍSICO DO CARBONO ORGÂNICO DE UM CAMBISSOLO APÓS 21 ANOS SOB DIFERENTES PREPAROS

RESUMO

O carbono orgânico do solo é utilizado como indicador de qualidade do solo. O objetivo foi avaliar frações químicas e físicas do carbono orgânico do solo em um Cambissolo Húmico submetido a diferentes manejos após 21 anos. Os tratamentos são preparo convencional (PC) e semeadura direta (SD). Como área de referência foi avaliado o campo nativo (CN), localizado próximo ao experimento. As amostras foram coletadas em três profundidades. As concentrações e estoques de carbono orgânico total (COT) e de carbono orgânico particulado (COP), e as substâncias húmicas (SH) foram avaliados. O COT e COP foram maiores na condição no campo nativo (CN) do que nos solos cultivados. SD apresenta mais carbono na forma de humina e ácido húmico que PC na camada superficial do solo. As frações físicas do carbono orgânico foram semelhantes entre os diferentes sistemas de manejo. SD apresenta maior estoque de carbono que PC após 15 anos de manejo e mostra maior potencial para conservação do carbono na superfície do solo. Neste sentido, experimentos de longa duração são importantes para avaliar o comportamento do solo em diferentes condições de manejo.

Palavras-chave: Uso do solo, matéria orgânica, substâncias húmicas

INTRODUCTION

Soil organic carbon is used as one of the main indicators of soil quality (FONTANA et al., 2011; CAETANO et al., 2013) because it is sensitive to management practices, such as tillage and crop systems (GAZOLLA et al., 2015; SÁ et al., 2015). In conservation agriculture it is recommended reducing soil mobilization intensity and adopting practices such as crop rotation and intercropping with permanent soil cover through crops and residues, that can increase soil organic matter under subtropical climate conditions (BAYER & MIELNICZUK, 1997). The separation of the organic carbon fractions can identify different changes caused by soil management systems (SALVO et al., 2010). These variations can be evaluated by physical and chemical fractionation. The physical fractionation allows obtaining the particulate carbon that can relate to the non-humified fraction of the soil organic matter. In contrast, chemical fractions such as humic substances are more resistant to biodegradation due to their recalcitrance and interaction with soil mineral colloids, forming stable clay-humic complexes (GRINHUT et al., 2007).

It must be noted that the non-humid fraction presents a short-term occurrence in the soil and a higher decomposition rate (VON LÜTZOW et al., 2007). On the other hand, the humified fraction, which represents most of the organic carbon in tropical and subtropical soils, has greater persistence in the soil and is notable for influencing several soil physical and chemical properties (FIGUEIREDO et al., 2010).

The objective of the study was to evaluate chemical and physical fractions of organic carbon in a Humic Cambisol after 21 years submitted to no-tillage (NT) and conventional tillage (CT) and to compare with a reference area of native grassland (NF).

MATERIALS AND METHODS

The research was carried out in the south region of Brazil, in an area located at 27° 49' south latitude and 50° 20' west longitude, with an altitude of 937m. The soil is an Aluminum Humic Cambisol. The climate is subtropical humid with temperate summer, type Cfb according to Köppen, and average annual precipitation of 1533mm (SCHICK et al., 2014). In the 0-20 cm layer, the soil contains 443 g kg^{-1} of clay, 402 g kg^{-1} of silt and 155 g kg^{-1} of sand.

The experiment was conducted in a completely randomized design with four replications. The evaluated treatments were conventional tillage (CT) (one plowing followed by two harrows before summer and winter crops) and no-tillage (NT), installed in plots that are 6.5 m wide and 14.5 m long. Previously to the installation of the experiment, the area was covered by native pasture with grazing. Samples were collected from the native grassland (NF) in an area adjacent to the experiment, to serve as a reference in the evaluation of the different chemical and physical fractions of carbon and carbon stock.

During the 21 years of the experiment, grasses and legumes were used, and they were intercalated and rotated in the winter and summer crops. The crops used in the years of soil cultivation were corn, soybeans, and beans in the summer; and oats, forage turnip and vetch in the winter. In the period from 1995 to 2005, in the conventional tillage, crop residues were removed from the soil surface after harvesting the summer crops, followed by winter fallow, with the objective of accelerating the soil degradation process. After 2006, the residues were maintained on the soil surface. In the conventional tillage, crop establishment was carried out with conventional seeder after the soil tillage in the summer crops. In no-tillage, the summer crop establishment was carried out with mechanized seeders and the winter species were broadcast hand-sow. The native grassland area was maintained after the experiment establishment without grazing, with periodic mowing.

The carbon input in the soil by crop residues was estimated every season after the summer and winter crops, by the above ground dry mass production evaluated in each treatment. The crop residues were collected using a wooden rectangle of 40 x 60cm, weighed and dried at 60ºC to constant mass. The addition of organic carbon by crop residues was estimated considering a carbon concentration in the plant tissue of 40% (LOVATO et al., 2004). The mass input related to the residues kept in the soil surface (NT) or incorporated (CT) was the following: no-tillage was 11.9 Mg ha^{-1} $year^{-1}$, with a total carbon content of 98.7 Mg ha^{-1} ; in conventional tillage the amount of residues added was 9.0 Mg ha^{-1} $year^{-1}$, making a total carbon input of 39.6 Mg ha^{-1}. These values refer to the 21 years of conduction of the experiment. For the conventional tillage the contribution of crop residues and carbon refers to the last 11 years (2005 to 2016) of cultivation with maintenance of the residues in the area. Soil samples were collected in November 2016, at depths of 0-2.5, 2.5-5.0, 5.0-10.0 and 10-20.0 cm, after the winter crop management, performed by using a roller crimper. The composite samples were collected at 4 locations in the center of the plot, in between row cultivation, and homogenized to form a composite sample in each plot of the experiment. The samples were packed in plastic bags and taken to the laboratory immediately after arrival at the laboratory and dried at 60 ° C for subsequent preparation.

The analyses carried out in the soil samples were total organic carbon (TOC) and the physical fractionation of the soil was performed to obtain the particulate organic carbon (POC). That fraction was determined according to the methodology described by Cambardella & Elliot (1992). The organic carbon in these samples was determined by titration method according to the procedures described by Tedesco et al. (1995). The TOC and POC stocks were calculated taking into account the soil density values in the four depths studied. In order to calculate the total organic carbon stocks of previous years, there were used data of total organic carbon content and soil density of published works referring to the same study area (BERTOL et al., 2001; BERTOL et al., 2004; ANDRADE et al., 2012). In the evaluation performed at 15 years after implantation, the native grassland was not evaluated.

The chemical fractionation of carbon followed the methodology described by Benites et al. (2003) based on solubility in acidic and alkaline media, with separation of fulvic acid, humic acid, and humin. Later, the organic carbon content in each fraction was determined by the wet combustion method.

The results were submitted to analysis of variance by the F test considering a completely randomized model. The means were compared by the Tukey test at 5% significance level, using SAS (Statistical Analysis System, version 9.0).

RESULTS AND DISCUSSION

Conventional tillage added less carbon than no-till over 21 years due to the intentional removal of crop residues during the first 11 years of cultivation under conventional tillage. The annual input of residues in the no-tillage was 53 % higher than in the conventional tillage in the

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summer crops and 10 % higher in the winter crops since in the conventional tilalge the soil remained fallow in the winter period. This higher input of biomass can improve soil quality and increase crop yields under NT (CONCEIÇÃO et al., 2005). In addition to the benefits related to total organic carbon increase, no-tillage is characterized by the maintenance of surface cover, which may improve soil physical and water conditions (BERTOL et al., 1997). The accumulation of residues and the higher carbon concentrations in soil surface allow greater stability of the porous system, that can reduce the effects of soil compaction (FRANZLUEBBERS, 2002) and protect the soil from erosion.

The total organic carbon contents in the reference area (NF) were higher in relation to the cropped treatments in all the layers evaluated (Figure 1a). This result was more evident in the surface layers and decreased downwards. In no-tillage there was a stratification of the carbon contents according to the layers, being the highest value found in the surface layer, decreasing in depth. In the conventional tillage the total organic carbon contents did not vary in depth. Souza et al. (2016) also found the same organic carbon distribution in a Cerrado Latosol under no-tillage. The minimal soil tillage, permanent soil cover by residues, and pronounced root growth can form an organic carbon gradient in the surface soil (BORDIN et al., 2008).

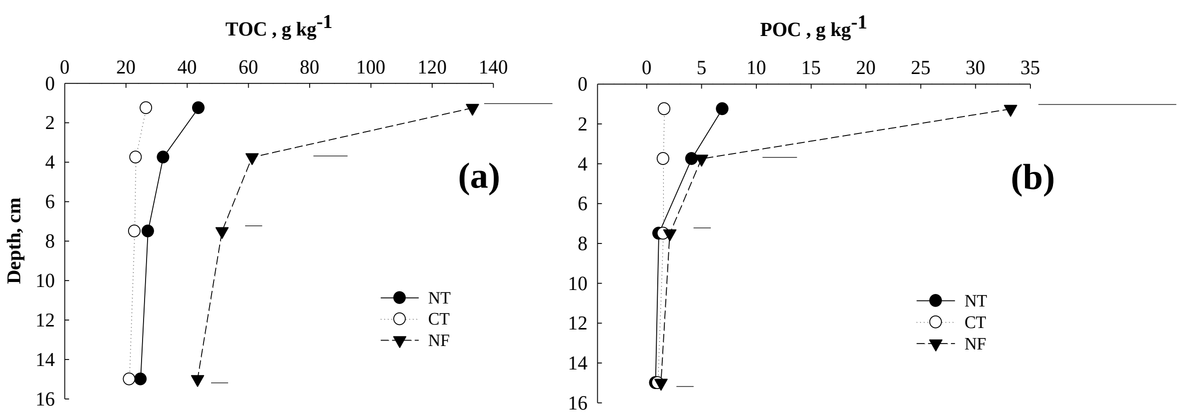

Figure 1. Total organic carbon (TOC) (a) and particulate organic carbon (POC) (b) in no-tillage (NT), conventional tillage (CT) and native grassland (NF) in a Cambisol after 21 years of cultivation. Lages, Santa Catarina state, Brazil, 2016. Bars in each depth are the honestly significant differences according to Tukey's test (P<0.05)

N0-tillage had similar carbon content in comparison to conventional tillage in all evaluated layers. This result differ from other NT management where reduced tillage and permanent soil cover can increase organic carbon contents in surface soil (SOUZA et al., 2016). It should be noted that in the initial period of the experiment, crop residues were removed from the plots under conventional tillage, which reduced the carbon input in the soil. In conventional tillage soil disturbance can accelerate the decomposition of organic residues.

The particulate organic carbon contents were similar between the cropped treatments and it was higher in native grassland than in these treatments (Figure 1b). the stratification of particulate organic carbon in the 0-5.0 cm in no-tillage can be related to crop residues accumulation in soil surface. In NT, the particulate organic carbon comprises 9% of the total organic carbon in the 0-20 cm layer, while in the CT the particulate organic carbon represents 5% of the total organic carbon reserve. These results show that the greatest contribution to the total organic carbon is the fraction associated with minerals. The particulate fraction consists of compounds such as proteins and amino acids, simple and complex carbohydrates, resins and lignins, composing a heterogeneous system that differs from one another by composition, function, and degree of accessibility by soil microbiota (CHRISTENSEN, 2000). Thus, it can be a sensitive indicator to different soil management systems. Souza et al. (2016) and Santos et al. (2013) recognize the POC fraction as an indicator more sensitive to the quality of soil management systems in the short term.

The TOC stocks were similar between NT and CT in the evaluations in 5 and 10 years after the beginning of the experiment, and increase in no-tillage in comparison with conventional tillage in the evaluations in 15 and 21 years (Figure 2). According to Mazzoncini et al. (2016), no-tillage development time plays an important role in determining the impact of TOC since changes in carbon stocks occur slowly and can be observed some years its development. For this reason, these changes can often only be identified in long-term experiments, as observed in the present study.

The increase in carbon stocks in no-tillage was not linear over the years. In this sense, Alvarez & Steinbach (2009) observed a small increase in carbon stocks during the first five years of NT. West & Post (2002) reported that the peak carbon sequestration in no-tillage is reached after 10 or 15 years of its development. However, carbon sequestration is a non-linear process, and the time required for a new balance is quite variable. In the present study, it is possible to identify stabilization of the carbon stock in NT, being more evident in the evaluation at 15 years. On the other hand, conventional tillage observed a decrease in the carbon stock after the evaluation at 15 years, evidencing the more degraded state of the soil quality and its low potential to sequester carbon.

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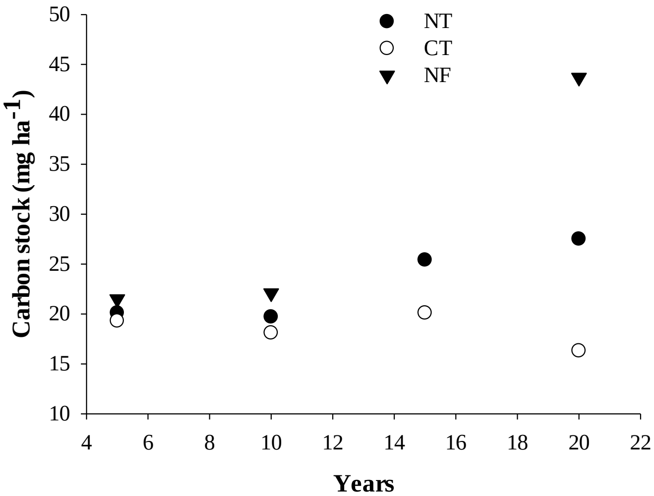

Figure 2. Soil organic carbon stocks in the 0-20 cm layer, observed in no-tillage (NT), conventional tillage (CT) and native grassland (NF) in a Cambisol after 21 years of soil cultivation. Lages, Santa Catarina State, Brazil, 2016.

The carbon stock in the native grassland increased throughout the period of evaluation of the experiment. This increase is due to its management after the beginning of the experiment (1995), when it was grazed by animals, and all biomass produced and mowed periodically was kept on the soil surface. Nicoloso et al. (2008) observed that the absence of grazing in the pastures contributes more with the addition of carbon to the soil than in the presence of grazing. The same authors observed that under grazing conditions there was a reduction of 50% in the addition of residues to the soil, regardless of the management systems adopted, in relation to the condition without grazing.

There were changes in carbon content in the fulvic acid fractions (FA), humic acids (HA) and humins (HU) in the evaluation done after 21 years of conducting the experiment (Figure 3). The humic substances (FA, HA, and HU) decreased with increasing depth in no-tillage and in the native grassland, whereas in the conventional tillage these levels were similar in all the layers evaluated, possibly due to the stirring and incorporation of residues, and is also possible to observe homogeneity in the profile of the TOC contents. This fact shows that soil inversion reduces carbon humification and formation of more stable organic compounds.

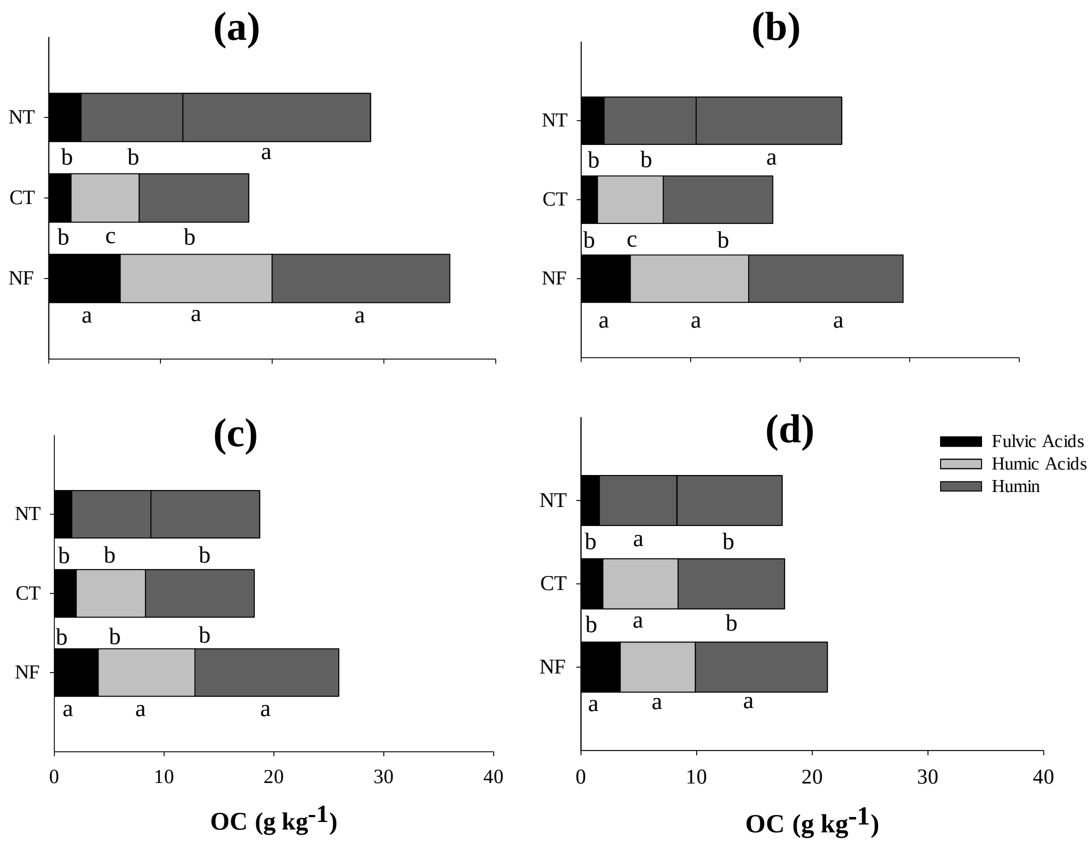

Figure 3. Carbon in humic substances: fulvic acids, humic acids and humin, observed at depths 0-2.5 (a), 2.5-5 (b), 5-10 (c) and 10-20 cm (d), in no-tillage (NT), conventional tillage (CT) and native grassland (NF) in a Cambisol after 21 years of cultivation. The letters compare treatments at the same depth by the Tukey test at 5 % significance. Lages, Santa Catarina State, Brazil, 2016.

The humic fraction represented 67% of the total organic carbon in the conventional tillage and no-tillage in the 0-2.5 cm layer, while in the NF, it was 26%. This result explains that in the cropped soil the TOC is composed mostly of the humic fraction of the soil, which is more resistant to biodegradation due to its recalcitrance and interaction with the soil colloids (GRINHUT et al., 2007). On the other hand, the labile fraction derived from the cultural residues presents a lower residence time in the soil and a higher decomposition rate (VON LÜTZOW et al., 2007), which contributed little to the TOC in the cultivated soil. In NF, the highest percentage of TOC is present in the non-humic fraction due to the continuous input of residues, without soil mobilization or nutrient and biomass removal via harvest.

The fulvic acid contents were lower than other humic fractions (HA and HU) in the two cropped treatments and in all the layers evaluated. This behavior of the fulvic acids was similar in

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the native grassland condition (Figure 3), but the native grassland had the highest levels of FA in all layers. The fulvic acid contents varied according to the adopted management system. The difference between no-tillage and conventional tillage was more evident in the 0-2.5 cm depth and did not occur downwards.

The humic acid fraction was higher in the native grassland in relation to the other treatments in all the layers, except in the layer 10-20 cm, where there was no difference between the different soil management systems.

The humin fraction was responsible for the highest percentage of soil organic carbon in the cultivated soil condition, representing 41% and 42% in the 0-20 cm layer in NT and CT, respectively. In native grassland, this fraction was only 21% in the 0-20 cm layer. This result in NF can be related to the high POC content present in the surface layer. The native grassland humin was equal to that of no-tillage in the two superficial layers (0-2.5 and 2.5-5 cm), representing the most stabilized form of the soil matter organic. Thus, no-tillage may maintain the carbon content in the humin fraction as similar as the natural condition (NF), due to the continuous contribution of crop residues and reduced soil mobilization. No-tillage presented 58 % more carbon in the humin fraction in the 0-2.5 cm layer than conventional tillage. This result demonstrates the effect of the soil cover and reduced tillage to stabilize and conserve soil carbon. The predominance of HU fraction in NT is related to its insolubility and resistance to biodegradation, which is related to the formation of stable organomineral complexes (FONTANA et al., 2011). This predominance of the most stabilized carbon fraction was also observed in other studies on Brazilian soils (RANGEL & SILVA, 2007; PORTUGAL et al., 2008).

The humin fraction was influenced by management in the surface soil up to 10 cm depth and in the 10-20 cm layer there were contents of this fraction in all treatments (6.5g kg^{-1}). This result shows the importance of the maintenance and conservation of the residues on the soil surface and their benefit in the carbon humification.

The relationship between humic acids and fulvic acids (HA/FA) was influenced by the different soil management systems. The highest proportion was observed in NT, with a ratio of 4.3, while in the NF the lowest ratio (2.1) was observed. These HA/FA values indicate well stabilized organic material. In tropical soils, generally, this ratio is less than 1, indicating a lower intensity of humification of the processes such as condensation and synthesis and the intense mineralization of residues (CERRI & VOKOFF, 1988). Values higher than 1 observed in this study in all evaluated treatments suggest carbon stabilization, especially in no-tillage where humification is more evident.

CONCLUSIONS

Conventional tillage reduced the soil carbon content after 21 years of cultivation, while in no-tillage the levels and stocks increased.

No-tillage has more carbon than conventional tillage in the humin and humic acid fractions in the surface soil. Physical fractions of organic carbon were similar between the management systems.

No-tillage has a greater organic carbon stock than conventional tillage 15 years after its development and shows greater potential for carbon conservation in the surface soil. Thus, long-term experiments are important to monitor soil behavior under different management conditions.

REFERENCES

ALVAREZ, R.; STEINBACH, H.S. 2009. A review of the effects of tillage on some soil physical properties water content, nitrate availability and crops yield in the Argentine Pampas. **Soil Till Research**, Amsterdam, v.104, p.1-15.

ANDRADE, A.P.; MAFRA, A. L.; PICCOLLA, C. D.; ALBUQUERQUE, J. A. BERTOL, I. 2012. Atributos químicos de um Cambissolo Húmico após 12 anos sob prepare convencional e semeadura direta em rotação e sucessão de culturas. **Ciência Rural**, Santa Maria, v.42, p.814-821.

BAYER, C.; MIELNICZUK, J. 1997. Características químicas do solo afetadas por métodos de preparo e sistemas de cultura. **Revista Brasileira de Ciência do Solo**, Viçosa, v.21, p.105-112.

BENITES, V.M. MÁDARI, B.; MACHADO, P. L. O. A.2003 **Extração e fracionamento quantitativo de substâncias húmicas do solo: um procedimento simplificado e de baixo custo**. Rio de Janeiro: Embrapa (Comunicado Técnico, 16).

BERTOL, I.; ALBUQUERQUE, J. A.; LEITE, D.; AMARAL, A. J.; ZOLDAN JUNIOR, W. A. 2004. Propriedades físicas do solo sob preparo convencional e semeadura direta em rotação e sucessão de culturas, comparadas às do campo nativo. **Revista Brasileira de Ciência do Solo**, Viçosa, v.28, p.155-163.

BERTOL, I.; COGO, N. P.; LEVIEN, R. 1997. Erosão hídrica em diferentes preparos do solo logo após as colheitas de milho e trigo, na presença e ausência de resíduos culturais. **Revista Brasileira de Ciência do Solo**, Viçosa, v.21, p.409-418.

BERTOL, I.; BEUTLER, J. F.; LEITE, D.; BATISTELA, O. 2001. Propriedades físicas de um Cambissolo Húmico afetadas pelo tipo de manejo do solo. **Scientia Agricola**, São Paulo, v.58, p.555-560.

BORDIN, I.; NEVES, C. S. V. J.; MEDINA, C. C.; SANTOS, J. C. F.; TORRES, E.; URQUIGA, S. 2008. Matéria seca, carbono e nitrogênio de raízes de soja e milho em plantio direto e convencional. **Pesquisa Agropecuária Brasileira**, Brasília, v.43, p.1785-1782.

DOI: 10.37856/bja.v95i1.3533

CAETANO, J.O.; BENITES, V. M.; SILVA, G. P.; SILVA, I.R.; ASSIS, R. L.; CARGNELUTTI FILHO, A. 2013. Dinâmica da matéria orgânica de um Neossolo Quartzarênico de Cerrado convertido para cultivo em sucessão de soja e milheto. **Revista Brasileira de Ciência do Solo**, Viçosa, v.37, p.1245-1255.

CAMBARDELLA, C.A.; ELLIOTT, E.T. 1992. Particulate soil organic-matter changes across a grassland cultivation sequence. **Soil Science Society of America Journal**, Madison, v.56, p.777-783.

CERRI, C.C.; VOLKOFF, B. 1988. Matéria orgânica de três solos dos campos inundáveis da ilha do Marajó-PA. **Revista Brasileira de Ciência do Solo**, Viçosa, v.12, p.93-100.

CONCEIÇÃO, P.C.; AMADO, T.J.C.; MIELNICZUK, J.; SPAGNOLLO, E. 2005. Qualidade do solo em sistemas de manejo avaliada pela dinâmica da matéria orgânica e atributos correlacionados. **Revista Brasileira de Ciência do Solo**, Viçosa, v.29, p.777-788.

CHRISTENSEN, B.T. 2000. Organic matter in soil: structure, function and turnover. Tjele: Dias, 95p.

FIGUEIREDO, C.C.; RESCK, D. V. S.; CARNEIRO, M. A. C. 2010. Labile and stable fractions of soil organic matter under management systems and native Cerrado. **Revista Brasileira de Ciência do Solo**, Viçosa, v.34, p.907-916.

FONTANA, A.; SILVA, C. F.; PEREIRA, M. G.; LOSS, A.; BRITO, R. J.; BENITES, V. M. 2011. Avaliação dos compartimentos da matéria orgânica em área de Mata Atlântica. **Acta Scientiarum Agronomy**, Maringá, v.33, p.545-550.

FRANZLUEBBERS, A.J. 2002. Soil organic matter stratification ratio as an indicator of soil quality. **Soil Tillage Research**, Amsterdam, v.66, p.95-106.

GAZOLLA, P.R.; GUARESCHI, R. F.; PERIN, A.; PEREIRA, M. G.; ROSSI, C. Q. 2015. Frações da matéria orgânica do solo sob pastagem, sistema plantio direto e integração lavoura-pecuária. **Semina: Ciências Agrárias**, Londrina, v.36, p. 693-704.

GRINHUT, T.; HADAR, Y.; CHEN, Y. 2007. Degradation and transformation of humic substances by saprotrophic fungi: processes and mechanisms. **Fungal Biology Reviews**, Londres, v.21, p.179-189.

LOVATO, T.; MIELNICKZUK, J.; BAYER, C.; VEZZANI, F. 2004. Adição de carbono e nitrogênio e sua relação com os estoques no solo e o rendimento do milho em sistemas de manejo. **Revista Brasileira de Ciência do Solo**, Viçosa, v.28, p.175-187.

MAZZONCINI, M.; ANTICHI, D.; DI BENE, C.; RISALITI, R.; PETRI, M.; BONARI, E. 2016. Soil carbon and nitrogen after 28 years of no-tillage management under Mediterranean conditions. **European Journal of Agronomy**, v.77. p.156-165.

NICOLOSO, R. S.; LOVATO, T.; CARNEIRO, T. J.; BAYER, C.; LANZANOVA, M. C. 2008. Balanço do carbono orgânico no solo sob integração lavoura-pecuaria no Sul do Brasil. **Revista Brasileira de Ciência do Solo**, Viçosa, v.32, p.2425-2433.

Portugal, A.F.; JUCKSCH, I.; SCHAEFER, C. E. G. R.; WENDLING, B. 2008. Determinação de estoques totais de carbono e nitrogênio e suas frações em sistemas agrícolas implantados em Argissolo Vermelho-amarelo. **Revista Brasileira de Ciência do Solo**, Viçosa, v.32, p.2091-2100.

RANGEL, O.J.P.; SILVA, C.A. 2007. Estoques de carbono e nitrogênio e frações orgânicas de Latossolo submetido a diferentes sistemas de uso e manejo. **Revista Brasileira de Ciência do Solo**, Viçosa, v.31, p.1609-1623.

SÁ, J. C. M.; SÉGUY, L.; TIVET, F.; LAL, R.; BOUZINAC, S.; BORZOWSKWI, P. R.; BRIEDIS, C.; SANTOS, J. B.; HARTMAN, D. C.; BERTOLONI, C. G.; ROSA, J.; FRIEDRICH, T. 2015. Carbon depletion by plowing and its restoration by no-till cropping systems in Oxisols of subtropical and tropical agroecoregions in Brazil. **Land Degradation and Development**, v.26, p.531-543.

SALVO, L.; HERNÁNDEZ, J.; ERNEST. O. 2010. Distribution of soil organic carbon in different size fractions, under pasture and crop rotations with conventional tillage and no-till systems. **Soil Tillage Research**, Amsterdam, v.109, p.116-122.

SANTOS, D. C.; OLIVEIRA, F. M.; LIMA, C. L. R.; KUNDEI, R. J.; PILLON, C. N.; FLORES, C. A. 2013. Fracionamento químico e físico da matéria orgânica de um Argissolo Vermelho sob diferentes sistemas de uso. **Ciência Rural**, Santa Maria, v.43, p.838-844.

SCHICK, J.; BERTOL, I.; COGO, N. P.; GONZÁLEZ, A. P. 2014. Erosividade das chuvas de Lages, Santa Catarina. **Revista Brasileira de Ciência do Solo**, Viçosa, v.38, p.1890-1905.

SOUZA, G. P.; FIGUEREDO, C. C.; SOUZA, D. M. G. 2016. Soil organic matter as affected by management systems, phosphate fertilization, and cover crops. **Pesquisa Agropecuária Brasileira**, Brasília, v.9, p.1668-1676.

TEDESCO, M. J.; GIANELLO, C.; BISSANI, C. A.; BOHNEN, H.; VOLKWEISS, S. J. 1995. **Análises de solo, plantas e outros materiais**. Porto Alegre: Universidade Federal do Rio Grande do Sul. (Boletim técnico, 5).

VON LÜTZOW, M.; KOGEL-KNABNER, I.; WKSCMITT, K.; FLESSA, H.; GUGGENBERGER, G.; MATZNER, E.; MARSCHNER, B. 2007. SOM fractionation methods: Relevance to functional pools and to stabilization mechanisms. **Soil Biology Biochemistry**, v.39, p.2183-2207.

WEST, T.O.; Post, W.M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. **Soil Science Society America Journal**, Medison, v.66, p1930-1946.

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