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Soil Structure and its Influence on Microbial Biomass[1]

Adriana Pereira da Silva [2]; Letícia Carlos Babujia [3]; Julio Cezar Franchini [4]; Ricardo Ralisch [5]; Mariangela Hungria [6]; Maria de Fátima Guimarães [7]

[1] Trabalho executado com recursos do Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
[2] Professor; Universidade Paranaense - UNIPAR; Umuarama, PR; E-mail: adrianapsilva@unipar.br; [3] Estudante de Pós-doutorado (bolsista CNPq); Embrapa – CNPSo; E-mail: leticiacb_@hotmail.com; [4] Pesquisador; Embrapa – CNPSo; E-mail: julio.franchini@embrapa.br; [5] Professor; Universidade Estadual de Londrina – UEL; E-mail: ralisch@uel.br; [6] Pesquisador; Embrapa – CNPSo; E-mail: mariangela.hungria@embrapa.br; [7] Professor; Universidade Estadual de Londrina; E-mail: mfatima@uel.br.

SUMMARY: Soil and crop management have a fundamental role in the maintenance and improvement of soil quality, as they have a direct influence its structure and on microorganisms habitats. The aim of this study was to quantify carbon and nitrogen microbial biomass in the HMUs in a dystroferric Red Latosol, in a 22-year experiment with treatments consisting of a no-tillage planting system (NT), no-tillage with chiseling every three years (NTC) and conventional tillage (CT), using crop rotation (CR) and succession (CS) systems, in order to determine the relationship between alterations in soil structure and modifications in the contents of microbial biomass. Significantly higher levels of carbon and nitrogen microbial biomass (CMB and NMB) were observed in the HMUs in NT and NTC systems under both CR and CS. On average, HMUs in the NT and NTC treatments presented 20% more CMB and 51% more NMB that in the CT treatment. NMB was the parameter most highly affected by the soil management. At depths of 0–20 cm, total organic carbon (TOC), was higher by an average of 21% than in the NT and NTC treatments. Total nitrogen (TN) was also affected by the soil management. This demonstrates how the tillage of the soil exposes the organic matter in the aggregates to oxidation and nitrogen mineralization.

Index terms: cultural profile, soil tillage, soil microorganisms.

INTRODUCTION

Changes in soil structure directly affect the habitat of microorganisms, which are considered to be critical components of natural and anthropogenic ecosystems as they regulate the level of decomposition of organic material and the cycling of nutrients (Morris et al., 2010). Due to the sensitivity of this parameter, microbial biomass has been used in studies as an indicator of changes provoked by soil and crop management and in the tropics (Babujia, et al., 2010). Positive correlations between microbial biomass and crop productivity have been observed (Hungria et al., 2009).

The hypothesis raised in this study is that morphological alterations observed in soil structure may be related to modifications in microbial biomass, validating the cultural profile method as a tool capable of providing an indication of the microorganisms present in the homogeneous morphological units (HMUs - soil volumes affected by use and soil management) found in soil profiles.

The aim of this study was to quantify carbon and nitrogen microbial biomass in the HMUs in a dystroferric Red Latosol, in a 22-year experiment with treatments consisting of a no-tillage planting system (NT), no-tillage with chiseling every three years (NTC) and conventional tillage (CT), using crop rotation (CR) and succession (CS) systems, in order to determine the relationship between alterations in soil structure and modifications in the contents of microbial biomass.

MATERIAL AND METHODS

Characterization of the experimental area

According to the Brazilian classification system, the soil is a very clayey dystroferric Red Latosol, and according to the American classification system it is a Rhodic Eutrudox with 710 g clay, 82 g silt and 208 g sand per kg^{-1} of soil.

The study compared the effects of three soil preparation systems: no-tillage planting (NT); no-tillage with chiseling every three years (NTC); and conventional tillage (CT).

In addition, each soil preparation system was submitted to the effects of crop rotation and succession. The crop rotation (CR) consisted of five different crop species: white lupine (*Lupinus albus*)-maize (*Zea mays*), black oat (*Avena strigosa*)-soybean (*Glycine max*), wheat (*Triticum aestivum*)-soybean, every three years; and crop succession (CS) with soybean in the summer and wheat in the winter.

Cultural Profile

The cultural profile method was used for the evaluations, as described by Tavares Filho et al. (1999). Cultural profile methodology classifies HMUs into two levels: (1) organization of clods in the soil profile (C- continuous; F- cracked; L- free and Z- laminar), and (2) internal state of the clods (μ- not compact; Δ- compact and μΔ/Δμ- ± compact).

Evaluation of microbial biomass

The carbon and nitrogen microbial biomass (CMB and NMB) was quantify as described by Babujia et al. (2010).

Total organic carbon and nitrogen

Total organic carbon (TOC) and total nitrogen (TN) were determined through combustion in a Thermo Scientific FLASH 2000 NC Analyzer.

Statistical analysis

The averages were first submitted to the tests of normality of the variables and of homogeneity of variances, and then to ANOVA. When confirming a statistically significant P value, was applied Tukey test ($P < 0.05$) to comparison procedure.

RESULTS AND DISCUSSION

The hypothesis that changes in soil structure may be correlated to modifications in microbial biomass was confirmed. The superior soil quality found in NT and NTC planting systems, which contain HMUs that are predominantly less compact and present a higher porosity than those observed in CT systems, produces higher levels of CMB and NMB **(Figures 1 and 2)**.

Changes in soil structure caused by intense tillage affect water percolation, temperature and aeration and increase soil erosion, significantly reducing microbial communities and biomass (López-Garrido et al., 2012), as was observed in our study.

NMB levels were more sensitive than CMB levels in indicating changes to the structure of the soil. On average, the soil structures of the NT and NTC profiles presented NMB levels 50% higher than the CT profiles **(Figure. 2)**.

The CμΔ/Δμ, CμΔ and Cμ structures with higher levels of NMB have a positive correlation with the NT treatments under crop rotation and succession and with the NTC treatments under succession.

According to Babujia et al. (2010), lower levels of NMB in some layers of the soil may indicate a lack of nitrogen caused by the increased mineralization of this element to meet the nutritional needs of the crop. The mineralization of nitrogen compounds occurs more steadily in NT systems, while in CT systems there is increased liberation of nitrogen soon after soil preparation due to the breaking up of aggregates, intensifying microbial activity and reducing levels of NMB.

TOC and TN levels were higher in the NT and NTC treatments compared to the CT treatments **(Figure 3)**, independent of the management system. TOC presented levels 20% higher for the NT and NTC treatments compared to the CT treatments. TOC was higher in this systems, can be attributed to the reduced tillage of the soil preserving its structure and contributing via aggregation to the protection and stabilization of organic material in these management systems (Siqueira Neto et al., 2010).

Similarly to NMB, TN was the parameter most affected by the type of soil management. The NT and NTC treatments presented values almost 50% higher for TN compared to the CT treatment **(Figure 3)**. This demonstrates that soil tillage substantially reduces nitrogen levels, a factor that can limit crop development and yield. According to Hungria et al. (2009), there is generally an increased immobilization of nitrogen in NT systems, while CT systems increase the nitrogen mineralization process as organic matter and crop residues are exposed to biotic (soil fauna) and abiotic factors (temperature, humidity and light) (Morris et al., 2010). The aggregation promotes TN and TOC accumulation in macroaggregates, which explains the high sensitivity of nitrogen to the disruption of the soil. This results emphasized the importance of nitrogen as a limiting component in the humification process, which is essential for the retention of carbon in the soil.

CONCLUSIONS

The cultural profile methodology has proven to be capable of indicating changes in levels of microbial biomass caused by agricultural practices.

The superior soil quality found in NT and NTC planting systems, which contain HMUs that are predominantly less compact and present a higher porosity than those observed in CT systems, produces higher levels of carbon and nitrogen microbial biomass.

TOC and TN were higher for the NT and NTC systems, as TN and NMB were the parameters most affected by soil management, indicating that increased disturbance of the soil reduces nitrogen levels.

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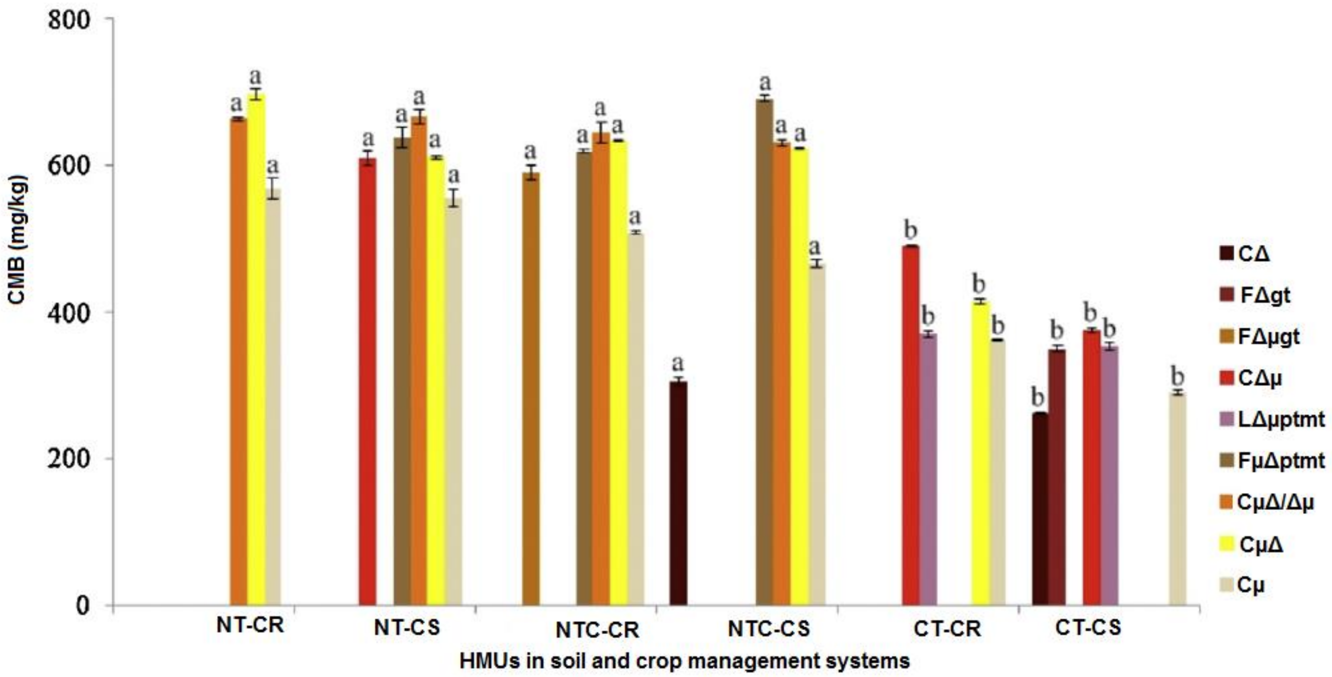

Figura 1 – Carbon microbial biomass (CMB) in homogeneous morphological units (HMUs) under no-tillage planting system (NT), no-tillage system with chiseling every three years (NTC) and conventional tillage system (CT) with crop rotation (CR) and crop succession (CS).

Organization of clods (HMUs): C, continuous soil volume; F, cracked soil volume; L, free soil volume. Internal state of clods: μ, porous; μΔ, porous with indications of compression; μΔ/Δμ, medium porosity; Δμ, compact with some porosity; Δ, compact with no visible porosity. Crop rotation (CR): lupine/maize/black oats/soybean/wheat/soybean. Crop succession (CS): soybean/wheat.

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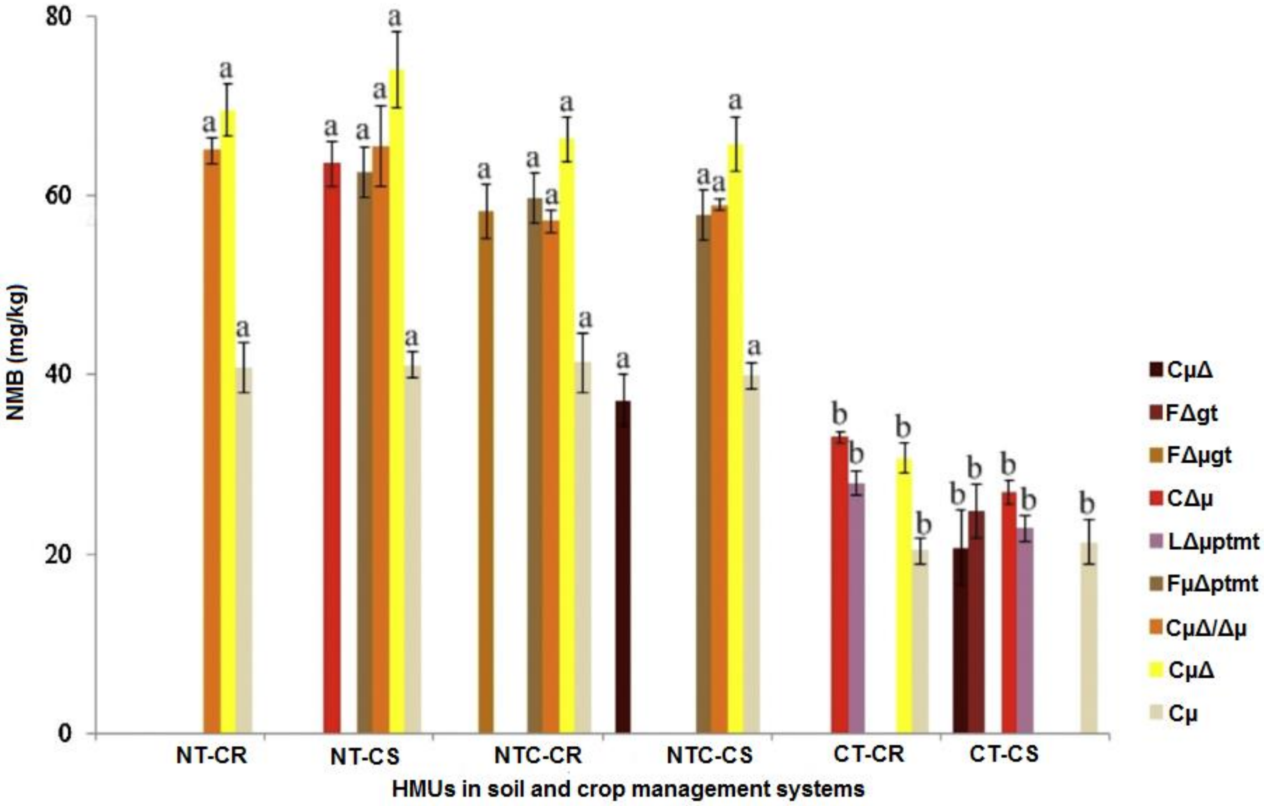

Figura 2 – Nitrogen microbial biomass (NMB) in homogeneous morphological units (HMUs) under no-tillage planting system (NT), no-tillage system with chiseling every three years (NTC) and conventional tillage system (CT) with crop rotation (CR) and crop succession (CS).
Organization of clods (HMUs): C, continuous soil volume; F, cracked soil volume; L, free soil volume. Internal state of clods: μ, porous; μΔ, porous with indications of compression; μΔ/Δμ, medium porosity; Δμ, compact with some porosity; Δ, compact with no visible porosity. Crop rotation (CR): lupine/maize/black oats/soybean/wheat/soybean. Crop succession (CS): soybean/wheat.

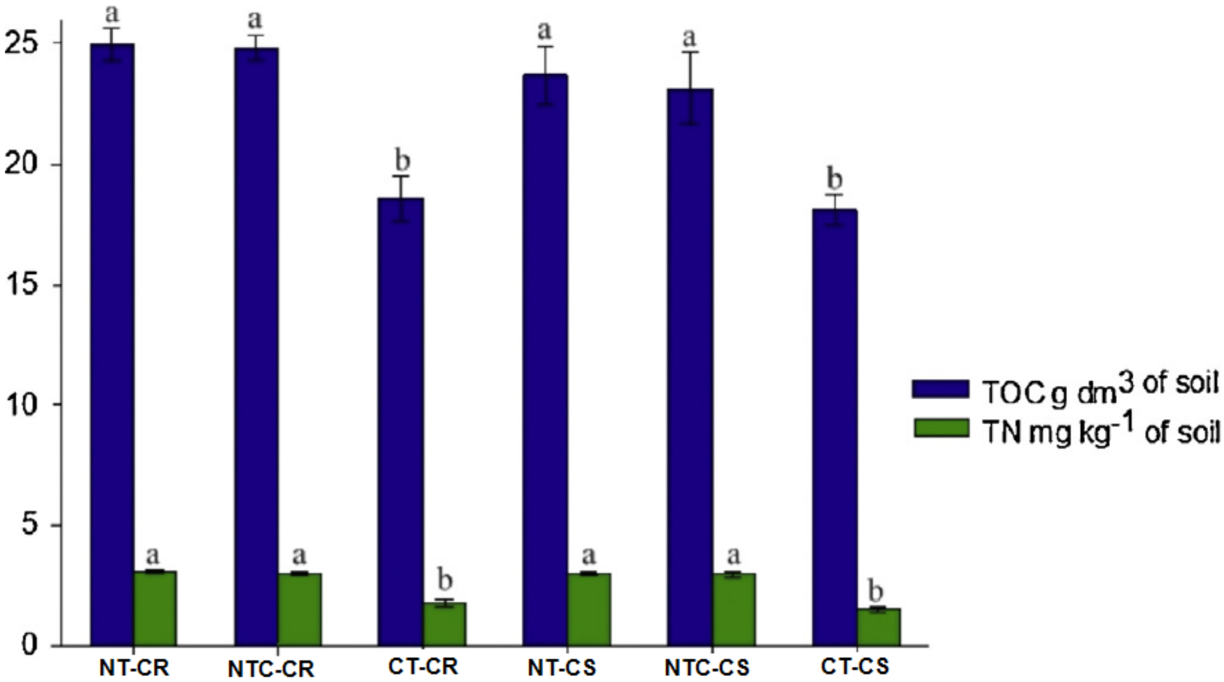

Figura 3 – Total organic carbon (TOC) and total nitrogen (TN) at depths of 0–20 cm under no-tillage planting system (NT), no-tillage system with chiseling every three years (NTC) and conventional tillage system (CT) with crop rotation (CR) and crop succession (CS).
Crop rotation (CR): lupine/maize/black oats/soybean/wheat/soybean. Crop succession (CS): soybean/wheat.