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No-tillage effect on carbon and microbiological attributes in corn grown in Manaus-AM, Brazil

Aleksander Westphal Muniz[1*], Ronielly Hadna da Silva Nunes[2], Telma Andréa Carvalho Silva[3], Enilson Luiz Saccol de Sá[4], Cláudia Majolo[1], Ana Beatriz Fiuza[1] and José Renato Pereira Cavallazzi[5]

[1]Embrapa Amazônia Ocidental, Rodovia AM 10, Manaus 69010-970, Brazil.
[2]UNINORTE, Av. Leonardo Malcher 715, 69020-010, Manaus, Brazil.
[3]INPA, Avenida Bem Te VI 8-406 Manaus, 69067-001, Brazil.
[4]UFRGS, Av. Bento Gonçalves 7712, Porto Alegre 91540-000, Brazil.
[5]UFAM, Avenida General Rodrigo Octavio Jordão Ramos 1200, Manaus, 69067-005, Brazil.

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The soil is the most important carbon reservoir, but agricultural practices involved in tillage systems decrease the soil carbon stock. This study aims to evaluate the effect of no-tillage (NT) on carbon and microbiological attributes of the soil in corn plantations in Manaus-AM, Brazil. Soil was sampled in a secondary forest (SF) and in corn grown under different tillage systems, including conventional tillage (CT), which makes use of plowing and harrowing operations, and no-tillage (NT). Soil variables studied included, carbon content, soil microbial carbon and basal respiration, metabolic and microbial quotients. The data were analyzed by analysis of variance and Tukey's test. The results demonstrated that NT resulted higher carbon, lower basal respiration, and lower metabolic quotient than CT and SF. However, soil microbial carbon was similar in all tillage systems studied. We conclude that NT corn cropping increased soil carbon content more than CT, while it decreased basal respiration and metabolic quotient when compared to NT and SF. Moreover, soil microbial biomass in corn was similar in all tillage systems studied. This research demonstrated the importance of NT to soil carbon conservation and soil management in corn cropping.

Key words: Tillage systems, land use, microbial soil biomass, basal respiration.

INTRODUCTION

Soil quality is very important for agricultural sustainability and environmental conservation (Khaledian et al., 2016). However, this quality is altered by interferences with the chemical, physical and biological properties of the soil (Cattelan et al., 1990; Andrist-Rangel et al., 2007; Cerdà et al., 2017) caused by the soil management practices

*Corresponding author. E-mail: aleksander.muniz@embrapa.br.

Figure 1. Sampling areas in a corn plantation.
A No-tillage, B conventional tillage and C secondary forest.

involved in the various tillage systems in use (Treseder, 2008; Lu et al., 2011). Differences in tillage systems are related to soil mobilization and disposal of plant residues (Lisboa et al., 2012).

Conventional tillage (CT) uses plowing operations that change soil structure and reduce soil organic matter and microbial activity (Allaiume et al., 2014). In contrast, no-tillage (NT) minimizes soil disturbance, thereby promoting the increase of carbon and microbial carbon in the soil (Bayer et al., 1997; Pérez et al., 2004). Microbial change is determined by microbial biomass, respiration and metabolic quotients (Tótola and Chaer, 2002; Gajda et al., 2012).

Microbial biomass is the live and active part of the soil organic matter (Tótola and Chaer, 2002). It is also a more evaluable organic matter reservoir (Roscoe et al., 2006). In addition, soil respiration can reflect disturbance and ecosystem productivity (Islam and Weil, 2000); while the microbial quotient was used in studies of soil organic matter dynamics (Tótola and Chaer, 2002). Moreover, tillage affects CO_2 liberation and soil compaction, which may enhance climate change and soil erosion (Bogunovic et al., 2017).

Effects of soil preparation on agricultural crops have scarcely been studied in the state of Amazonas. Thus, the objective of this work is to evaluate the effect of NT on carbon and microbiological attributes of the soil in corn grown in Manaus-AM.

MATERIALS AND METHODS

Soil sampling was carried out in March of 2012 in Ferrosols (WRB, 2014) located in Manaus (2°53'47.27"S, 59°58'29.76"O) Amazonas. Spacing between samples was 10 m and sampling depth was 10 cm. Samples were obtained in secondary forestland and in a corn plantation under either CT with plowing and harrowing operations or under a NT, without soil movement. Ferrosols represent 18.15% of the soils in the state of Amazonas and correspond to 285,041.75 km^2 (Teixeira et al., 2010). These sampling areas are shown in Figure 1. Cultivation of corn under NT was carried out between 2008 and 2012. The crop was fertilized with 425 kg ha^{-1} of 4N-14P-8K at sowing. Additionally, 2 kg ha^{-1} Zn and 90 kg ha^{-1} N were applied by broadcasting. Finally, 1,500 kg.ha^{-1} dolomitic limestone was applied (CFSEMG, 1999).

Soil samples were sieved through a 2 mm mesh prior to chemical analysis according to Claessen et al. (1997). Results are summarized in Table 1. After that, the soil carbon was determined by wet oxidation method (Walkley and Black, 1934). Microbial biomass carbon (MBC) and basal respiration (BR) were evaluated by Infra-Red Gas Analyzer (IRGA) measurements according to Anderson and Domsh (1978). MBC was calculated using the formula below:

$$MBC = (BR \times 40.04) + 0.37$$

Where:

BR = μL CO_2 min^{-1}.g^{-1}.

Other formulas were used for metabolic and microbial quotient respectively:

$$qCO2 = MBC/BR;\ qMic = \left(\frac{MBC}{Ct}\right) \times 100$$

The results were subjected to analysis of variance to detect significant effects (Fisher, 1925), while means were compared by Tukey's test (Pimentel-Gomes, 2009). The analysis was done using Matlab software using $p<0.05$ for Ct, RB and qCO_2, and $p<0.10$ for CBM and *q*Mic (Table 1).

RESULTS AND DISCUSSION

NT corn and SF showed higher soil carbon concentration

Table 1. Soil analysis in corn plantation areas and secondary forest.

System	pH	P	K	OM	Al	Ca	Mg	H+Al	CEC
	1:1	---mg.dm^3---		Percentage (%)	-----------------cmol$_c$/dm^3-------------				
Corn NT	5.0	44.7	97.2	4.2	0.6	0.8	0.4	5.1	6.5
Forest	4.6	2.8	15.8	3.8	1.2	0.2	0.1	6.3	6.7
Corn CT	4.7	46.5	93.1	4.2	1.0	0.6	0.3	4.6	5.7

*OM= organic matter, CEC=cation exchange capacity, cmol= centimole, NT= no-tillage, CT= conventional tillage.

Table 2. Soil Carbon (Ct), basal respiration (BR), microbial biomass carbon (MBC), metabolic quotient (qCO_2) and microbial quotient (*q*Mic) in conventional tillage (CT) and no-tillage (NT) corn cropping and secondary forest (SF).

System	Ct (g.kg soil^{-1})*	BR (mg C-CO_2.dia^{-1})*	MBC (mg C.Kg soil^{-1})**	qCO_2 (mg C-CO_2. g^{-1} CBM.h^{-1})*	*q*Mic (%)**
Corn NT	24.4^A	5.4^C	744.9^{AB}	0.3^C	3.0^{AB}
Forest	24.2^A	10.7^B	993.1^A	0.5^B	4.2^A
Corn CT	22.1^B	22.8^A	586.2^B	1.7^A	2.4^B

Means with the same letter within columns do not differ significantly by Tukey's test ($p < 0.05$; ** $p < 0.10$).

than conventional tillage (CT) corn (Table 2). This higher carbon concentration was due to plant residue accumulation during crop growth (Freixo et al., 2002; Lovato et al., 2004; Sisti et al., 2004; Hickmann and Costa, 2012; Asmann et al., 2014). Furthermore, it could be due to a decrease in mineralization rate (DICK, 1983). Conversely, carbon concentration in SF occurred because of rhizodeposition, fall of leaves and lixiviation (Richter et al., 1999). Rhizodeposition in the forest was affected by plant composition and litter quality (Wilcke and Lilienfein 2004; Wiesmeier et al., 2009). On the other hand, litter quality on the surface of the soil changed due to a high CN ratio and low biodegradability (Tejada et al., 2009) (Table 2).

Basal respiration was lower in NT corn than in the other systems studied (Table 2). These results differed from those observed by D'Andréa et al. (2002) in Goiás, Brazil, where no basal respiration differences between tillage systems for corn production were found. Moreover, the higher basal respiration in the CT corn crop, and SF was due to increased organic matter and nutrients available in the soil (Emmerling et al., 2000).

Microbial biomass carbon (MBC), was higher in SF than in CT corn, but showed no difference with respect to NT corn (Table 2). Higher MBC in SF is related to the higher quantity and quality of plant residues and organic matter quantity (Jacinthe et al., 2000; Fierer et al., 2009; Diacono and Montemurro, 2010). We recorded a decrease in MBC in CT corn, caused by the combined effect of a reduction in carbon input and a decrease in soil carbon stock (Kallenbach and Grandy, 2011). This decrease was also a result of agricultural practices, such as soil plowing and fertilizer use (Treseder, 2008; Lu et al., 2011). Results for NT in this study were different from those obtained in other studies, which showed higher CBM content in NT than in CT corn crops in Paraná state and the Cerrado areas of Brazil (Balota et al., 1998; Balota et al., 2004). However, CBM under NT showed a similar behavior to that observed in Minas Gerais state (Rangel and Silva, 2007).

The qCO_2 was lower for NT than for the other systems (Table 2). The same was observed in other studies on NT in southern Brazil (Balota et al., 2004). The higher qCO_2 in Ct corn may be due to the incorporation of plant residues into the soil (Ocio and Brookes, 1990). Therefore, the differences between NT and CT corn were due to microbial access to the substrate (Alvarez et al., 1995). Soil qCO_2 in CT corn showed an imbalance and was probably dominated by organisms growing faster (Sakamoto and Obo, 1994). Instead, the lower qCO_2 in NT corn and SF occurred due a greater efficiency of the microbial biomass in using environmental resources with lower carbon losses, such as CO_2 (Anderson and Domsch, 1985). Hence, the qCO_2 values in SF and NT corn indicated a greater stability of the microbial biomass in these systems (Santos et al., 2005). The higher qCO_2 value in SF than in NT likely occurred due to the more advanced stage of plant succession (Chapman et al., 2003).

Higher qMic was observed in SF than in CT corn, but it did not differ from qMic registered for NT corn (Table 2). Overall, qMic values measured in this study were higher than values measured in other areas of the Amazon rainforest, where qMic values ranged from 1.1% to 3.7% (Pfenning et al., 1992, Geraldes et al., 1995, Moreira and Malavolta, 2004).

Corn growing areas showed qMic values similar to those found in other Amazonian sites with 2.6% (Pfenning et al., 1992). Differences observed in qMic values in this study may have occurred due to the formation and conversion efficiency of recalcitrant organic matter into microbial biomass carbon (Sparling, 1992). We also observed that qMic values obtained in SF and in corn growing areas were 2.2% higher, which is the suggested value for a balanced soil (Jenkinson and Ladd, 1981).

Conclusions

The no-tillage corn system increased soil carbon content over that registered under the conventional tillage system. Moreover, no-tillage displayed lower basal respiration and metabolic quotient values, compared to conventional tillage and secondary forest. Furthermore, it showed similar microbial biomass to that which characterized these other systems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Andrist-Rangel Y, Edwards AC, Hillier S, Öborn I (2007). Long-term K dynamics in organic and conventional mixed cropping systems as related to management and soil properties. Agric. Ecosyst. Environ. 122:413-426.

Asmann JM, Anghinoni I, Martins AP, Costa SEVGA, Cecagno D, Carlos FS, Carvalho PCF (2014). Soil carbon and nitrogen stocks and fractions in a long-term integrated crop-livestock system under no tillage in southern Brazil. Agric. Ecosyst. Environ. 190:52-59.

Anderson T-H, Domsch KH (1985). Determination of ecophysiological maintenance carbon requirements of soil microorganisms in a dormant state. Biol. Fert. Soils 1:81-89.

Balota EL, Colozzi-Filho A, Andrade DS, Dick RP (2004). Long-term tillage and crop rotation effects on microbial biomass and C and N mineralization in a Brazilian Oxisol. Soil Till. Res. 77:137-145.

Balota EL, Colozzi-Filho A, Andrade DS, Hungria M (1998). Biomassa microbiana e sua atividade em solos sob diferentes sistemas de preparo e sucessão de culturas. R. Bras. Cienc. Solo 22:641-649.

Bogunovic, I, Bilandzija, D, Andabaka, Z, Stupic, D, Comino JR, Cacic, M, Brezinscak, L, Maletic E, Pereira P (2017). Soil compaction under different management practices in a Croatian vineyard. Arab. J. Geosci. 10:340.

CFSEMG -Comissão de Fertilidade do Solo do Estado de Minas Gerais (1999). Recomendações para o uso de corretivos e fertilizantes em Minas Gerais: 5ª aproximação. In: RIBEIRO, A.C.; GUIMARÃES, P.T.G.; ALVARES, V.H. (Eds.). Viçosa, MG: UFV 359p.

Cerdà A, Rodrigo-Comino J, Giménez-Morera A, Keesstra SD (2017). An economic, perception and biophysical approach to the use of oat straw as mulch in Mediterranean rainfed agriculture land. Ecol. Eng. 108:162-171.

Chapman SJ, Campbell CD, Puri G (2003). Native woodland expansion: soil chemical and microbiological indicators of change. Soil Biol. Biochem. 35:753-764.

Claessen MEC, Barreto WdO, Paula JLD, Duarte MN (1997) Manual de Métodos de Análise de Solo. EMBRAPA, Rio de Janeiro P 212.

Diacono M, Montemurro F (2010). Long-term effects of organic amendments on soil fertility: a review. Agron. Sustain. Dev. 30:401-422.

Dick WA (1983). Organic carbon, nitrogen, and phosphorous concentrations and pH in soil profiles as affected by tillage intensity. Soil Sci. Soc. Am. J. 68:1935-1944.

Fierer N, Strickland MS, Liptzin D, Bradford MA, CLEVELAND CC (2009). Global patterns in belowground communities. Ecol. Lett. 12:1238-1249.

Freixo AA, Machado PLA, Santos HP, Silva CA, Fadigas FS (2002). Soil organic carbon and fractions of a Rhodic Ferrasol under the influence of tillage and crop rotation systems in southern Brazil. Soil Till. Res. 64:221-230.

Geraldes APA, Cerri CC, Feigl BJ (1995). Biomassa microbiana de solo sob pastagens na Amazônia. R. Bras. Cienc. Solo 19:55-60.

Hickmann C, Costa LM (2012). Estoque de carbono no solo e agregados em argissolos sob diferentes manejos de longa duração. Rev. Bras. Eng. Agríc. Ambient. 16:1055-1061.

Islam KR, Weil RR (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric. Ecosyst. Environ 79:9-16.

Jacinthe PA, Lal R, Kimble JM (2000). Organic carbon storage and dynamics in croplands and terrestrial deposits as influenced by subsurface tile drainage. Soil Sci.166:322-325.

Jenkinson DS, Ladd JM (1981). Microbial biomass in soil: measurement and turnover. In: Paul, E. A.; Ladd, J. M. (Ed.). Soil Biochemistry. New York: M. Dekker 5:415-471.

Kallenbach C, Grandy AS (2011). Controls over soil microbial biomass responses to carbon amendments in agricultural systems: A meta-analysis. Agric. Ecosyst. Environ. 144:241-252.

Khaledian Y, Kiani F, Ebrahimi S, Brevik EC, Aitkenhead-Peterson J (2016). Assessment and monitoring of soil degradation during land use change using multivariate analysis. Land Degrad. Dev. 28:128–141.

Lovato T, Mielniczuk J, Bayer C, Vezzani F (2004). Adição de carbono e nitrogênio e sua relação com os estoques no solo e com o rendimento do milho em sistemas de manejo. R. Bras. Cienc. Solo 28:175-187.

Lu M, Yang YH, Luo YQ, Fang CM, Zhou XH, Chen JK, Yang X, Li B (2011). Responses of ecosystem nitrogen cycle to nitrogen addition: a meta-analysis. New Phytol.189:1040-1050.

Moreira A, Malavolta E (2004). Dinâmica da matéria orgânica e da biomassa microbiana em solo submetido a diferentes sistemas de manejo na Amazônia Ocidental. Pesq. Agropec. Bras. 39:1103-1110.

Pérez KSS, Ramos MLG, Mcmanus C (2004). Carbono da biomassa microbiana em solo cultivado com soja sob diferentes sistemas de manejo nos Cerrados. Pesq. Agropec. Bras. 39(6):567-573.

Pfenning L, Eduardo BP, Cerri CC (1992). Os métodos de fumigação-incubação e fumigação-extração na estimativa da biomassa microbiana de solos da Amazônia. R. Bras. Cienc. Solo 16:31-37.

Rangel OJP, Silva CA (2007). Estoques de carbono e nitrogênio e frações orgânicas de latossolo submetido a diferentes sistemas de uso e manejo. R. Bras. Cienc. Solo 31:1609-1623.

Richter DD, Markewitz D, Trumbore SE, Wells CG (1999). Rapid accumulation and turnover of soil carbon in a re-establishing forest. Nature 400:56-58.

Roscoe R, Mercante FM, Salton JC (2006). Dinâmica da matéria orgânica do solo em sistemas conservacionistas: modelagem matemática e métodos auxiliares. Dourados: Embrapa Agropecuária Oeste 304p.

Sakamoto K, Obo Y (1994). Effects of fungal to bacterial ratio on the relationship between CO_2 evolution and total soil microbial biomass. Biol. Fert. Soils 17(1):39-44.

Santos JB, Jakelaitis A, Silva AA, Vivian R, Costa MD, Silva AF (2005). Atividade microbiana do solo após aplicação de herbicidas em sistemas de plantio direto e convencional. Planta Daninha 23(4):683-691.

Sisti CPJ, Santos HP, Kohhann R, Alves BJR, Urquiaga S, Boddey RM (2004). Change in carbon and nitrogen stocks in soil under 13 years of conventional or zero tillage in southern Brazil. Soil Tillage Res. 76: 39-58.

Sparling GP (1992). Ratio of microbial biomass carbon to soil organic carbon as a sensitive indicator of changes in soil organic matter. Aust. J. Soil Res. 30:195-207.

Teixeira WG, Arruda W, Shinzato E, Macedo RS, Martins GC, Lima HN, Rodrigues TE (2010) Solos. In: Geodiversidade do estado do Amazonas. Org: Maria Adelaide Mansini Maia e José Luíz Marmos, Manaus: CPRM, pp. 71-86.

Tejada M, Hernandez MT, Garcia C (2009). Soil restoration using composted plant residues: effects on soil properties. Soil Till. Res. 102:109-117.

Tótola MR, Chaer GM (2002). Microrganismos e processos microbiológicos como indicadores da qualidade dos solos. In: Alvarez V., V.H.; Schaefer, C.E.G.R.; Barros, N.F.; Mello, J.W.V. & Costa, L.M., eds. Tópicos em ciência do solo. Viçosa, MG, Sociedade Bras. De Ciênc. do Solo pp.196-275.

Treseder KK (2008). Nitrogen additions and microbial biomass: a meta-analysis of ecosystem studies. Ecol. Lett. 11:1111-1120.

Wiesmeier M, Dick DP, Rumpel C, Dalmolin RSD, Hilscher A, Knicker H (2009). Depletion of soil organic carbon and nitrogen under *Pinus taeda* plantations in southern Brazilian grasslands. Eur. J. Soil Sci. 60:347-359.

Wilcke W, Lilienfein J (2004). Soil carbon-13 natural abundance under native and managed vegetation in Brazil. Soil Sci. Soc. Am. J. 68:827-832.

World Reference Base (WRB) (2014).World reference base for soil resources 2014. Edited by Schad P, van Huyssteen C, Micheli E. World Soil Resources Reports No. 106. FAO, Rome. 189p. ISBN 978-92-5-108369-7