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Total nitrogen and humic substances in aggregates of soils with onion crops under no-tillage and conventional tillage systems

Nitrógeno total y sustancias húmicas en agregados del suelo cultivado con cebolla bajo siembra directa y preparación convencional

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Cover plants at 60 days after sowing.

Photo: M. Souza

ABSTRACT

The objective of this study was to evaluate the soil total nitrogen (TN), and N contents in humic substances (HS) of the organic matter in aggregates of soils cultivated with onion under no-till system for horticulture (NTSH) and conventional tillage system (CTS), comparing with an area of forest. The evaluated treatments were natural vegetation (control), 100% black oats, 100% rye, 100% oilseed radish, intercrop of oilseed (14%) + rye (86%), intercrop of oilseed (14%) + black oats (86%), area under CTS of onion for ±37 years, and area with secondary forest for ±30 years. Five years after the NTSH implementation, undisturbed soil samples from the layers 0-5 cm, 5-10 cm, and 10-20 cm were collected; these samples presented aggregate sizes between 2.0 mm and 8.00 mm. The TN, and N contents of the HS were subdivided into fulvic acids (N-FA), humic acids (N-HA), and humin (N-HU) fractions. The change from CTS to NTSH increases the TN and N-HU contents in the 0-5 cm soil layer. The intercrop of oats and oilseed radish, used as soil plant cover species in NTSH, presented a greater increase in N-HU (0-20 cm) than the other treatments. Black oats, and natural

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vegetation presented a greater increased in N-HA, and N-FA contents, respectively, in the 10-20 cm layer, than the other treatments in NTSH and CTS. CTS with millet as soil plant cover presented a greater increase in N-FA (0-20 cm) contents than the NTSH treatments.

Additional key words: *Allium cepa* L., cover plants, aggregation, humic acids, soil nitrogen, tillage system.

RESUMEN

Se evaluaron los niveles de nitrógeno total (NT) y N de las sustancias húmicas (SH) de la materia orgánica en agregados de suelo cultivado con cebolla bajo siembra directa de hortalizas (SDH) y sistema de preparación convencional (SPC), comparando con un área de bosque. Los tratamientos evaluados fueron: vegetación espontánea; 100% avena; 100% centeno; 100% nabo; cultivos asociados de nabo (14%) + centeno (86%); cultivos asociados de nabo (14%) + avena (86%); área bajo SPC de cebolla (±37 años) y de bosque secundario de ±30 años). Cinco años después de la implantación del SDH fueran recogidas muestras no disturbados del suelo en las capas 0-5, 5-10 y 10-20 cm y obtenidos los agregados (entre 2,0 y 8,00 mm). En estos se determinaron los niveles de NT y el N de las SH, subdivididos en fracción ácidos fúlvicos (N-FAF), ácidos húmicos (N-FAH) y humina (N-HUM). La conversión de áreas de SPC a SDH favorece el aumento de los niveles de NT y N-HUM en la capa de 0-5 cm. Entre las especies de plantas de cobertura utilizadas en el SDH, los cultivos asociados de avena + nabo favorecieron el aumento del N-HUM (0-20 cm) en comparación a los demás tratamientos. La avena solo y el control con vegetación espontánea aumentaron los niveles de N-FAH y N-FAF, respectivamente, en la capa de 10-20 cm, en comparación a los demás tratamientos en SDH y SPC. El SPC con mijo como planta de cobertura aumentó los niveles de N-FAF (0-20 cm) en comparación con el SDH.

Palabras clave adicionales: *Allium cepa* L., plantas de cobertura, agregación, ácidos húmicos, nitrógeno del suelo, sistemas de labranza.

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INTRODUCTION

Onion (*Allium cepa* L.) crops cover an area of approximately 60,000 ha annually in Brazil, producing approximately 1.6 million t of onion bulbs (IBGE, 2017). The southern region of the country produces 49% of the national production, where the state of Santa Catarina (SC) stands out as the largest national producer since 1990, with a profitable production that has becoming more sustainable due to organic production studies (ACATE, 2014).

Soil conventional tillage system (CTS) is the most used system for onion crops in SC, comprising frequent turning of the soil (plowing, harrowing, subsoiling or scarification) in the preparation of the soil of the planting bed (Menezes *et al*., 2013). This soil preparation increases the occurrence of erosive processes and changes edaphic attributes, decreasing nutrient availability to plants and soil organic matter content (Loss *et al*., 2015). CTS is an important system for food, fiber and energy production, however, it impacts the soil; thus, the search for soil management and conservation practices has been a constant challenge. No-till system for horticulture (NTSH) has stood out as a promising alternative for onion crops (Menezes *et al*., 2013). Soil turning in NTSH is done only in the planting line, and cover plants are used for the production and maintenance of plant residues on the soil. This practice maintains or increases the soil organic matter (SOM), thus improving edaphic attributes (Briedis *et al*., 2012; Loss *et al*., 2014; 2015). The use NTSH is a developing management strategy and differs from the current NTS in technological and social aspects, including the non-use of herbicides and the social bias, since this practice has potential for the development of sustainable agriculture (Fayad and Mondardo, 2004; Menezes *et al*., 2013).

Evaluations of soil attributes after change from CTS to NTSH showed variations in total nitrogen (TN), and N contents in humic substances - fulvic acids (N-FA), humic acids (N-HA), and humin (N-HU fractions) - indicating changes in edaphic attributes and the impacts of the management system used on the soil quality (Assis *et al*., 2006; Guerra *et al*., 2008). These changes are mainly due to the N high dynamics and interactions with practically all processes occurring in the soil.

Humic substances (HS) are usually evaluated in deformed soil samples, because of the greater easiness and speed in obtaining the results. However, Loss *et al*. (2015) showed significant differences in aggregation between soils managed under CTS and NTSH, especially in the formation of macroaggregates (8.00 mm > Ø ≥ 2.0 mm). Thus, the use of undisturbed soil samples is important to better assess the effects of management systems in evaluations of HS contained in aggregates of the soil.

The soil loses its stability, its macroaggregates fragmentate (Loss *et al*., 2015), and the SOM within its aggregates decompose (Six *et al.*, 2000) due to the conditions in management systems with frequent turning of the soil, such as CTS. However, more conservative systems that prioritize the contribution of organic residues and less soil turning, such as NTSH, have been efficient in maintaining the soil N contents, preserving its quality (Zibilske *et al*., 2002; Lovato *et al*., 2004; Assis *et al*., 2006). Therefore, the quantification of N contents in HS in soil aggregates assists in studies on their dynamics, since the sizes of the aggregates denote the SOM time, stability, and sensitivity to soil management practices. The SOM content and quality are dependent on the land use and management system used, thus, the objective of this study was to evaluate the soil total nitrogen, and N contents in HS (N-FA, N-HA and N-HU) in aggregates of a Humic Cambisol (Inceptisol) cultivated with onion under NTSH and CTS, comparing with an area of secondary forest.

MATERIALS AND METHODS

The study was conducted in the Experimental Station of the "Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri)" in Ituporanga (Santa Catarina State, Brazil) (27°24'52" S and 49°36'9" W, at an altitude of 475 m). The climate of the region is subtropical humid mesotherm (Cfa), with hot summers, no frequent frosts, no defined dry season, average annual temperature of 17.6°C, and average annual precipitation of 1,400 mm.

The experiment was carried out in a Humic Cambisol (Inceptisol) of clay loam texture (Loss *et al*., 2015), with 380 g kg^{-1} clay, 200 g kg^{-1} silt and 420 g kg^{-1} sand. The area was cultivated with onion in CTS (plowing, harrowing and scarification) for about 20 years until 1996. In that year, liming with dolomitic limestone was incorporated to the 0-20 cm soil layer to increase the soil pH in water to 6.0. The minimum cultivation system of onion, rotated with cover plants - oats, *Avena strigose* Schreb.; mucuna, *Mucuna aterrima* Piper and Tracy; millet, *Pennisetum glaucum* (L.) R.Br.; crotalaria, *Crotalaria juncea* L.; and vetch, *Vicia sativa* L. - was adopted from 1996 to 2007. The area was cultivated with sweet potatoes (*Ipomoea batatas* [L.] Lam.) in 2008 and 2009. Then, the experiment with onion in NTSH and CTS was conducted; the natural vegetation was controlled using glyphosate herbicide, and no further pesticide applications was applied.

The soil characteristics before the NTSH implementation in the 0-10 cm soil layer were: 23.2 g kg^{-1} of total organic carbon, pH in water of 6.0, SMP index of 6.2, 26.6 mg dm^{-3} of P, 145.2 mg dm^{-3} of K, 0.0 $cmol_c$ kg^{-1} of Al^{3+}, 7.2 $cmol_c$ kg^{-1} of Ca^{2+}, and 3.4 $cmol_c$ kg^{-1} of Mg^{2+} (Tedesco *et al.,* 1995). The treatments used in the experiment were: control with natural vegetation, with predominant plants of the Amaranthaceae, Asteraceae, Caryophyllaceae, Compositae, Convolvulaceae, Cruciferae, Cyperaceae Euphorbiaceae, Fabaceae, Lamiaceae, Leguminosae, Liliaceae, Malvaceae, Oxalidaceae, Plantaginaceae, Poaceae e Polygonaceae families (1); black oats (*A. strigosa*) in the entire area, with sowing density of 120 kg ha^{-1} (2); rye (*Secale cereale* L.) in the entire area, with sowing density of 120 kg ha^{-1} (3); oilseed radish (*Raphanus sativus* L.) in the entire area, with sowing density of 20 kg ha^{-1} (4); intercropping of oilseed radish (14%) and rye (86%), with sowing density of 10 and 60 kg ha^{-1}, respectively (5); intercrop of oilseed radish (14%) and oats (86%), with sowing density of 10 and 60 kg ha^{-1}, respectively (6); area with onion crops under CTS for ±37 years, until 2013, when the soil samples were collected (7); and area with a ±30 years old secondary forest, at approximately 500 m from the experiment area, representing the natural condition of the soil.

Seeds of the soil plant cover species were broadcasted in April of each year, and a grain-seeding machine was passed twice in the area to incorporate the seeds. The amount of seeds used per hectare was calculated according to the recommendations of Monegat (1991). Each experimental unit was 25 m^2 (5×5 m); they were arranged in a complete randomized block design with five replicates. A knife-roller (model RF240, MBO Ltd, Chaska, MN) was applied to all soil plant cover species in July of each year.

In the CTS area, the onion was cultivated in rotation with millet in the summer from 2007. The millet was managed with a knife-roller at flowering, and plowing followed by harvesting to the implementation of the onion crop were carried out after 30 to 60 d. Soil fertilization was carried out according to the recommendations of CQFSRS/SC (2004), with 165 kg ha^{-1} of P_2O_5 (triple superphosphate), 105 kg ha^{-1} K_2O (potassium chloride) and 192 kg ha^{-1} of N (ammonium nitrate). Liming with dolomitic limestone was performed in 2010 to increase the soil pH to 6.0.

In the NTSH area, the soil cover plants were managed and soil fertilization was performed in July of each year, with 96 kg ha^{-1} of P_2O_5 (natural phosphate of milled Gafsa), and 175 kg ha^{-1} of P_2O_5, 125 kg ha^{-1} of K_2O, and 160 kg ha^{-1} of N (poultry manure), applying half at planting of the onion seedlings and half at 30 days after planting (dap). No natural phosphate was applied from the 2011 crop season, since the soil presented high levels of P (CQFSRS/SC, 2004). Furrows were opened using an adapted no-tillage machine, and the onion seedlings (cultivar Bola Precoce, Empasc 352) were manually transplanted. The spacing used was 0.50 m between rows and 0.10 m between plants, with 10 rows of onion per plot. Weeding was done at 60 and 90 dap of the onion seedlings.

Mucuna (*M. aterrima*) was planted in December (summer) of each year in the entire area after harvesting of the onions, using a sowing density of 120 kg ha^{-1}. The mucuna was managed with a knife roller in March of each year and the soil cover plants were sowed in April. The mean dry matter, and onion productions were described by Loss *et al*. (2015).

Trenches with dimensions of 0.40×0.40×0.40 m were opened with a spade in each plot, and five undisturbed samples of soil from the 0-5, 5-10 and 10-20 cm layers were collected five years after the implementation of the treatments under NTSH, in September 2013. The samples collected were packed in plastic bags and sent to the laboratory; they were air dried and manually disaggregated, following cracks or weak points, and passed through 8.00-mm and 4.00-mm mesh sieves to obtain the soil aggregates (Claessen, 1997). The weight of each undisturbed sample was 900 to 1,000 g.

The aggregates (8.00 mm > Ø ≥ 4.0 mm) used to evaluate the TN, and N contents in HS represented about 60% of the soil mass in the NTSH, and forest areas; and 30 to 35% of the soil mass in the CTS areas.

The aggregates retained in the 4.00-mm mesh sieve were manually disaggregated and passed through a 2.00-mm mesh sieve. The obtained air-dried fine earth of the aggregates was used to perform the chemical analysis and determine the TN and N in HS - humin (N-HU), humic acid (N-HA), and fulvic acid (N-FA).

TN, and N in HS was determined according to Tedesco *et al*. (1995). The HS was extracted and separated according to the differential solubility technique established by the International Humic Substances Society (Swift, 1996). The standard methodology for soil TN (Tedesco *et al.*, 1995) was used to determine the N in the HU, since it is insoluble. An aliquot of 10 mL of the substances obtained in the chemical fractionation was used to determine the N-FA and N-HA (Swift, 1996). The sample was digested with sulfuric acid (H_2SO_4) and hydrogen peroxide, followed by distillation with sodium hydroxide and titration with H_2SO_4 of the solution collected in the boric acid indicator. The temperature of the block for the turning point of the color for FA was approximately 150°C, and for HA was 300°C.

The results were analyzed for data normality and homogeneity using the Lilliefors and Bartlet tests, respectively, and evaluated in a randomized block design with eight treatments and five replications. The results were subjected to analysis of variance by the F test and significant means were compared by the Scott-Knott test at 5% probability.

RESULTS AND DISCUSSION

Total nitrogen contents

The TN contents in the soil aggregates were higher (P>0.05) in the forest area, in the three depths evaluated. The average TN content in the 0-20 cm soil layer of the forest area was 65% (3.0 g kg^{-1} TN), higher than that found in areas with onion crops. TN contents were higher in the 0-5 cm layer, decreasing with increasing depth in both NTSH and CTS areas, with lower TN in CTS (Fig. 1).

The highest TN content was found in the forest area due to the higher deposition of organic material (litterfall), accumulating N on the soil surface as the plant residues are humidified (Mafra *et al*., 2008). Imbalances in organic residue deposition, and decomposition rate, with a rapid decrease in TN content, were observed in the cultivated areas, depending on the management system used, and its time of implementation (Scholes and Breemen, 1997). These results were confirmed in the 0-5 cm layer (Fig. 1), with CTS presenting lower TN than NTSH.

CTS has higher annual input of dry matter than NTSH (Loss *et al*., 2015), however, the soil TN accumulation and maintenance reduced, showing the negative effects of soil turning and pesticide spraying of the CTS and its stronger impacts on the environment, compared to the addition of crop residues through soil cover plants. Other studies have reported negative correlations between soil turning and soil N loss (Zibilske *et al*., 2002; Mielniczuk *et al*., 2003).

The soil TN content in the NTSH and CTS depends on the amount of dry matter (shoot and root) produced by the soil cover crops and the adopted management. Therefore, systems that increase the production and maintenance of dry matter on the soil surface provide higher contents and accumulation of TN in the soil. This was observed in the comparison between NTSH and CTS in the 0-5 cm soil layer (Fig. 1); the lower TN in CTS was due to the increased TN mineralization caused by the soil turning, which fragmentates plant residues and favors the attack by microorganisms. These results confirm those found by Six *et al*. (2000), Lovato *et al*. (2004), and Loss *et al*. (2014), who reported losses in TN in soils with frequent turning due to increased microbial activity and greater exposure of plant residues to microorganisms and their enzymes. CTS had the greatest input of dry matter (Loss *et al*., 2015), however, the soil tillage practices (plowing and harrowing) resulted in rupture of aggregates, with subsequent exposure of the N that was physically protected, reducing TN contents in the soil surface layers.

Some studies report the use of management systems with conservative practices and restricted soil turning, such as the NTSH, with a tendency of increasing the SOM contents, and reducing the losses of N of the CTS (Zibilske *et al*., 2002; Mielniczuk *et al*., 2003; Mrabet, 2006). The TN content found in the soil

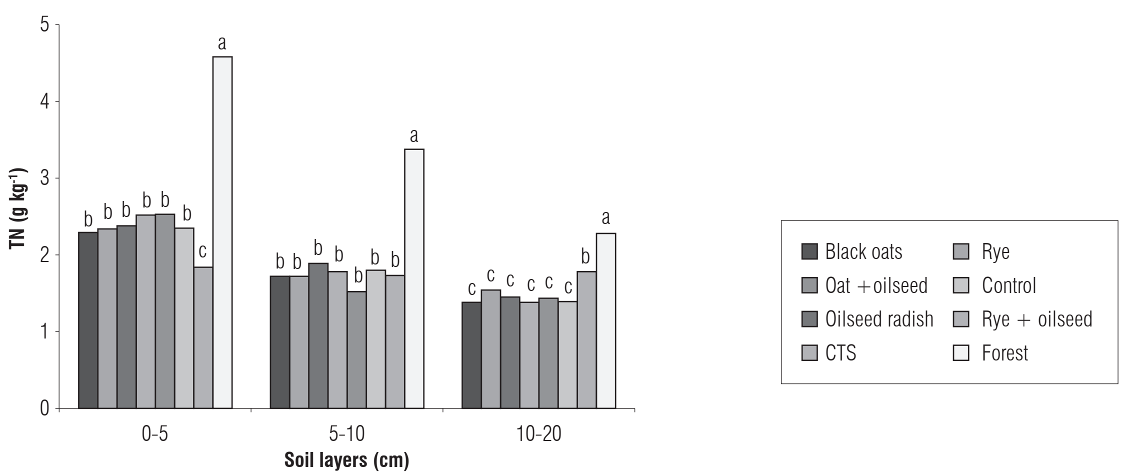

Figure 1. Total nitrogen (TN) contents in soil aggregates in onion crops, and forest areas. Columns with different letters in the same depth are statistically different by the Scott-Knott test ($P \leq 0.05$).

aggregates of the 0-5 cm soil layer at five years after implementing the NTSH increased to 36.8% (rye and cultivated-radish), 24.3% (oats), 37.3% (oats and cultivated-radish), 27.0% (control), 27.0% (rye), 23.8% (cultivated-radish), compared to the CTS. These results show the potential of NTSH for the increase of TN contents in soils under CTS, and the sustainability of agricultural systems. Moreover, the higher TN contents in the NTSH is connected to its higher soil aggregation indices (weighted average diameter, and macroaggregates and mesoaggregates) in the 0-5 cm layer, as observed by Loss *et al*. (2015) in the same experiment and treatments.

The absence of differences between the NTSH and CTS at depths of 5-10 cm indicates the similarity of the cover plants used in the NTSH in adding N. However, the higher TN of the CTS in the 10-20 cm soil layer may be due to the incorporation of millet plant residues into deeper layers, homogenizing the TN in the layers 0-5 cm, 5-10 cm, and 10-20 cm, and increasing the TN contents in the layer 10-20 cm. Similar result for TN accumulation was described by Assis *et al*. (2006) in aggregates of a Red Latosol (Oxisol) managed under NTS for 4 years, and under CTS for 30 years, with reduced TN contents in cultivated soils, compared to native forest soils (subcaducifolia forest).

N contents in humic substances

The N-HU fraction was, in general, greater than the N-HA and N-FA fractions, especially in the 0-5 cm layer, indicating that the systems generated favorable conditions for the humification process of the organic material (Tab. 1). The highest N-HU, N-HA and N-FA contents were found in the forest, except the N-FA in the layer 0-5 cm, which was higher in the CTS. The NTSH treatment presented higher N-HU contents than the CTS in the 0-5 cm layer, as well as the oat and oilseed radish in the layer 5-10 cm. In the layer 10-20 cm, the N-HU contents of the treatments oats, oats and cultivated-radish, and control were similar to the contents found in the forest area (Tab. 1).

The N in HS of the forest area, and areas under NTSH had a similar pattern, with addition rates, transformation, and losses of N in the soil maintained in balance, favoring the humification process. Therefore, they presented the highest N content in the more stable fractions of the SOM, especially in the 0-5 cm layer. According to Assis *et al*. (2006), the presence of N in HS indicates that part of the N of the soil is stable, with low recycling rate and availability to plants. These authors evaluated aggregates of an Oxisol and found that land use and management systems -NTS for four years with rotation of maize and soybean crops, CTS for 30 years with maize, and a native forest area - change the N content in the different aggregate size classes; and soil cultivation reduce N contents in HS.

The treatments oat, oat and cultivated-radish, and control of the NTSH stood out in N-HU contents in the 10-20 cm layer, due to their root systems and the diversity of species in the control. The abundance and diversity of these root systems affect the soil at different depths, distributing root exudates more evenly. Thus, the soil aggregates, and the N within the aggregates is protected, increasing N in deeper layers, especially in more stable fractions of the SOM, such as N-HU and N-HA (Santos *et al*., 2008).

The effect of the intercropping of oats and oilseed radish, and rye and oilseed radish in the 0-5 cm layer was stronger compared to oilseed radish alone; N-HU contents were higher in the intercrops with oilseed radish. These differences may be due to the root system of grasses (oats and rye); their dense and fasciculate roots in contact with mineral particles promote stabilization of SOM fractions; the C from the roots has a 2.4-fold mean residence time compared to the C from the shoot; and the roots contribute 30% more to SOM than the shoot (Rasse *et al*., 2005).

CTS presented the lowest ΣN-HU in the 0-20 cm layer, and the intercrop of oat and oilseed radish presented the highest ΣN-HU in NTSH. The decrease of N contents in the soil aggregates and, consequently, N in the humin fraction, in the CTS was due to the soil disaggregation and plant residue fragmentation resulting from plowing and harvesting practices; this increases microbial activity due to a greater aeration, higher temperature, and more frequent soil wetting and drying (Stevenson, 1994; Assis *et al*., 2006). In addition, the continuous use of agricultural implements for soil preparation in CTS favors C and N losses caused by soil erosion (Pinheiro *et al*., 2003). In the intercrop of oat and cultivated-radish, the absence of soil turning and the different root systems of oats and oilseed radish increased N protection in the aggregates, generating a higher N-HU content.

Table 1. Mean nitrogen content in humic substances (g kg^{-1}) in aggregates of a Humic cambisol (Inceptsol) cultivated with onion under different soil cover management systems, and a native forest, Ituporanga-SC, Brazil.

Treatments	N-HU			ΣN-HU	N-HA			ΣN-HA	N-FA			ΣN-FA
	Soil layers (cm)				Soil layers (cm)				Soil layers (cm)			
	0-5	5-10	10-20	0-20	0-5	5-10	10-20	0-20	0-5	5-10	10-20	0-20
Black oats	1.40 b	1.22 b	1.04 a	3.66 c	0.22 b	0.24 b	0.28 b	0.74 b	0.16 c	0.16 b	0.10 b	0.42 c
Rye	1.76 b	1.16 b	0.72 b	3.64 c	0.24 b	0.20 b	0.24 c	0.68 b	0.10 d	0.12 b	0.12 b	0.34 c
Oilseed radish	1.22 c	1.26 b	0.66 b	3.14 c	0.24 b	0.28 b	0.24 c	0.76 b	0.10 d	0.10 b	0.12 b	0.32 c
Rye + oilseed	1.60 b	0.78 c	0.70 b	3.08 c	0.26 b	0.22 b	0.20 c	0.68 b	0.10 d	0.14 b	0.10 b	0.34 c
Oat +oilseed	1.52 b	1.52 a	1.22 a	4.26 b	0.28 b	0.25 b	0.20 c	0.73 b	0.12 d	0.12 b	0.14 b	0.38 c
Control	1.62 b	0.80 c	0.88 a	3.30 c	0.26 b	0.28 b	0.20 c	0.74 b	0.22 c	0.12 b	0.22 a	0.56 b
CTS	0.86 d	0.84 c	0.60 b	2.30 d	0.26 b	0.22 b	0.22 c	0.70 b	0.40 a	0.20 a	0.12 b	0.72 a
Forest	2.68 a	1.72 a	1.02 a	5.42 a	0.80 a	0.54 a	0.36 a	1.70 a	0.28 b	0.25 a	0.22 a	0.75 a
CV (%)	12.62	20.10	26.77	22.12	20.37	22.04	24.40	25.51	37.74	46.37	31.94	30.15

Means followed by the same letter in the column do not differ by the Scott-Knott test ($P \leq 0.05$). Control: natural vegetation; CV: coefficient of variation; N-HU: nitrogen of the humin fraction; N-HA: nitrogen of the humic acid fraction; N-FA: nitrogen of the fulvic acid fraction; ΣN: sum of the N contents; CTS: conventional tillage system.

The CTS presented the lowest N-HU contents in the 0-5 cm layer and the highest N-FA contents in the 0-5 and 5-10 cm layers - similar to the forest in the 5-10 cm layer. These differences can be attributed to the soil turning in the CTS, which causes disaggregation and subsequent aeration of the soil, resulting in greater microbial activity, and favoring the formation of FA (Guerra *et al*., 2008). These results confirm those found by Assis *et al*. (2006), who found higher values of N-FA in CTS compared to NTS.

The treatments under NTSH and CTS were similar in N-HA contents and presented lower means than the forest area in the 0-5 cm and 5-10 cm layers. The oat treatment stood out from the other NTSH and CTS treatments in the 10-20 cm layer, presenting similar N-HA contents to the forest area. The higher N-HA content found in the oat treatment indicate that the plant material (oat shoot and root) is more efficient in increasing N-HA contents than the other plants in NTSH and CTS. No differences were found between NTSH and CTS for the ΣN-HA (Tab. 1).

The N-FA contents of the treatments in NTSH in the 5-10 cm layer were similar. The oat, and control treatments stood out with the highest N-FA contents in the 0-5 cm layer.

The control had similar N-FA content to the forest, and higher to the other treatments under NTSH, in the 10-20 cm layer. These results may be due to the diversity and releasing speed of compounds in the decomposition of the natural vegetation biomass; since the control area presented the highest ΣN-FA among the treatments in NTSH. The highest ΣN-FA was found in the CTS areas due to the incorporation of the plant residues into the soil and their fragmentation through the practices of plowing and harvesting, which increase the microbial activity and formation of FA.

The N contents in HS represent a passive fraction of the SOM; HS are highly recalcitrant organic molecules in the soil, i.e., they are more difficult to be altered by management practices (Stevenson, 1994). However, the CTS areas had reduced N-HU contents (0-5 cm), indicating that practices adopted in CTS do not favor the more stable fraction of the SOM (humin); and the NTSH increase the humification of the SOM. This pattern is corroborated by the higher TN contents (Fig. 1) in the NTSH compared to the CTS in the 0-5 cm layer, which may directly affect the agricultural productivity and longevity of the agricultural soil.

CONCLUSIONS

The change of areas from CTS to NTSH increases TN and N-HU contents in the 0-5 cm soil layer. However, these increases are still lower than those found in native forest areas.

The intercrop of oat and oilseed radish increased the ΣN-HU, compared to the other treatments and species of cover crops used in NTSH.

The oat, and natural vegetation (control) treatments increased the N-HA and N-FA contents, respectively, in the 10-20 cm soil layer, compared to the other treatments in NTSH and CTS.

The CTS area with millet as cover plant increased the ΣN-FA contents, compared to NTSH.

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