Soil & Tillage Research 184 (2018) 195–202

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Carbon and nitrogen contents and aggregation index of soil cultivated with onion for seven years using crop successions and rotations

Jucinei José Comin[a], Lucas Borges Ferreira[a], Luiz Henrique dos Santos[a], Leôncio de Paula Koucher[a], Ludmila Nascimento Machado[a], Elano dos Santos Junior[a], Álvaro Luiz Mafra[b], Claudinei Kurtz[c], Monique Souza[a], Gustavo Brunetto[d], Arcângelo Loss[a,*]

[a] Universidade Federal de Santa Catarina, Centro de Ciências Agrárias, Itacorubi, Florianopolis, SC, Brazil
[b] Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinárias, Lages, SC, Brazil
[c] Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Ituporanga, SC, Brazil
[d] Universidade Federal de Santa Maria, Centro de Ciências Rurais, Camobi, Santa Maria, RS, Brazil

ARTICLE INFO

Keywords:
Weighted mean diameter
No-till
Conventional tillage
Cover plants
Plant species diversity
Macroaggregates
Microaggregates

ABSTRACT

Onion is usually cultivated using conventional tillage system (CTS), with excessive soil turning, leaving it with low or no vegetation cover. This favors erosive processes and impacts negatively diverse edaphic attributes. Adopting soil management systems with conservationist bases that use permanent soil coverage and crop rotation can maintain or improve these attributes (for example, soil aggregation and soil organic matter). The objective of this work was to evaluate the total organic carbon (TOC) and total nitrogen (TN) contents, aggregation index, and aggregate mass distribution of a Humic Cambisol cultivated with onions in succession or rotation with other species in no-tillage system (NTS) and CTS. The treatments were: maize/onion (NTS-T1); cover plants (winter)/onion (NTS-T2); maize/winter grasses/onion (NTS-T3); velvet bean/onion (NTS-T4); millet/cover plants (winter)/onion (NTS-T5); velvet bean/rye/onion (NTS-T6); maize/onion (CTS-T7); intercrops cover plants (summer)/onion (NTS-T8). Seven years after the implementation of the experiment, the weighted mean diameter (WMD) of the aggregates, distribution of macroaggregates, mesoaggregates, and microaggregates, and TOC, and TN contents of the soil (0–0.05, 0.05–0.10 and 0.10–0.20 m layers) were evaluated. Periodic soil turning (CTS) in the succession of maize, and onion (T7) reduces TOC and TN contents in the soil surface layer, compared to succession and rotation systems with onion crops in NTS. This negative effect on soil quality is connected to the reduction of aggregate stability, especially the decrease in the amount of macroaggregates. The use of grasses, especially winter grasses in rotation with maize (T3), preceding onion crops in NTS increases TOC content in the soil surface layer. Higher TN accumulation in the surface layer is found in areas with more soil cover plant species in rotation or succession with onion in NTS (T2, T3, T5, T6 and T8). The use of NTS for onion crops generates high soil aggregate stability, with predominance of macroaggregates, regardless of the crop succession or rotation system used. Treatments with no winter soil cover plants (T1, T4 and T7) reduce soil TOC contents and the mass of water-stable macroaggregates and increase the amount of microaggregates in the soil surface layer when compared to the other treatments.

1. Introduction

Onion (*Allium cepa*) is grown worldwide in 3.72 million hectares; China, India and the United States are the main producing countries; and Brazil has the ninth greatest onion production (The Daily Records, 2018). Onion crops have economic and social importance in Brazil; they generate jobs and income throughout its production chain. The South of Brazil accounts for 47% of the Brazilian onion production; the state of Santa Catarina was the largest onion producer in the last 25 years, with 20,000 ha of onion, representing one third of the Brazilian production (ACATE, 2014; IBGE, 2016). These crops are distributed in 18,000 farms, which are mainly managed by family farmers, and most of them are managed using conventional soil tillage system (CTS) (EPAGRI, 2013). The use of CTS in these regions can damage soil quality, considering their soil and environmental characteristics.

The practices carried out in CTS to obtain a suitable environment for

* Corresponding author.
E-mail address: arcangelo.loss@ufsc.br (A. Loss).

https://doi.org/10.1016/j.still.2018.08.002
Received 18 May 2018; Received in revised form 3 August 2018; Accepted 6 August 2018

the crops usually involves the use of plowing and harrowing (Magdoff and Van Es, 2009) or cultivators (Balesdent et al., 2000; So et al., 2009). These practices leave the soil with no or low coverage, favoring erosion processes (Bhatt and Khera, 2006; So et al., 2009), and affects negatively the soil macroporosity, aggregate stability (Franzluebbers, 2002; Paglia et al., 2004; So et al., 2009; Sheehy et al., 2015), and total organic carbon (TOC) and total nitrogen (TN) contents (Busari et al., 2015; Mazzoncinia et al., 2016).

Therefore, the adoption of no-tillage system (NTS) is growing and contributing to improve the soil physical, chemical, and biological characteristics (Busari et al., 2015; Bhatt, 2017). NTS increases the soil TOC (Ussiri and Lal, 2009; Busari et al., 2015; Mazzoncinia et al., 2016) and TN (Busari et al., 2015; Mazzoncinia et al., 2016) contents and, consequently, the soil aggregate stability (So et al., 2009; Sheehy et al., 2015). The use of NTS combined with crop rotation assists in the maintenance or even improves soil fertility, soil organic matter (SOM), and structure, in the control of pests, diseases and weeds (Ball et al., 2005), and increases crop yield (Stanger and Lauer, 2008; Campbell et al., 2011). The soil aggregate stability is improved by the plant species richness, and presence of certain grass and legume species due to their root architecture (Gould et al., 2016).

The use of soil cover crops, especially grasses, protects the soil against climatic events, and increases soil TOC, mainly by rhizodeposition. According to Thivierge et al. (2016), maize, sorghum, and millet root systems contributed to the C contents in the soil at depth of 0.30 m, with higher C accumulation after harvest due to crop residues for maize (243 g C m^{-2}) than for sorghum (197 g C m^{-2}) and millet (131 g C m^{-2}). Most of this C were from the fine roots, with diameters smaller than 0.5 mm. Oat plants have fasciculate root system that reaches depths of up to 0.76 m, average shoot dry matter production of 6 Mg ha^{-1}, and high C/N ratio (average of 31.5). Rye plants have high nutrient cycling capacity, fasciculate root system that reaches depths of up to 1.22 m, average shoot dry matter production of 4.5 Mg ha^{-1}, and high C/N ratio (average of 30.5). Maize plants have an extensive and branched root system, reaching depths of up to 1.8 m, average shoot dry matter production of 6 Mg ha^{-1}, and high C/N ratio (average of 52) (Weaver, 1926; Lima Filho et al., 2014).

Thierfelder and Wall (2010) compared the effect of CTS (monoculture of maize, and maize in succession with cotton – *Gossypium hirsutum* L.) and NTS (two-year and three-year rotations of maize with cotton, and *Crotalaria juncea* as soil cover plant) over four years and found similar results. They found higher water infiltration rates, earthworm population, TOC contents, and aggregate stability in NTS treatments. Several studies have reported positive correlations between SOM and aggregate stability (Amezketa, 1999; Balesdent et al., 2000; Carrizo et al., 2015; Sheehy et al., 2015). Soil turning disaggregates the soil, exposing the SOM that was protected to microbial attack, accelerating its loss (Amezketa, 1999) and, consequently, decreasing aggregate stability.

Evaluating the effects of NTS, CTS, secondary forest, and pasture (*Axonopus compressus*) on the soil aggregation, SOM content in water, TOC, and mineralizable carbon of a Red Nitosol (Alfisol) in Marmeleiro PR, Brazil; Loss et al. (2014) found lower aggregation indices (weighted mean diameter index) and TOC contents in CTS when compared to NTS. Loss et al. (2015) also found similar results when evaluating chemical and physical characteristics of soil aggregates; after five years of NTS with onion in a Humic Distrudept, they compared the effects of different intercrops, and onion crop in CTS for 37 years on the soil aggregation and TOC and found that the use of soil cover crops (single or intercropped) in NTS increases soil aggregation and TOC contents, compared to CTS.

NTS increases aggregate stability, and TOC contents inside the aggregates. So et al. (2009) compared the effect of using CTS and NTS for 14 years on soil physical properties and TOC contents and found lower silt and clay contents dispersed in water and higher aggregation index (WMD) for NTS, i.e., a more stable and better aggregated soil surface layer due to the higher TOC in NTS (33.7 g kg^{-1}), compared to CTS (16.7 g kg^{-1}).

The roots of the plants are temporary agents of macroaggregate stabilization. Several studies have shown improvement in the stability of these structures by the root activity (Amezketa, 1999; Six et al., 2004; Gould et al., 2016). The positive effects of roots on soil aggregation may be due to the fine particles within stable macroaggregates; the drying of the soil around the roots, which reorganizes and approaches clay particles that are parallel to the root axis; the input of decomposable organic residues to the soil; the supporting to a high microbial population in the rhizosphere; the provision of food for the soil fauna; and the release of polyvalent cations, which increases ion concentration in the soil solution. Pérès et al. (2013) evaluated the soil aggregate stability with 60 native plant species of four functional groups – 16 grasses, 12 small herbs, 20 large herbs, and 12 legumes – in a pasture in Jena, Germany and found a significant increase in aggregate stability in soils with intercrops of species, and grasses, and a decrease with legume species, compared to areas with single species; however, the effects varied depending on the measures of stability of the aggregates –rupture by humidity, mechanical rupture, and microcracks.

Plant community characteristics such as diversity of plant species and the presence of grasses and legumes can affect soil aggregate stability. It can be connected to changes in root biomass, TOC, soil microbial biomass, and earthworm biomass. Although legumes assist in essential ecosystem processes, such as primary production, by increasing TN availability, they may disfavor soil aggregate stability. However, mixtures of plants with higher proportion of grasses increase aggregate stability by increasing root biomass, TOC, and soil microbial biomass (Pérès et al., 2013; Lange et al., 2015).

In this study, we hypothesized that (a) maize/onion succession in CTS reduces soil quality compared to NTS; (b) grasses in succession or rotation with onion in NTS increases TOC content; (c) treatments that do not use cover crops in winter reduces SOM content and soil aggregation compared to treatments using winter cover crops for onion cultivation. In this context, the objective of this work was to evaluate the TOC and TN contents, aggregation index, and aggregate mass distribution of a Humic Cambisol cultivated with onions in succession or rotation with other species for seven years.

2. Material and methods

2.1. Location of the experiment and treatments

The experiment was carried out in April 2007, in Ituporanga, Santa Catarina State, Brazil, at the Experimental Station of the Research and Agricultural Extension Company of Santa Catarina (27°24′52″S, 49°36′9″W, and altitude of 475 m). The soil of the region was classified as dystrophic Humic Cambisol (EMBRAPA, 2013), or Humic Distrudept (Soil Survey Staff, 2006), and derived from Permian sediments of the Guatá Group (EMBRAPA, 2004). Its physical and chemical attributes in the 0-0.10 m layer presented 410, 264 and 326 g kg^{-1} of sand, silt and clay, respectively (EMBRAPA, 1997); pH in H_2O of 6.1; 23.08 g kg^{-1} of TOC, exchangeable Ca, Mg and Al of 6.4, 2.7 and 0.0 $cmol_c\,dm^{-3}$, respectively (extracted by KCl 1 mol L^{-1}); and available P and K of 42 and 208 mg dm^{-3}, respectively (extracted by Mehlich-1).

According to the Köppen classification, the climate of the region is Cfa, subtropical mesothermal humid, with hot summers, infrequent frosts, and no defined dry season; it presents average annual temperature of 17.6 °C and average annual precipitation of 1400 mm. A randomized complete block design, with eight treatments, five replications, and plots of 8.7 m^2 was used. The treatments were the management systems for onion crops, with different soil cover plant species. Oat, vetch, and oilseed radish were used in 2007, when experiment was implemented with eight treatments, using cover plants and commercial crops (Table 1).