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SOIL ORGANIC MATTER, N AND P IN A SOIL CONSERVATION SYSTEM FOR ONION

Belo Afonso Muetanene[1], Daibou Alassane[2], Álvaro Luiz Mafra[3], Claudinei Kurtz[4], Erbesson Souza Brito[5], Luiz Alexandre Peternelli[2], Jackson Adriano Albuquerque[3]

[1]UniLúrio-Faculdade de Ciências Agrárias, Moçambique. E-mail: floriafonso@gmail.com
[2]UFV – Universidade Federal de Viçosa, Minas Gerais, Brasil. E-mails: daiboualassane@yahoo.fr, peternelli@ufv.br
[3]UDESC – Universidade do Estado de Santa Catarina, Santa Catarina, Brasil. E-mails: alvaro.mafra@udesc.br, jackson.irai@gmail.com
[4]EPAGRI - Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Santa Catarina, Brasil. E-mail: kurtz@epagri.sc.gov.br
[5]USP – Universidade de São Paulo, São Paulo, Brasil. E-mail: erbessonbrito@usp.br

ABSTRACT

The objective of this study was to evaluate soil chemical attributes in a soil conservation experiment for onion, under different cropping systems. The study was conducted on a Humic Dystrudept in Ituporanga, Santa Catarina state, Brazil. Eight different cropping systems for onion were evaluated: T1: maize-onion succession, T2: common vetch-maize/rye+fodder raddish-onion-maize/rye+fodder raddish-common bean, T3: rye-onion-maize/black oat-maize, T4: onion-velvet bean succession, T5: rye-onion-millet/black oat-onion-millet, T6: rye-onion-velvet bean succession, T7: onion-velvet bean+millet+sunflower succession, from T1 to T7 were conducted under no tillage system T8: maize-onion succession, was conducted under conventional tillage system. We used the randomized complete block design, with 5 replications. The soil chemical samples were collected and evaluated at the 0-5, 5-10 and 10-20 cm soil layers, the soil chemical attributes evaluated as follows: total organic carbon, particulate organic carbon, carbon associated to soil minerals, N and P. At the 0-5 cm layer, P concentrations were severely affected by the different cropping system. In terms of treatments similarities, the treatments may be grouped in three clusters as follows: cluster 1: T2, T3, T7, cluster 2: T1 and T8 and cluster 3: T4, T5, T6. For N concentration, the different cropping system affected its concentration at the 10-20 cm layer. Carbon associated to soil minerals wasn´t affected by the different cropping systems.

Keywords: Crops rotation, nutrients, cover crops, clustering

INTRODUCTION

Santa Catarina State is the major onion grower in Brazil (EPAGRI, 2013; KURTZ et al., 2019), in this state onion is grown by small and median farmers, contributing for the generation of incomes, employment and people establishment in the rural areas, about 85% of the states production is concentrated in Itajaí, the largest onion growing area; in this region, the conventional tillage system (CTS) is the most dominant (MENEZES JÚNIOR et al., 2014).

In the state of Santa Catarina, the onion growing soils are intensively degraded due to use of ploughs, chisel and rotary tiller used in the CTS, which causes water, nutrients and soil losses, by soil erosion (PANACHUKI et al., 2011). Thus, no tillage system (NTS) for legumes has long been regarded as one of the most important cropping systems to enable sustainable cropping intensification to meet future agricultural demands (DERPSCH et al., 2014).

From the beginning of the 1980s, the NTS has been encouraged, cover crops, especially grasses such as black oat (*Avena strigosa* Schreb.) and rye *(Secale cereale* L.), oilseed radish (Raphanus sativus) are grown as single or mixed crops in fall/winter (SOUZA et al., 2013). In the NTS the straw accumulated by the cover crops is very important for the maintenance or recovery of soil physical and chemical properties (MENDONÇA et al., 2013). The cover crops straw after decomposing increases biological activity (BABUJIA et al., 2010), nutrients and soil organic matter accumulation in the soil surface layer (LIMA FILHO et al., 2014).

The NTS includes crops rotations systems (CRS) which allow the inclusion of species with different root systems, crops residues and C/N ratios, this contributes for the alterations of decomposition rates and nutrients cycling, the crop residues at the soil surface benefit the crops in succession, improving the soil physical, chemical and biological properties (COSTA et al., 2015). Due to the soil conservation importance, nowadays, a lot of research has been conducted in NTS field, on a dystrophic Hapludult, CRS increased P availability (CARDOSO et al., 2013), cover crops associated to crops rotation systems increased soil organic matter, Ca, Mg and cations exchange capacity (STEINER et al., 2011). Oliveira et al. (2016) studying cover crops effects on soil chemical properties and onion yield observed that the cultivation and addition of dry residue of cover crops increased the onion yield at 2.5 Mg ha^{-1}.

Therefore, understanding soil chemical changes in soils under NTS associated to crops rotation systems and cover crops are very important to the soil chemical quality improvement in onion growing fields such as Santa Catarina. This study aimed to evaluate soil chemical attributes in a soil conservation experiment for onion, under different cropping systems.

MATERIAL AND METHODS

The experiment was established in 2007 in Ituporanga (27º24'52" S e 49º36'9" W, 475 m altitude), Santa Catarina state, Brazil, on a Humic Dystrudept (SOIL SURVEY STAFF, 2014). This area had been previously cultivated under no-tillage system (NTS) since 1995, when the soil was limed to 6 pH. The climate is a humid mesothermal with hot summers, Cfa, according to the Köppen classification (POTTER et al., 2004). It has an average annual temperature of 17.6 °C and an average annual precipitation of 1400 mm (COMIN et al., 2018). The soil particle size distribution is characterized by 430, 300 and 270 g/kg respectively of sand, clay and silt. The experiment was conducted in a randomized block design, with 5 replications and eight treatments comprised by different cropping systems described in table 1.

Table 1. Treatments description, Ituporanga, Santa Catarina State, Brazil (November, 2014).

Treatments	Cropping system	Description	Crops family
T1	Crops succession, under NTS	Maize (*Zea mays* L.) - onion (*Allium cepa* L.)	Poaceae and Liliaceae
T2	Crops rotation, under NTS	Common vetch (*Vicia sativa* L.) -maize/rye (*Secale cereale* L.) + fodder radish (*Raphanus sativus* L.) - onion-maize/rye+fodder radish-common bean (*Phaseolus vulgaris* L.)	Fabaceae, Poaceae, Brassicaceae and Liliaceae
T3	Crops rotation, under NTS	Rye-onion-maize/black oat (*Avena strigosa* Schreb.) - maize	Poaceae and Liliaceae
T4	Crops succession, under NTS	Onion-velvet bean (*Stizolobium aterrimum* Piper and Tracy)	Liliaceae and Fabaceae
T5	Crops rotation, under NTS	Rye-onion- pearl millet (*Pennisetum americanum* L.)/black oat-onion-pearl millet	Poaceae and Liliaceae
T6	Crops succession, under NTS	Rye-onion-velvet bean	Poaceae, Liliaceae and Fabaceae
T7	Crops succession, under NTS	Onion-velvet bean+pearl millet+sunflower (*Helianthus annuus* L.)	Liliaceae, Fabaceae, Poaceae and Asteraceae
T8	Crops succession, under CTS	Maize-onion	Poaceae and Liliaceae

NTS stands for no tillage system and CTS conventional tillage system

The selection of the species was based on traditional use, adaptation, seed availability, easiness to grow and suitable mass production. Before the introduction of T8, the experimental area had been previously managed only under NTS since 1995, when the soil was limed to 6.0 pH.

Each plot had an area of 8.7 m², with 7 planting rows of onion, variety Epagri 352 with a planting distance of 0.4 x 0.1 m. The soil fertilization used for onion in this experiment was 120 kg/hectare of N, applying 20 kg/hectare in the planting and applications of 33 kg/hectare at 40, 65 and 85 days after the transplant in the form of NH_4NO_3, 80 kg/hectare of P_2O_5 in the planting in the form of triple superphosphate, 90 kg/hectare of K_2O in the form of KNO_3, applying 60 kg/hectare in the planting and 30 kg/hectare 65 days after the transplant and 30 kg/hectare of S 45 days after the transplant in the form of gypsum. All the treatments were cultivated under the no-tillage system (NTS) from 2007 to 2011, since then, T8 has been managed under CTS (chisel and rotary tiller) to evaluate soil degradation after a previous conservation management system.

Determination of soil chemical attributes

Soil samples were collected in November 2014, in the 0-5, 5-10 and 10-20 cm layers, using 10 subsamples to form a composite sample. These samples were then air-dried, sieved at 2 mm mesh and stored for chemical analysis. Total organic carbon (TOC), particulate organic carbon (POC) and carbon associated to soil minerals (CASM) fractions were determined according to Cambardella and Elliott (1992), 20 g of soil was mixed with 60 mL of a sodium hexametaphosphate solution (5 g L^{-1}), the soil samples were horizontally shaken for 15 h and then separated by sieving through a 53 µm mesh with the help of water. Then, the material retained in the sieve (POC) was air dried in an oven at 50 ^{0}C, then ground in a porcelain mortar. Then the content of carbon in the soil samples were quantified through a dry combustion in a Multi C/N 2100S analyzer (Analytikjena, Germany). The CASM fraction was obtained by difference between the TOC and POC. The total N was determined according to EMBRAPA (2017), P was extracted by Mehlich-1 solution and spectrophotometry (TEDESCO et al., 1995).

Statistical analysis

The results per each response variable in each layer were submitted to the Bartlett test of homogeneity of variances and Shapiro-Wilk normality test. Friedman´s test was used for cases where the assumption of homogeneity of variances was violated. Afterwards, analysis of variance and means comparison using Duncan test was performed. To group the treatments based on their similarities, we performed the K-means clustering approach, according to our classification

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purpose, we predefined three groups. All the data analysis was performed on the R programming language (R, 2020).

RESULTS AND DISCUSSION

Linear correlations results among N, P, TOC, POC and CASM are presented in figure 1, for TOC (total organic carbon) treatments were similar in all the layers (Table 2). Souza et al. (2013) evaluating the dry matter of cover crops, bulbs yields and soil chemical attributes in an agro-ecological no tillage system (NTS) didn´t obtain TOC significant differences at the 0-10 cm layer in Ituporanga, different results were obtained by Loss et al. (2015) in Ituporanga, where comparing cover crops in NTS and in CTS (conventional tillage system) in the 0-5 cm layer, the CTS had the lowest TOC concentration.

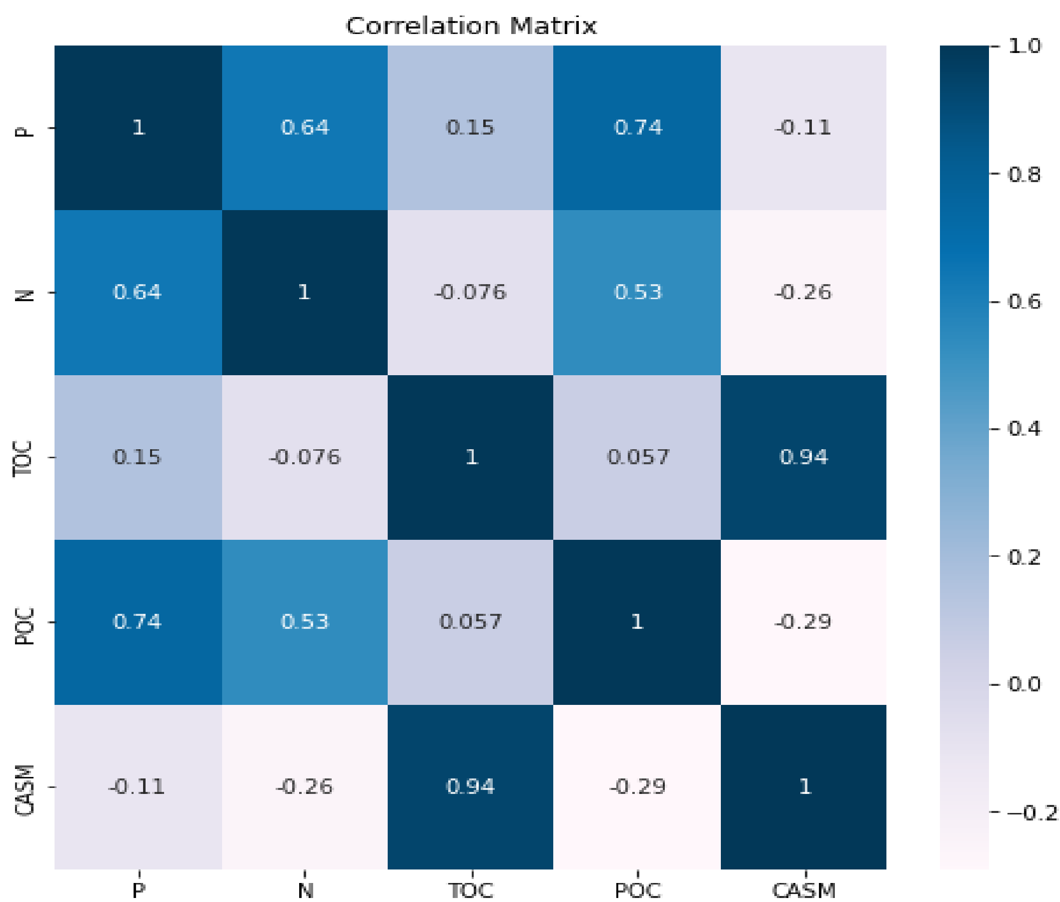

Figure 1. Correlation matrix among the N, P, POC and CASM. POC: particulate soil organic carbon, CASM: carbon associated to soil minerals, Ituporanga, Santa Catarina State, Brazil, 2014.

Table 2. P, N, TOC, POC and CASM under different soil tillage and crop rotation systems for onion, Ituporanga, Santa Catarina State, Brazil, 2014.

Treatments	P mg/kg	N g/kg	TOC g/kg	POC g/kg	CASM g/kg
			0-5 cm layer		
T1	152 a	1.12^{WD}	35.9^{WD}	2.4^{WD}	33.5^{WD}
T2	86 b	0.88	27.4	2.9	24.5
T3	84 b	0.82	27.2	2.5	24.8
T4	125 ab	1.10	33.3	6.2	27.0
T5	135 ab	1.20	31.4	4.4	26.9
T6	175 a	1.16	31.2	3.5	27.8
T7	137 ab	0.78	30.0	5.5	24.4
T8	85 b	1.00	32.4	2.2	30.2
		5-10 cm layer			
T1	60^{WD}	0.58^{WD}	30.4^{WD}	0.6 b	29.8^{WD}
T2	62	0.86	28.1	2.0 a	26.2
T3	63	0.88	28.7	1.5 a	27.2
T4	51	1.10	25.5	2.0 a	23.5
T5	70	0.94	23.5	1.4 a	22.1
T6	90	0.92	35.1	1.6 a	33.5
T7	84	0.98	24.2	1.8 a	22.4
T8	68	0.88	26.2	1.7 a	24.5
			10-20 cm layer		
T1	62^{WD}	0.60** c	38.9^{WD}	0.9^{WD}	38.0^{WD}
T2	24	0.72 bc	28.6	1.0	27.6
T3	32	0.68 bc	30.0	1.4	28.7
T4	43	0.86 ab	35.5	1.7	33.8
T5	47	0.92 a	26.6	1.3	25.4
T6	30	0.88 ab	34.5	1.2	33.3
T7	45	0.82 abc	34.3	1.4	32.9
T8	29	0.66 abc	29.5	1.1	28.3

T1: maize-onion succession, T2: common vetch-maize/rye+fodder raddish-onion-maize/rye+fodder raddish-common bean, T3: rye-onion-mayze/black oat-maize, T4: onion-velvet bean succession, T5: rye-onion-millet/black oat-onion-millet, T6: rye-onion-velvet bean succession, T7: onion-velvet bean+millet+sunflower succession, T8: maize-onion succession, in conventional tillage system (chisel and rotary tiller). In each column, means followed by the same letter are not significantly different: * Duncan test 5%, ** Friedman´s test 5%, WD for means without significant differences at 5%. TOC: total organic carbon, POC: particulate organic carbon, CASM: carbon associated to soil minerals.

According to the same authors, in the conventional tillage system (CTS), as the soil structure is destroyed by the use of the chisel and rotary tiller, the soil aggregates are disrupted and consequently the soil organic matter stays more exposed to decomposition by soil microorganisms, reducing the TOC concentrations at the soil surface layer. In our study, this phenomenon was not observed, indicating that may be more study time is needed, as reported by Carvalho et al. (2010), the increase of TOC in fields under NTS in comparison to different soil management systems may be related mainly to the establishment time, since the carbon accumulation in NTS occurs slowly, taking 10 to 15 to be more expressive. It´s also important to consider that in the study conducted by Loss et al. (2015), the CTS had 20 years, in our study, soil samples were collected seven years after the establishment of the CTS. In a similar study, Comin et al. (2018) observed significant differences only at the 0-5 cm layer, where the treatment under CTS presented the lowest TOC concentration when compared to the other treatments conducted under NTS, in their study, significant differences were also observed among the treatments under NTS. For POC, at the 0-5 cm layer, all the treatments were similar, however, despite the absence of significant differences in this layer, it´s important to highlight that T4 (onion-velvet bean succession) presented the highest POC concentration, with a value corresponding to 2.8 times the T8 (maize-onion succession in CTS) value which presented the minimum concentration. The minimum POC concentration presented by T8 may be justified by the use of chisel and rotary tiller which deteriorates the soil structure mainly at the soil surface layer as also verified in this experiment by Muetanene et al. (2021).

In a study conducted by Giumbelli et al. (2021) to evaluate the effects of combinations of different plant species and soil management systems using rotation with soil cover crops for onion crops on the light organic matter, C, and N contents in the soil organic matter granulometric fractions, observed that at the 0-5 cm layer, T8 presented the lowest POC concentration. The authors attributed the result to the fact that in the treatments under NTS, there´s an annual additions of plant residues combined with a minimum soil turning, allowing the soil cover to remain on the soil surface, which increases POC contents in the soil, unlike what happens in T8. At the 5-10 cm layer, treatments were different, T1 presented the lowest concentration, T1 is a maize-onion succession, a treatment with no winter soil cover plants (COMIN et al., 2018), it provides to the soil less crops residues when compared to the other treatments, mainly T2, T3, T4, T5, T6 and T7, this fact may justify the T1 concentration. In a study conducted by Carmo et al. (2012) to evaluate the effect of five grass crops on the soil organic carbon fractions, differences for POC were obtained only at the 0-5 cm layer, however, in that study, all the crops involved were of the same family (Poaceae). CASM (carbon associated to soil minerals) was positively correlated with TOC (figure 1) and significant differences weren´t observed for CASM in all the soil layers, however, in a study conducted by Carmo et al. (2012) significant differences for CASM were observed at the 0-5, 5-10 cm layers where the treatment based on planting only maize presented the highest CASM concentration. In another study conducted by Guareschi et al. (2013) to evaluate five systems namely: native cerrado, planted pasture with *Brachiaria decumbens*; no tillage system with three years (NTS 3) years of implementation; NTS with 15 years (NTS 15) of implementation and NTS with more than 20 (NTS 20) years of implementation, they observed that at the 0-5 cm layer, NTS 20 presented the highest CASM concentration. In our study, the absence of significant differences for CASM in all the soil layers may be justified by the reduced alteration which this soil organic fraction suffers among different soil management systems, as reported by Bayer et al. (20004), i.e., CASM is little sensible to different soil management systems on the short term, as it interacts with the soil mineral fraction and it forms organic composites which interact with soil minerals, creating a chemical stabilization in the soil (CHRISTENSEN, 1996). Guareschi et al. (2013) verified that the increase of CASM implies in a decrease of POC because they are negatively correlated (figure 1), meaning that the CASM is formed from the POC decomposition, being the CASM the stabilized carbon in the soil and the POC the more labile carbon fraction which depends on the supply of crop residues for its increase in the soil, this behavior was verified in the present study (figure 2). POC concentration reduced from the 0-5 down to the 10-20 cm layer because POC is mostly influenced by crops residues deposition at the soil surface, in the deeper layers, crops residues supply is more reduced (Figure 2).

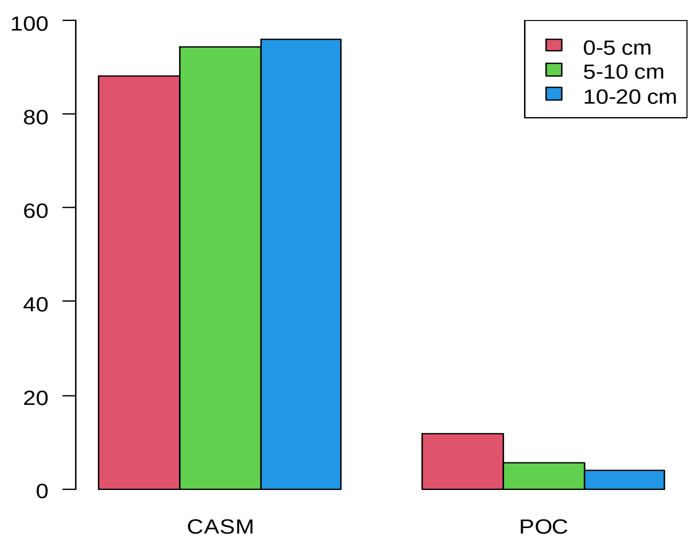

Figure 2. Percentages (%) of POC/TOC and CASM/TOC per layer, in a Humic Dystrudept under different soil tillage and crop rotation systems for onion, in Ituporanga, Santa Catarina State, Brazil. TOC:total organic carbon, POC: particulate organic carbon, CASM: carbon associated to soil minerals, Ituporanga, Santa Catarina State, Brazil, 2014.

About N, the treatments were similar at the 0-5 and 5-10 cm layers, despite the absence differences in these layers, at the 0-5 cm layer, T5 which presented the maximum concentration corresponding to 1.5 times the T7 concentration which presented the minim concentration. In this layer, T6 presented the closest N concentration to T5, this may be explained by the presence of velvet bean (Fabaceae family) in T6. Differences for N were observed at the 10-20 cm layer, where T5 presented the highest value and T1 the least, in T5, besides onion, there´re crops such as millet, black oat and rye, millet is characterized by having a deep root system which can reach 200 cm depth, having capacity to uptake huge nutrients quantities even from low fertility soils, being able to produce 10 tonnes of dry matter and medium C/N ratio (BRÜCK et al., 2003; LIMA FILHO et al., 2014). Black out is a rustic plant, owns a fasciculated root system, reaching in general 76 cm depth, being able to grow in soil of low fertility, producing 6 tons/hectare of dry matter, with a high C/N ratio (LIMA FILHO et al., 2014). Rye is also a rustic plant, adapted to low fertility soils, high nutrients cycling capacity, a fasciculated root system which grow until 122 cm depth, C/N ratio of 30 on average and dry matter production of 4.5 tons/hectare. Thus, the features of these three crops together may explain the high N value observed for T5 at the 0-5 and 10-20 cm layers. However, in a study conducted by Comin et al. (2018), evaluating carbon and nitrogen contents and aggregation index of soil cultivated with onion for seven years using crop successions and rotations, at the 0-5 cm layer, CTS (conventional tillage system, maize-onion succession) presented lower N concentration than the treatments conducted under no tillage system. Nitrogen and P are positively correlated (figure 1), and with P, significant differences were only observed at the 0-5 cm layer, where the minimum P concentration was observed in T8, and maximum concentration in T6, it´s important to observe that T1 presented a higher P concentration than T8, both treatments are composed by maize-onion succession, but T1 conducted in NTS and T8 in CTS, this difference illustrates the advantage of the NTS to elevate the P levels in the soil. However, absence of significant differences of P was observed by Souza et al. (2013) evaluating dry matter of cover crops, onion yield and soil chemical attributes under an agro-ecological NTS in Ituporanga, however, their study was evaluated in a shorter period (from 2009 to 2011) than ours. Absence of significant differences for P at the 0-10 cm layer was also verified by Oliveira et al. (2016) evaluating cover crops effects on soil chemical properties and onion yield.

The K means clustering algorithm revealed the presence of three clusters (Figure 3), namely: cluster 1: T2, T3 and T7, cluster 2: T1 and T8 and cluster 3: T4, T5 and T6.

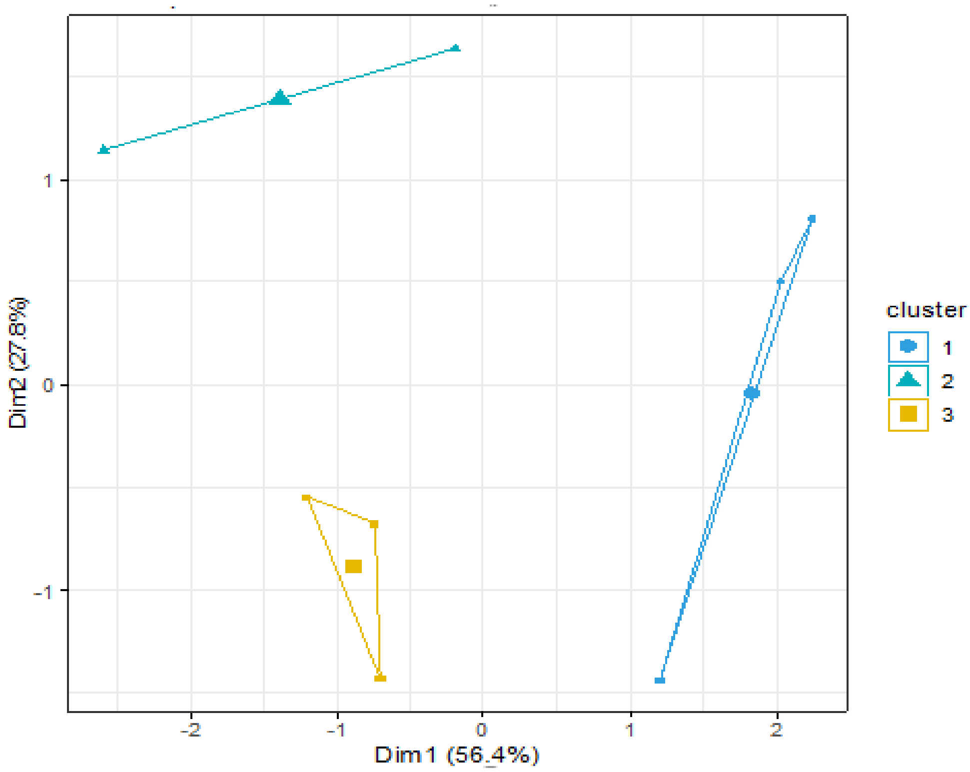

Figure 3. Treatments clustering. Cluster 1: T2, T3, T7, cluster 2: T1 and T8, cluster 3: T4, T5, T6 Dim 1: principal component 1, Dim 2:principal componente 2, Ituporanga, Santa Catarina State, Brazil, 2014.

At the 0-5 cm layer, it´s interesting to notice that in cluster 2, there´re two treatments, T1 and T8, both treatments are comprised by maize-onion succession (Poaceae and Liliaceae families) being T1 in no tillage and T8 in conventional tillage system. In cluster 1 (T2, T3 and T4) is composed by treatments with the lowest N, TOC and CASM concentrations at the 0-5 cm layer. In cluster 3, we find the treatments which numerically presented higher N, TOC and CASM concentrations when compared to the cluster 1 treatments.

CONCLUSION

In terms of treatments similarities, the treatments may be grouped in three clusters as follows: cluster 1: T2, T3, T7, cluster 2: T1 and T8 and cluster 3: T4, T5, T6.

At the 0-5 cm layer, higher nitrogen and total organic carbon were observed in T4, T5 and T6.

Carbon associated to soil minerals wasn´t affected by the different cropping systems, indicating that more time is needed to study this soil organic carbon fraction.

REFERENCES

BRÜCK, H.; PIRO, B.; SATTELMACHER, B.; PAYNE, W. A. 2003. Spatial distribution of roots of pearl millet on sandy soils of Niger. **Plant and Soil**, Switzerland, v. 256, p.149-159. DOI: https://doi.org/10.1023/A:1026246728095

BABUJIA, L. C.; HUNGRIA, M.; FRANCHINI, J. C.; BROOKES, P. C. 2010. Microbial biomass and activity at various soil depths in a Brazilian Oxisol after two decades of no-tillage and conventional tillage. **Soil Biology and Biochemistry**, Oxford, England, v.42, p. 2174–2181. DOI: https://doi.org/10.1016/j.soilbio.2010.08.013

BAYER, C.; MARTIN-NETO, L.; MIELNICZUK, J.; PAVINATO, A. 2004. Armazenamento de carbono em frações lábeis na matéria orgânica de um Latossolo Vermelho sob plantio direto. **Pesquisa Agropecuária Brasileira**, Brasília, v. 39, n. 7, p. 677-683. DOI: https://doi.org/10.1590/S0100-204X2004000700009

CHRISTENSEN, B. T. 1996. Carbon in primary and secondary organomineral complexes. In: CARTER, M. R.; STEWART, B. A. (eds.). **Structure and organic matter storage in agricultural soils**. Boca Raton, United States: CRC Lewis.

CAMBARDELLA, C. A.; ELLIOTT, E. T. 1992. Particulate soil organic-matter changes across a grassland cultivation sequence. **Soil Science Society of America Journal**, United States, v. 56, p. 777-783. DOI: https://doi.org/10.2136/sssaj1992.03615995005600030017x

CARDOSO D. P.; SILVA, M. L. N.; CARVALHO, G. J.; FREITAS, D. A. F.; AVANZI, J.C. 2013. Espécies de plantas de cobertura no recondicionamento químico e físico do solo. **Revista Brasileira de Ciências Agrárias**, Pernambuco, v. 8, p. 375-382. DOI: https://doi.org/10.5039/agraria.v8i3a2421

CARVALHO, J. L. N.; AVANZI, J. C.; SILVA, M. L. N.; MELLO, C. R.; CERRI, C. E. P. 2010. Potencial de sequestro de carbono em diferentes biomas do brasil. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 34, n. 2, p. 277- 289. DOI: https://doi.org/10.1590/S0100-06832010000200001

CARMO, F. F.; FIGUEIREDO, C. C.; RAMOS, M. L. G.; VIVALDI, L. J.; ARAÚJO, L. G. 2012. Frações granulométricas da matéria orgânica em latossolo sob plantio direto com gramíneas. **Bioscience Journal**, Uberlândia, v. 28, p. 420-431. DOI: https://seer.ufu.br/index.php/biosciencejournal/article/view/12351

COMIN, J. J.; FERREIRA, L. B.; SANTOS, L. H.; KOUCHER, L. P.; MACHADO, JUNIOR, L. N.; E. S.; MAFRA, A. L; KURTZ, C.; SOUZA, M.; BRUNETTO, G.; LOSS, A. 2018. Carbon and nitrogen contents and aggregation index of soil cultivated with onion for seven years using crop successions and rotations. **Soil and Tillage Research**, Amsterdam, Netherlands, v. 184, p. 195–202. DOI: https://doi.org/10.1016/j.still.2018.08.002

COSTA, N. R.; ANDREOTTI, M.; LOPES, K. S. M.; YOKOBATAKE, K. L.; FERREIRA, J. P.; PARIZ, C. M.; BONINI, C. S. B.; LONGHINI, V. Z. 2015. Atributos do solo e acúmulo de carbono na integração lavoura-pecuária em sistema plantio direto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 39, p. 852-863. DOI: https://doi.org/10.1590/01000683rbcs20140269

DERPSCH, R.; FRANZLUEBBERS, A. J.; DUIKER, S. W.; REICOSKY, D. C.; KOELLER, K.; FRIEDRICH, T.; STURNY, W. G.; SÁ, J. C. M.; WEISS, K. 2014. Why do we need to standardize no-tillage research? **Soil Tillage Research**, Amsterdam, Netherlands, v. 137, p. 16–22. DOI: http://dx.doi.org/10.1016/j.still.2013.10.002

POTTER, R. O.; CARVALHO, A. P.; FLORES, C. A.; BOGNOLA, I. 2004. **Solos do Estado de Santa Catarina**. Rio de Janeiro: Embrapa Solos. 721p. DOI: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/964417

EMBRAPA. Embrapa Solos. 2017. **Manual de métodos de análise de solo**. Brasília, DF: Embrapa, 3 ed. ver. e ampl. 574p. DOI: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1085209

EPAGRI. 2013. **Sistema de produção para cebola: Santa Catarina**. Florianópolis: Epagri. 106p.

GUARESCHI, R. F.; PEREIRA, M. G.; PERIN, A. 2013. Frações da matéria orgânica em áreas de Latossolo sob diferentes sistemas de manejo no Cerrado do estado de Goiás. **Semina: Ciências. Agrárias**, Londrina, v. 34, p. 2615-2628. DOI: http://dx.doi.org/10.5433/1679-0359.2013v34n6p2615

GIUMBELLI, L. D.; LOSS, A.; KURTZ, C.; MAFRA, A. L.; PICCOLO, M. C.; TORRES, J. L. R.; LOURENZI, C. R.; BRUNETTO, G.; COMIN, J. J. 2021. Combinations of plant species for rotation with onion crops: effects on the light fraction, carbon, and nitrogen contents in granulometric fractions of the soil organic matter. **Journal of Agricultural Studies**, United States, v. 9, n. 1, p. 202-2030. DOI: https://doi.org/10.5296/jas.v9i1.17930

KURTZ, C.; SGROTT, E. Z.; COMIN, J. J.; HIGASHIKAWA, F. S.; SOUZA, M. 2019. Sistema de plantio direto de hortaliças: princípios de transição para sistemas de produção ecológicos e redesenho de propriedades familiares. In: FAYAD, J. A.; ARL, V.; COMIN, J. J.; MAFRA, A. L.; MARCHESI, D. R. (eds.) **Sistema de plantio direto de hortaliças: métodos de transição para um novo modo de produção**. São Paulo: Expressão Popular, 1 ed. 432p

LIMA FILHO, O. F.; AMBROSANO, E. J.; ROSSI, F.; CARLOS, J. A. D. 2014. **Adubação verde e plantas de cobertura no Brasil: fundamentos e prática**. Brasília: Embrapa, v. 1. 507p.

LOSS, A.; BASSO, A.; OLIVEIRA, B. S.; KOUCHER, L. P.; OLIVEIRA, R. A.; KURTZ, C.; LOVATO, P. E.; CURMI, P.; BRUNETTO, G.; COMIN, J. J. 2015. Carbono orgânico total e agregação do solo em sistema de plantio direto agroecológico e convencional de cebola. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 39, p. 1212-24. DOI:http://dx.doi.org/10.1590/01000683rbcs20140718

MENDONÇA, V. Z.; MELLO, L. M. M.; ANDREOTTI, M.; PEREIRA, F. C. B. L.; LIMA, R. C.; Filho, W. V. V.; YANO, E. H. 2013. Avaliação dos atributos físicos do solo em consórcio de forrageiras e milho em sucessão com soja em região de Cerrados. Revista Brasileira de Ciência do Solo, Viçosa, v. 37, p. 251-259. DOI: http://dx.doi.org/10.1590/S0100-06832013000100026

MENEZES JÚNIOR, F. O. G.; GONÇALVES, P. A. S.; NETO, |J. V. 2014. Produtividade da cebola em cultivo mínimo no sistema convencional e orgânico com biofertilizantes. **Horticultura brasileira**, Recife, v. 32, p. 475-81. DOI: http://dx.doi.org/10.1590/S0102-053620140000400017

MUETANENE, B. A; MAFRA, A. L.; ALBUQUERQUE, J. A.; PETERNELLI, L. A.; KURTZ, C. 2021. Soil physical properties in a long-term conservation system for onion. **Brazilian Journal of Agriculture**, Piracicaba, v. 96, n. 3, p. 496–509. DOI: https://doi.org/10.37856/bja.v96i3.4285

OLIVEIRA, R. A.; BRUNETTO, G.; LOSS, A.; GATIBONI, L. C.; KÜRTZ, C.; MÜLLER JÚNIOR, V. LOVATO, P. E.; OLIVEIRA, B. S.; SOUZA, M.; COMIN, J. J. 2016. Cover Crops Effects on Soil Chemical Properties and Onion Yield. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 40, p. 0.1-17. DOI: 10.1590/18069657rbcs20150099

SOIL SURVEY STAFF. 2014. **Keys to Soil Taxonomy**. Washington, DC, USA: Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), 12th ed. 372p

SOUZA M.; COMIN, J. J.; LEGUIZAMÓN, E. S.; KURTZ, C.; BRUNETTO, G.; JÚNIOR, V. M.; VENTURA, B.; CAMARGO, A. P. 2013. Matéria seca de plantas de cobertura, produção de cebola e atributos químicos do solo em sistema plantio direto agroecológico. **Ciência Rural**, Santa Maria, v. 43, p. 21-7. DOI: https://doi.org/10.1590/S0103-84782012005000150

STEINER, F.; COSTA, M. S. S. M.; COSTA, L. A. M.; PIVETTA, L.A.; CASTOLDI, G. 2011. Atributos químicos do solo em diferentes sistemas de culturas e fontes de adubação. **Global Science and Technology**, Rio Verde, v. 04, p. 16 – 28

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, 2 ed., Boletim técnico, 5.

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