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Soil exchangeable cations and acidity components in different cropping systems for onion

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Abstract

This study aimed to evaluate K, Ca, Mg, Al concentrations and active acidity (pH-H_2O) in different cropping systems for onion. The study was conducted on a Humic Dystrudept in Ituporanga, Santa Catarina state, Brazil, where eight different cropping systems for onion were evaluated, namely: 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 (NTS), T8, T8: maize-onion succession, was conducted under conventional tillage system. We used the randomized complete block design, with 5 replications. All the chemical samples were collected and evaluated at the 0-5, 5-10 and 10-20 cm soil layers. We observed that the different cropping systems were similar in terms of Ca, Mg and K concentrations in all the soil layers, significant differences were only found for exchangeable Al concentrations at the 0-5 cm layer. More time is needed to observe better the performance of the treatments since their effect on the soil depends a lot on the time of implantation.

Keywords: No tillage, nutrients, conventional tillage system

INTRODUCTION

Several studies have shown that different soil tillage systems have different impacts on the soil chemical, physical and biological properties, the conventional tillage system often leads to serious soil and water loss, resulting in the depletion of soil nutrients, deterioration of the ecological environment, and unsustainable productivity of agricultural systems (Huang *et al*., 2018). Thus, achieving sustainable agricultural development and eco-environmental protection requires a deeper understanding of the effect of conservation tillage on soil chemical properties, such as soil organic matter, nutrient elements and soil pH (Lv *et al*., 2022).

Santa Catarina state is the major onion (*Allium cepa* L) grower (Kurtz *et al*., 2019) in Brazil, being accountable for a third of the national production, nearly 500 thousand tons/year (Epapagri-Ciram, 2022), with an average yield of 26 Mg ha^{-1} and a yield of 485 000 Mg in the 2018/2019 crop season (Epagri, 2019). The conventional tillage system is the most dominant in this region (Menezes Júnior *et al*., 2014; Oliveira *et al*., 2016) causing soil deterioration. An alternative to circumvent this soil degradation is the use of the n tillage system (NTS), in Brazil, the NTS is known as an agricultural production system, composed of the basic principles of crop rotation, permanent soil cover and sowing without previous soil mobilization, in Brazil, this system has been encouraged since the 1980s (Oliveira *et al*., 2016). For onion, cover crop residues are deposited between plant rows, especially in late Winter and early Spring, residues protect the soil surface from the impact of raindrops and reduces erosion, suppresses the incidence of weeds, and increases water storage in the soil profile (Chen et al., 2014). Several long-term studies in different Brazilian regions, climates and soils have shown that the continuous use of NTS may improve the chemical (Rheinheimer *et al*., 2019), physical (Reichert *et al*., 2016; Pires *et al*., 2017; Muetanene *et al*., 2021;) and biological soil properties (Balota *et al*., 2014; Demetrio *et al*., 2020), and increase the soil organic matter stock (Ferreira *et al*., 2018; Veloso *et al*., 2020), with its corresponding social and environmental advantages (Freitas and Landers, 2014). Thus, NTS has proven to be a reference in soil and water conservation management in Brazilian agriculture (Freitas and Landers, 2014) as well as globally (Derpsch *et al*., 2010).

That's why understanding the soil chemical changes in soils under no tillage and conventional tillage systems associated to crops rotation systems and formation of cover crops is crucial in onion growing fields such as the Santa Catarina state, Brazil. This study aimed to evaluate K, Ca, Mg, Al concentrations and active acidity in different cropping systems for onion in Santa Catarina state, Brazil.

MATERIALS AND METHODS

Experimental design and treatments

This experiment was established in 2007 in Ituporanga (27°24'52" S e 49°36'9" 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 (EMBRAPA, 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 five replications and eight treatments comprised by different cropping systems described in table 1.

Table 1. Treatments description, Santa Catarina State, Brazil

Treatments	Cropping systems	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

Before the introduction of T8, the experimental area had been previously managed only under no tillage systems (NTS) since 1995, when the soil was limed to 6.0 pH. Each plot had an area of 8.7 m^2, 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/ha 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 conventional tillage system (chisel and rotary tiller) to evaluate soil degradation after a previous conservation management system.

Soil sampling and statistical analysis

For the determinations of K, Ca, Mg, exchangeable Al concentrations and active acidity (measured by pH-H_2O), 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. All the soil chemical analysis was conducted according to Tedesco *et al*. (1995).

For statistical analysis, the results per each chemical attribute in each layer were submitted to the Bartlett test of homogeneity of variances and Shapiro-Wilk normality test, and then the analysis of variance and means comparison using the Scott-Knott test when necessary was performed. The great advantage of the Scott-Knott test is that it doesn´t allow the same treatment to belong to two or more different groups at the same time reducing the ambiguity in the treatments comparison. All the statistical analysis was conducted at 5%. To group the treatments based on their similarities, we performed the Tocher´s clustering approach based on the Mahalanobis distance. Principal components analysis was also conducted to reduce the dimensionality of the data and to describe better the variation observed on the data. All the data analysis was performed on the R (R, 2020).

RESULTS AND DISCUSSION

Linear correlations results among K, Ca, Mg, exchangeable Al and active acidity are presented in figure 1. For the soil active acidity, pH-H_2O low values were observed (table 2) in all the layers, being classified as high active acidity (CQFS-RS/SC, 2004), the treatments were similar at the 0-5 and 10-20 cm layers, at the 5-10 cm layer,

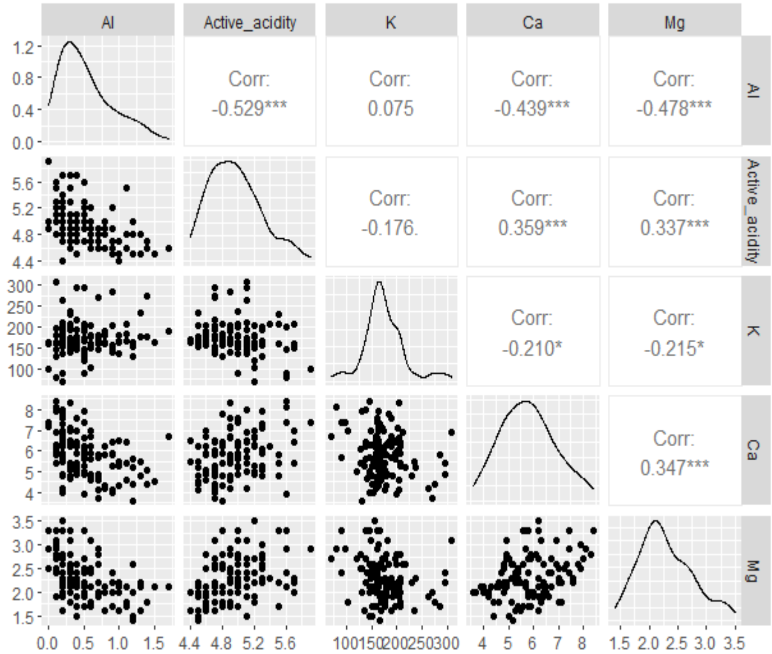

Figure 1. Correlations among Al, active acidity (pH-H_2O), K, Ca, and Mg.

The main diagonal represents the data distribution of the variable, the upper half diagonal represents the values of correlation coefficients. The lower half diagonal represents a scatter plot between two variables

T4, T5, T6 and T7 presented lower values (table 1) than all the other ones. Active acidity was positively correlated to Ca and Mg (figure 1).

Table 2. K, Ca, Mg, Al and pH-H_2O under different soil tillage and crop rotation systems for onion (Santa Catarina, Ituporanga, 2014)

	K	Ca	Mg	Al	Active acidity (pH-H_2O)
	mg/kg	g/kg	g/kg	g/kg	
Treatments			0-5 cm layer		
T1	202^{WD}	6.4^{WD}	2.0^{WD}	0.7 a	4.8^{WD}
T2	171	5.7	2.7	0.3 b	4.8
T3	222	5.2	2.2	0.7 a	4.8
T4	172	5.4	2.2	1.0 a	4.7
T5	184	5.8	2.4	0.6 a	4.7
T6	195	5.6	2.0	1.0 a	4.6
T7	216	5.0	2.1	0.8 a	4.6
T8	193	5.8	2.5	0.3 b	4.8
		5-10 cm layer			
T1	186^{WD}	5.4^{WD}	2.3^{WD}	0.3^{WD}	5.3 a
T2	178	5.8	2.8	0.3	5.0 a
T3	175	5.6	2.1	0.4	5.0 a
T4	155	5.2	2.2	0.6	4.8 b

T5	177	5.7	2.3	0.5	4.8 b
T6	166	6.1	2.0	0.7	4.8 b
T7	168	5.4	2.0	0.6	4.7 b
T8	160	6.3	2.5	0.3	5.2 a
		10-20 cm layer			
T1	174^{WD}	6.2^{WD}	2.2^{WD}	0.4^{WD}	5.4^{WD}
T2	141	6.5	2.6	0.3	5.3
T3	170	5.9	2.3	0.3	5.2
T4	153	6	2.5	0.5	4.9
T5	191	5.2	2.1	0.4	5.1
T6	121	6.5	2.2	0.4	5.1
T7	180	5.3	2.0	0.8	5.2
T8	150	6.9	2.5	0.4	5.1

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: * Scott-Knott test 5%, WD for means without significant differences at 5%.

Higher active acidity of a no-tillage system than conventional tillage system down to a 10 cm depth was observed by Ciotta *et al.* (2002), the authors attributed the result to the possible increase of electrolyte concentration evidenced by the higher electrical conductivity. It would be to expect that the T8 (maize-onion, under no tillage system) would present lower active acidity, due to the soil tillage as this activity mixes the soil till a 20-30 cm depth and greater amounts of soil help to avoid pH-H_2O change, this phenomenon wasn't verified in our study. However, the crops composition in each treatment and the time of adoption of the no tillage system are relevant factors to be considered in this result. Absence of significant differences in the active acidity was also verified by Loss *et al*. (2020) studying effect of crop succession or rotation on soil fertility after seven years of onion cultivation.

For soil exchangeable Al concentrations, significant differences were only observed at the 0-5 cm layer, where T2 and T8 presented the lowest concentrations, the values observed for exchangeable Al are considered medium (Alvarez *et al*., 1999), exchangeable Al was negatively correlated to the active acidity, Mg and Ca (figure 1), it´s important to highlight that this soil experiment was fertilized by NH_4NHO_3 and was last limed in 1995, these facts may be influencing the low active acidity values and the medium Al mainly at the 0-5 cm layer. Despite the medium exchangeable Al concentrations observed in the special case of the treatments conducted under no-tillage system, the lower phytotoxicity of Al in the no-tillage system is associated to its complexation by the soil organic matter, which promotes the Al removal from the soil solution (Hargrove and Thomas, 1984) and to the formation of complexes with dissolved soil organic matter (Zambrosi *et al*, 2007). The negative effects of soil acidity, as well as the Al phytotoxicity, have not been observed in several soils cultivated under NTS (Alleoni *et al*., 2003, 2005; Caires *et al*., 1998, 1999, 2006). However, Cardoso *et al*. (2013) did not obtain Al differences evaluating the potential of cover plant species on the reconditioning of soil physical and chemical properties, the same results were found by Souza *et al*. (2013).

For Ca, Mg and K the treatments were similar in all the layers, being in adequate concentrations for crops development (CQFS-RS/SC, 2004), this soil was fertilized by gypsum, this application may be contributing to the high Ca concentrations found in this study. It´s also important to observe that both Ca and Mg are positively correlated (figure 1) and that in this experiment, no significant differences were observed for the soil organic matter (Muetanene *et al*., 2022), these facts may also explain these results. In our study, K showed a weak negative correlation with Ca and Mg (figure 1), absence of significant differences of Ca Mg, Al and K, and active acidity were found by Souza *et al*. (2013) evaluating dry matter of cover crops, onion yield and soil chemical attributes under an agro-ecological NTS in Ituporanga. Oliveira *et al*. (2016) studying cover crops effects on soil chemical properties and onion yield didn´t observe significant differences for active acidity, Ca, Mg and Al, only for K differences were observed. It´s important to highlight that the absence of significant differences observed in our study (except for Al) mainly at the 0-5 cm layer, may be explained by the recent implantation of the conventional tillage system (implanted in 2011) while the no-tillage systems were implanted in 2007, as differences in nutrients content depend also on the duration of the implantation of such systems as also reported by Carvalho *et al*. (2010) in similar studies. Due to the treatments huge absence of significant differences among the treatments in all the layers, we clustered all the treatments in all the layers. The Tocher´s clustering approach revealed the existence of two clusters (figure 2), in cluster 1: T1b (maize-onion succession, under conventional tillage system, at the 5-10 cm layer) and in cluster 2 are included all the other samples.

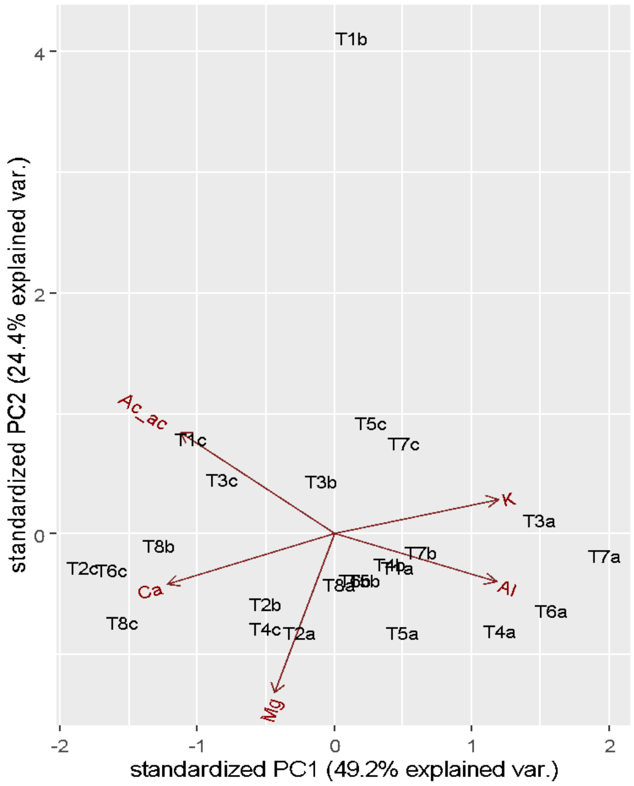

Figure 2. Treatments clustering.

PC1: principal component 1, PC2: principal component 2

a: 0-5 cm layer, b: 5-10 cm layer and c: 10-20 cm layer

figure 2 shows that in general, only T1b (maize-onion succession at the 5-10 cm layer) showed a different pattern from all the other samples, this clustering results also show that in general, the soil surface layers (0-5 and 5-10 cm layers) do not differ when compared to the deeper layers (10-20 cm layer) in each treatment. This leads us to observe that more time is needed so that these treatments can show different patterns.

CONCLUSIONS

The different cropping systems were similar in terms of Ca, Mg and K concentrations in all the soil layers.

The huge similarities among the treatments allowed the grouping of the samples in 2 clusters, where in cluster 1 is the T1b (maize-onion succession, under conventional tillage system, 5-10 cm layer) and cluster 2 we find all the other treatments layers.

More time is needed to observe better the performance of the treatments.

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