SILVESTRE, Wendel Paulo. VICENÇO, Camila Bonatto. MARTINI, Mauro. PAULETTI, Gabriel Fernandes. **Efeito da aplicação de material orgânico em dois solos da região 'Vale do Caí', Sul do Brasil.** Revista Interdisciplinar Científica Aplicada, Blumenau, V.15, nº 3, p.94-109. TRI III 2021. ISSN 1980-7031.

EFFECT OF ORGANIC MATERIAL APPLICATION IN TWO SOILS OF THE 'VALE DO CAÍ' REGION, SOUTH BRAZIL

EFEITO DA APLICAÇÃO DE MATERIAL ORGÂNICO EM DOIS SOLOS DA REGIÃO 'VALE DO CAÍ', SUL DO BRASIL

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ABSTRACT

This work aimed to evaluate the application of several doses of two sources of organic material in the physical-chemical properties of two soils of the 'Vale do Caí' region. The experiment was carried out using clayish and sandy soils. Four treatments were tested: organic compost with the doses of zero (control; T0), 40 Mg·ha^{-1} (T1), and 80 Mg·ha^{-1} (T2); and a treatment using an industrialized humic substance at the dose of 50 Mg·ha^{-1} (T3). The physical properties of total porosity, macro and micropores, and water retention capacity were evaluated; the chemical properties of pH and electrical conductivity were also evaluated. The results showed that the addition of 80 Mg·ha^{-1} (T2) of OM increased the total porosity, and the quantity of macro and micropores in the sandy soil, not affecting the clayish soil. The treatment using the industrialized humic substance (T3) reduced the total porosity of the sandy soil. The CE and pH values increased with the dose of organic material, with exception of the industrialized source (T3), which has not differed from the control (T0).

Keywords: Physical properties. Organic compost. Humic substances.

RESUMO

Efeito da aplicação de matéria orgânica em dois tipos de solo no Vale do Caí, Sul do Brasil

Este trabalho buscou avaliar o efeito da aplicação de diferentes doses de duas fontes de MO sobre as propriedades físico-químicas de dois solos da região do Vale do Caí. O experimento foi conduzido em solos com classes texturais argilosa e arenosa. Foram realizados 4 tratamentos: composto orgânico nas doses de zero (controle; T0), 40 Mg·ha^{-1} (T1) e 80 Mg·ha^{-1} (T2) e um tratamento com substância húmica industrializada na dose de 50 Mg·ha^{-1} (T3). Foram avaliadas as propriedades físicas de porosidade total, quantidade de macro e microporos e capacidade de retenção de água; e as propriedades químicas de condutividade elétrica (CE) e pH. Os resultados apontam que a adição de MO na dose de 80 Mg·ha^{-1} (T2) aumentou os teores de porosidade total, macroporos e microporos em solo arenoso, e não teve efeito em solo argiloso. O tratamento de ácido húmico industrializado (T3) reduziu significativamente a porosidade total no solo arenoso. CE e pH

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aumentaram de acordo com a dose de MO, com exceção do ácido húmico industrializado, que não apresentou diferença do controle.
Palavras-chave: Propriedades físicas. Composto orgânico. Substâncias húmicas.

1. INTRODUCTION

The chemical, physical, and biological properties of the soil are directly influenced by its organic matter (OM) content (MASCIANDARO et al., 2013). Besides enhancing the cation exchange capacity (CEC) and organic carbon content, the OM in the soil surface (top layer), acts in soil structure and aggregate formation, consequently, influencing the soil water retention capacity (WRC) and availability, due to the higher presence of micropores and enhanced aggregate stability (MOHAMMADI et al., 2011).

All of the organic carbon present in the soil in the form of organic compost, industrialized organic material, fresh residues (even under several stages of decomposition), humified compounds, and carbonized materials, with or without an inorganic material present, are considered soil OM (REN et al., 2018). Soil OM presents itself mostly (85%) in the humified form. The non-humified form (15%) is composed of decaying animal and plant material. It constitutes the main source of soil fertility, being directly linked to its physical-chemical properties (SHARMA et al., 2019).

Conventional soil management tends to destroy the porous structure of the soil, increasing its density, reducing the empty spaces occupied by water and air; this affects directly the soil fertility and productivity (BAI et al., 2018). Vezzani and Mielniczuk (2011) highlight the importance of the retention of higher amounts of microaggregates and carbon in soil physical properties, keeping high fertility and productivity. Other soil properties, such as consistency (on which OM has a positive effect), horizon depth, and temperature distribution are also negatively affected by excessive management (MALAVOLA, 2006).

Soil texture is defined by the proportion of clay, silt, and sand, which present as a characteristic some difficulty to change in small periods (SEBEN JÚNIOR et al., 2014). Therefore, soil structure derives from the arrangement of the textural fractions, which define the physical characteristics, such as porosity (empty space between the particles), whereupon the OM and clay contents have an important effect (BAI et al., 2018; MELLEK et al., 2010).

Among the main functions of OM in soil, Mohammadi et al. (2011), Haynes and Zhou (2019), and Gondek et al. (2020) cite its role in composing the transition phase of nutrients to soil solution along with clay minerals; contribution to the physical characteristics of the soil; enhancement of the soil electrical charge density, increasing CEC; Al^{3+} and heavy metal neutralization by chelating effect; reduction in phosphate fixation by the blockage of exchange sites; chelation of micronutrients from the soil solution, increasing their availability to plants; and also being a food source to microorganisms.

According to Moreira and Malavolta (2004), soils that underwent different management systems when compared to native forest presented a reduction in nitrogen and OM content due to changes in the soil structure, causing diminishment of biological activity. Changes in nitrogen sources were also observed, with a quicker transition of ammoniacal nitrogen to nitrate due to a lower C/N relation in the soil.

Literature comments on the option of evaluating the OM content and soil aggregation by the humic substances, which have cementing effect, assisting in the formation of stable aggregates (FONTANA et al., 2010; PORTUGAL et al., 2010). When soil is managed, the humified fractions undergo alterations, with exception of the free fulvic acid fraction (FFAF), which keeps carbon in the top layer of soil (MELLEK et al., 2010; SOUZA et al., 2016).

In managed soils, the most efficient strategy to recover the nitrogen stocks is to increase soil OM content; the techniques of no-till of green cover with leguminous planting may be used. These procedures aim to enhance the soil structure and increase the microbial activity in the biological fixation of nutrients. Several authors comment on the importance of both soil texture and mineralogy in the maintenance of the nitrogen and organic carbon soil stocks (CONCEIÇÃO et al., 2005).

The presence and content of organic matter also have a major impact on water absorption and retention by the soil. Soil water has several biologic functions, besides the effects on both plant growth and metabolism. In the soil, water has functions related to nutrient cycles and OM (MINASNY; MCBRATNEY, 2018). Water availability in the soil varies mainly with soil porosity, due to the gravitational and capillary characteristics of the soil-water interactions. Sandy soils retain small amounts of water at field capacity (FC), have a lower permanent wilting point (PWP), and have less porosity, indicating a smaller water availability to plants. Clayey soils retain more water at

FC, have higher PWP, presenting a higher water availability to plants (COSTA et al., 2013; HEWELKE et al., 2015).

The addition of organic material may have different effects due to soil texture, especially in the formation and maintenance of stable aggregates. The addition of organic material to clayey soil tends to improve soil drainage, also increasing soil porosity and aeration. On the other hand, the addition of organic material to sandy soils tends to reduce soil drainage and improve its resistance to leaching of nutrients. It also tends to reduce excessive aeration, helping to develop a more compact structure to the sandy soils, whereas it helps in the disintegration of the compact structure of clayey soils (CONCEIÇÃO et al., 2005; OLIVEIRA et al., 2016).

In this sense, the objective of the present work was to evaluate the effect of the application of organic material on the chemical and physical properties of sandy and clay soils, also evaluating the effects on the physical-chemical properties of the soils with the application of an organic compost compared to an industrialized humic substance.

2. MATERIAL AND METHODS

The experiment was carried out in the ‘Vale do Caí’ region, which, according to Köppen climate classification, has a Cfa climate (subtropical climate with warm summer) (ALVARES et al., 2013). The average altitude of the experimental areas was 60 m above sea level. A soil with clayey texture and one with sandy texture were studied. The physical-chemical characterization of the soils was carried out following the procedures described by Tedesco et al. (1995) and Donagema et al. (2011).

According to the physical analysis, the sandy soil presented clay, silt, and sand contents of 11, 7, and 82 wt.%, respectively, corresponding to a loamy sand soil, according to USDA soil classification (USDA, 1999) and to a sandy soil by the Brazilian classification (Santos et al., 2018). The clayey soil had clay, silt, and sand contents of 39, 30, and 31 wt.%, respectively, corresponding to a clay loam soil by the USDA classification (USDA, 1999) and a medium texture in the Brazilian classification (Santos et al., 2018). The experiment using the sandy soil was performed in the municipality of São Sebastião do Caí, RS (geographical coordinates 29°36'55.8"S; 51°20'38.3"W); the experiment with the clayey soil was carried out in the municipality of Feliz, RS (geographical coordinates 29°29'07.0"S; 51°18'00.4"W). The detailed physical-chemical characterization of the tested soils is presented in Table 1.

Table 1 – Fertility and physical parameters of the tested soils.

Parameter	Clayey soil	Sandy soil
pH	5.77	7.23
pH-SMP	5.98	7.54
Electrical conductivity ($mS \cdot cm^{-1}$)	0.41	0.38
Clay (% m/v)	74	30
OM (% m/v)	3.1	1.6
P ($mg \cdot dm^{-3}$)	53.0	14.0
K ($mg \cdot dm^{-3}$)	98	23
Ca ($cmol_c \cdot dm^{-3}$)	2.37	1.18
Mg ($cmol_c \cdot dm^{-3}$)	0.94	0.55
Cu ($mg \cdot dm^{-3}$)	38.4	11.2
Zn ($mg \cdot dm^{-3}$)	20.9	19.4
Mn ($mg \cdot dm^{-3}$)	18	10
Fe (% m/v)	2.28	1.34
Na ($mg \cdot dm^{-3}$)	3.0	2.0
Al ($cmol_c \cdot dm^{-3}$)	zero	zero
H+Al ($cmol_c \cdot dm^{-3}$)	zero	zero
CTC pH 7 ($mg \cdot dm^{-3}$)	3.56	1.79
Bulk density ($Mg \cdot Mg^{-1}$)	0.877	1.028
Particle density ($Mg \cdot Mg^{-1}$)	3.123	2.600
Water retention capacity ($Mg \cdot Mg^{-1}$)	0.719	0.500
Total porosity ($Mg \cdot Mg^{-1}$)	0.718	0.600
Macroporosity ($Mg \cdot Mg^{-1}$)	0.684	0.577
Microporosity ($Mg \cdot Mg^{-1}$)	0.035	0.023

It was used the experimental design of randomized blocks, with four replicates for each treatment. The treatments applied in the soil were two doses of organic compost (obtained from wastes of orange juice extraction) supplied by EcoCitrus (Brazil); an industrialized humic substance (Greenhum WP®, Greenhas, Brazil), and a control treatment. The composition of the humic substances used is presented in Table 2.

Table 2 – Chemical composition of the humic substances used in this work.

Parameter	Organic compost	Industrialized humic substance
Moisture ($Mg \cdot Mg^{-1}$)	0.32	0.18
Carbon ($Mg \cdot Mg^{-1}$)	0.38	0.46
Total nitrogen ($Mg \cdot Mg^{-1}$)	0.02	0.01
Ash ($Mg \cdot Mg^{-1}$)	0.09	0.07

The treatments were the following: T0 – control (soil without addition of organic material); T1 – organic compost at the dose of 40 $Mg \cdot ha^{-1}$; T2 – organic compost at the dose of 80 $Mg \cdot ha^{-1}$; T3 – industrialized humic substance at the dose of 50 $Mg \cdot ha^{-1}$. The test areas were composed of only pasture (to reduce soil/plant interactions, since the study focused on evaluating only the soil properties, and not the performance relative to a crop). The organic compost was manually incorporated into the soil in field conditions by using a hoe down to a depth of 20 cm; the industrialized humic substance was dissolved in tap water (1:3) and applied using manual irrigation.

The dose of 50 $Mg \cdot ha^{-1}$ for the industrialized humic substance followed the largest dose recommendation of the manufacturer (two applications of 25 $Mg \cdot ha^{-1}$), but in a single application, since the treated areas were composed only of pasture. The doses of 40 and 80 $Mg \cdot ha^{-1}$ for the organic compost were chosen to verify the behavior of a smaller and greater dose relative to a commercial product, and also to verify a proportional increase with larger compost doses.

Thirty days after application, 20 soil sub-samples of approximately 500 g each were collected according to the procedures described by the Fertilization and Liming Manual for the RS and SC States (CQFS, 2016). The subsamples were mixed and a soil sample of about 1.0 kg was collected. This process was repeated four times in each treatment to generate the four replicates. The samples obtained were analyzed to determine the soil physical-chemical properties.

Granulometric analysis (clay, silt, and sand contents) was carried out using the pipette method, according to the procedures described by Tedesco et al. (1995). The determination of the physical properties (bulk and particle densities, water retention capacity, and porosity) followed the methods described by Embrapa Solos, using a 100 cm^3 volumetric ring (Donagema et al., 2011).

The determination of pH and electrical conductivity (EC) values was carried out by the addition of distilled water to the soil samples in the proportion of 2:1 (water:soil), followed by mixing and resting by 30 min. Afterward, the pH of the supernatant liquid was measured using a Digimed DM-22 pH meter, with an Ag/AgCl glass electrode. The supernatant liquid was filtered using a qualitative paper filter (blue range; pore diameter of 2 µm; grammage of 80 $g \cdot m^{-2}$), and the EC of the filtered extract was measured using a Digimed DM-32 conductivity meter and a platinum cell with a constant of 1.0 cm^{-1}.

The data underwent analysis of variance (ANOVA), and the means were compared by Tukey's multiple range test at 5% probability ($\alpha = 0.05$). The software AgroEstat® was used to carry out the statistical analysis.

3. RESULTS AND DISCUSSION

It was observed a trend of reduction of the bulk density of the clayey soil (from 0.877 to 0.792 $Mg \cdot m^{-3}$; a reduction of 9.7%) with the application of a higher dose of the solid humic compost (T2), which has not occurred with the application of the liquid humic substance (0.888

$Mg \cdot m^{-3}$ - T3), neither with the application of a lower dose of the solid humic compound (0.852 $Mg \cdot m^{-3}$ - T1). For the sandy soil, only the treatment T2 caused a reduction of the bulk density (from 1.028 to 0.985 $Mg \cdot m^{-3}$; a reduction of 4.2%), whereas the other treatments have not changed this property (all presented 1.028 $Mg \cdot m^{-3}$). Table 3 presents the results of bulk density for both the clayey and sandy soils.

Table 3 – Bulk and particle densities of the clayey and sandy soils with the application of different doses and kinds of OM.

Treatment	Bulk density ($Mg \cdot m^{-3}$)		Particle density ($Mg \cdot m^{-3}$)	
	Clayey soil	Sandy soil	Clayey soil	Sandy soil
T0	0.877 ab	1.028 a	3.123 a	2.600 a
T1	0.852 b	1.028 a	3.120 a	2.690 a
T2	0.792 c	0.985 b	2.906 a	2.980 a
T3	0.888 a	1.028 a	2.729 a	2.820 a
CV (%)	4.15	2.27	8.45	6.68

Means followed by the same letter in column do not present statistical difference by Tukey's multiple range test at 5% probability. Source: authors (2020).

The lower density of OM when compared to the soil and its addition in higher doses eventually reduces the overall soil mass by unit volume, being this a possible cause for the reduction of the bulk density of the treated soil, especially for clayey soils, which are denser and with less empty spaces for the accommodation of incorporated material (SOUZA et al., 2016). Celik et al. (2010), Chaudhari et al. (2013), and Sakin et al. (2011) commented that literature reports a negative relationship between the content of organic matter in the soil and its bulk density; the same authors also cited the formation of aggregates besides the lower density as the most probable mechanisms for OM to reduce the soil bulk density.

Table 3 presents the results of particle density for both soils with the four treatments using OM. There was no statistical difference among the treatments in both the sandy and clayey soils. The incorporation of any material to the soil, unless in high amounts, does not cause sensible changes in soil particle density despite being locally associated with the granulometry of soil horizon (MELLEK et al., 2010; PORTUGAL et al., 2010). The maximum dose applied in this work was 80 $Mg \cdot ha^{-1}$ (8 $kg \cdot m^{-2}$); for a soil profundity of 20 cm (considered as the main tillable part of soil), this corresponds to a soil volume of 200 L. This renders an application density of 40 $kg \cdot m^{-3}$; although high, liming doses may well exceed these values in soils that need extensive acidity correction (CQFS, 2016). Ruehlmann (2020) commented that the OM content may influence the soil particle density; however, the OM effect may be influenced by other factors, such as clay content, moisture, and soil drainage.

Table 4 presents the total porosity of the soils relative to the treatments applied.

Table 4 – Macroporosity, microporosity, and total porosity of the clayey and sandy soils with the application of different doses and kinds of OM.

Treatment	Macroporosity ($m^3 \cdot m^{-3}$)		Microporosity ($m^3 \cdot m^{-3}$)		Total porosity ($m^3 \cdot m^{-3}$)	
	Clayey soil	Sandy soil	Clayey soil	Sandy soil	Clayey soil	Sandy soil
T0	0.684 a	0.577 c	0.035 a	0.023 b	0.718 a	0.600 c
T1	0.682 a	0.596 bc	0.046 a	0.022 b	0.727 a	0.617 b
T2	0.686 a	0.638 a	0.040 a	0.031 a	0.726 a	0.668 a
T3	0.657 b	0.603 b	0.027 b	0.020 b	0.673 b	0.636 b
CV (%)	2.97	3.38	9.75	8.94	5.04	7.21

Means followed by the same letter in column do not present statistical difference by Tukey's multiple range test at 5% probability. Source: authors (2020).

It was observed that total porosity (TP) varied from 0.673 to 0.727 $m^3 \cdot m^{-3}$ in the clayey soil and from 0.600 to 0.668 $m^3 \cdot m^{-3}$ in the sandy soil with the treatments applied. As can be observed in Table 4, TP was higher in the clayey soil (0.718 $m^3 \cdot m^{-3}$ for the untreated clayey soil and 0.600 $m^3 \cdot m^{-3}$ for the untreated sandy soil). No statistical difference has occurred among the treatments T0, T1, and T2 in the clayey soil (0.718-0.727 $m^3 \cdot m^{-3}$); however, the TP value for treatment T3 (liquid industrialized humic substance) was statistically inferior (0.673 $m^3 \cdot m^{-3}$; a reduction of 6.3% relative to T0) to the other treatments. Jiang et al. (2012) observed little to no effect of the application of vinasse in two clayey soils (clay content above 0.70 $Mg \cdot Mg^{-1}$); a weak inverse relationship between the porosity of clayey soil and the application of liquid dairy manure was reported by Cavalcante et al. (2020).

For the sandy soil, the behavior was different, occurring an increase in total porosity with an increase in OM dose (from 0.600 $m^3 \cdot m^{-3}$ in T0 to 0.668 $m^3 \cdot m^{-3}$ in T2; an increase of 11.3%). The addition of the solid humic compost (T1 and T2) increased the total, macro, and microporosity of the sandy soil; however, the addition of the liquid humic substance (T3) also increased the total and macroporosity but has not influenced the soil microporosity. Aggelides et al. (2000), who studied the application of increasing doses of compost in two soils, reported a positive relationship between the dose applied and the soil porosity. The authors commented that the introduction of more particles in the soil may disaggregate it, rendering a more porous structure. Song and Lee (2010) also observed a similar trend of increase in soil porosity with an increase of the compost dose applied.

Clayey soils have lower densities and higher porosity than sandy ones (CONCEIÇÃO et al., 2005). However, clayey soils are more prone to the reduction of the TP and increase of density when subjected to intensive use, especially due to the compaction process that occurs after soil aeration (USDA, 1999). According to Baiamonte et al. (2015), the chemical and biological properties of the soil are more sensitive to the management effects than the physical properties for short periods (e.g., in the first year of cultivation). This may be the reason for the small variation of the porosity in the clayey soil.

The macroporosity (MP) values (0.657-0.686 $m^3 \cdot m^{-3}$ for the clayey soil and 0.577-0.638 $m^3 \cdot m^{-3}$ for the sandy soil) were similar to the ones of TP in both soils, indicating that most of the pores present in the soils were macropores, with a small fraction of the TP being composed of micropores (Table 4).

For MP in the clayey soil, there was no statistical difference among the treatments relative to the control (T0), with exception of the treatment T3, which presented smaller MP values than the control (0.684 $m^3 \cdot m^{-3}$ for T0 and 0.657 $m^3 \cdot m^{-3}$ for T3). According to Jiang et al. (2012) and Cavalcante et al. (2020), this behavior may be a result of the liquid form of application of T3, because, having more fluidity and mobility, the liquid organic material could penetrate more easily in the empty spaces of the soil structure, filling the pores a reducing overall soil porosity.

For the sandy soil, it was observed another trend, in which the treatment T2 was statistically superior to the others (0.638 $m^3 \cdot m^{-3}$ for T2, 0.577-0.603 $m^3 \cdot m^{-3}$ for the other treatments). Baiamonte et al. (2015) also reported an increase in the MP values and the aggregate stability index (ASI) after increasing doses of organic compost in soils with sandy-clay structure due to the cementing/aggregating effect of OM on the sand particles.

Microporosity (MIC) values varied as a function of soil kind and treatment applied; in the clayey soil, it varied between 0.027-0.046 $m^3 \cdot m^{-3}$ and between 0.020-0.031 in the sandy soil. As can be seen in Table 4, MIC presented itself higher in the clayey soil than in the sandy one. In the clayey soil, the treatments with organic compost (T1 and T2) have not differed from the control (T0), whereas the treatment with liquid humic substance (T3) had presented lower MIC values (0.027 $m^3 \cdot m^{-3}$ for T3 and 0.035-0.046 $m^3 \cdot m^{-3}$ for the other treatments; a reduction of 22.9%). For the sandy soil, the behavior was different, in which the treatment T2 was statistically higher than the other treatments (0.031 $m^3 \cdot m^{-3}$ for T2 and 0.020-0.023 $m^3 \cdot m^{-3}$ for the other treatments; an increase of 34.8%).

Since water tends to be entrapped in the micropores of the soil structure, the application of liquid compost may have allowed for the organic material to be deposited in the micropores; water evaporation led to a filling of the pores with organic material, 'sealing' them and reducing the overall MIP. Since sandy soils have much fewer micropores, the treatment T2 very probably increased the overall MIP due to the disrupting effect in the structure of the sandy soil, opening empty spaces in which micropores may have been formed by aggregating effects of the OM on sand particles (Baiamonte et al., 2015; Cavalcante et al., 2020).

Table 5 compiles the results of water retention capacity, electrical conductivity, and pH of the treated soils.

Table 5 – Water retention capacity, electrical conductivity, and pH of the clayey and sandy soils with the application of different doses and kinds of OM.

Treatment	Water retention capacity ($Mg·Mg^{-1}$)		Electrical conductivity ($mS·cm^{-1}$)		pH	
	Clayey soil	Sandy soil	Clayey soil	Sandy soil	Clayey soil	Sandy soil
T0	0.719 ab	0.500 b	0.41 c	0.38 b	5.77 c	7.23 b
T1	0.727 a	0.515 ab	0.91 b	0.99 a	6.27 b	7.38 ab
T2	0.726 a	0.557 a	1.52 a	1.14 a	7.21 a	7.50 a
T3	0.683 b	0.530 ab	0.35 d	0.43 b	6.16 b	7.16 b
CV (%)	7.11	6.59	4.31	7.03	8.44	5.23

Means followed by the same letter do not present statistical difference by Tukey's multiple range test at 5% probability.

The application of solid OM (treatments T1 and T2) in the clayey soil (Table 5), increased slightly the soil water retention capacity (0.719 $Mg·Mg^{-1}$ for the control and 0.726-0.727 $Mg·Mg^{-1}$ for the T1 and T2 treatments), whereas the liquid OM (T3) reduced the soil water retention capacity (from 0.719 to 0.683 $Mg·Mg^{-1}$). This effect may be the result of a reduction of the microporosity of the clayey soil due to the penetrating nature of the liquid humic substance, or by a coating effect. Eden et al. (2017) commented in a review work that some organic materials, when applied to the soil, may reduce the overall soil WRC; however, this effect depends on the hydrophilicity of the organic material, the clay content of the soil, and also on the chemical properties, as pH and soluble salts dissolved (electrical capacity).

The sandy soil, on the other hand, had its WRC increased with the three treatments relative to the control (T0), in which the treatment T2 has had the highest WRC values (0.500 $Mg·Mg^{-1}$ for T0 and 0.557 $Mg·Mg^{-1}$ for T2; an increase of 11.4%). Zemanék (2011) reported a positive trend between soil WRC and the application of compost, citing that OM fosters water penetration and helps retaining it, acting like a sponge, which ends up increasing the overall WRC of the soil. The importance of the role of OM in retaining soil water and humidity also depends on soil texture. In soil with a sandier texture, the WRC is more sensitive to the amount of OM added than in more clayey soils, which, due to the presence of smaller particles, tends to have a more porous structure, which helps to retain water by capillary effect (SILVA; MENDONÇA, 2007).

Relative to the electrical conductivity (EC) of the clayey soil, it was possible to observe a clear trend between soil EC and the dose of organic compost. The EC values increased from 0.41 $mS{\cdot}cm^{-1}$ for T0 to 0.91 $mS{\cdot}cm^{-1}$ for T1 (40 $Mg{\cdot}ha^{-1}$ of organic compost) and to 1.52 $mS{\cdot}cm^{-1}$ for T2 (80 $Mg{\cdot}ha^{-1}$ of organic compost). The incorporation of this material adds to the soil, beyond OM, also nutrients and ions, which contribute to increasing the EC values (Cavalcante et al., 2020; Eden et al., 2017). On the other hand, the treatment with liquid humic substance (T3; 50 $Mg{\cdot}ha^{-1}$) has not differed from the control (0.35 $mS{\cdot}cm^{-1}$), very probably due to a diluting effect of the vehicle (water).

In the sandy soil (Table 5), the treatments T1 and T2 have not differed between themselves (0.99 and 1.14 $mS{\cdot}cm^{-1}$, respectively), being higher than both the control (T0; 0.38 $mS{\cdot}cm^{-1}$) and the liquid humic substance application (T3; 0.43 $mS{\cdot}cm^{-1}$). The varying behavior between the soil types, as pointed by Carmo et al. (2016), may be attributed to the varying texture of the soils and the quantity of organic material applied.

As EC reflects the number of dissolved ions in soil water, the response is generally directly proportional to soil texture; the higher the texture, the higher the response. Rodrigues et al. (2011) observed stronger positive effects on the fertility of sandy loam soils relative to sandy ones, which need the application of higher amounts of organic material to achieve the same results. It is also important to cite the higher cation exchange capacity (CEC) of clayey soils, which increases EC values when compared to soils with a sandier texture, which undergo more leaching of nutrients (BAIAMONTE et al., 2015; PORTUGAL et al., 2010).

Table 5 presents the results of pH for each treatment and soil kind. The incorporation of organic material caused a significant increase in soil pH, especially in the clayey one (from 5.77 in T0 to 7.21 in T2). In the sandy soil, the pH of the control (T0) already was high (7.23), so that, despite statistically significant, the differences between treatments were not very pronounced (7.38 for T1 and 7.50 for T2, respectively).

The main difference was in the treatment T3 (liquid humic substance), whose application caused an increase of the pH of the clayey soil (from 5.77 to 6.16), whereas it induced a reduction of the pH of the sandy one (from 7.23 to 7.16). Portugal et al. (2010) and Silva and Mendonça (2007) cited the weak resistance of the soils with sandy texture to leaching. The leaching of cations and the substitution of the empty sites by hydrogen/hydronium (H^+/H_3O^+) cations ends up reducing the pH of the soil solution, rendering it more acidic.

It is also noteworthy to cite the high pH of the treated soils. For most cultures, the pH range considered as optimal lies between 5.50 and 6.50; soils with high pH values tend to have low availability of micronutrients, especially transition metals, which impacts negatively overall soil fertility and reduces crop development and productivity (Donagema et al., 2011). As strategies to mitigate these issues, Bai et al. (2018), Gondek et al. (2020), and the Commission of Chemistry and Soil Fertility (CQFS, 2018) commented on the joint application of composts with different chemical properties, aiming to obtain a mixture with more appropriate or matched physical-chemical parameters to the soil in which the organic material will be applied.

The literature cites the trend of pH increase with the addition of organic composts in the soil, mainly due to the effect of the OM on the exchangeable bases, such as Ca^{2+}, Mg^{2+}, K^+, and Na^+ (MALAVOLTA, 2006). The increase of pH is also a result of the capture and absorption of H^+ ions by anions present in the organic substances or due to the release of OH^- ions in the absorption of immobilized micronutrient cations in hydroxide form, such as Cu^{2+}, Zn^{2+}, $Fe^{2+/3+}$, Mn^{2+}, among others (BAIAMONTE et al., 2015; MALAVOLTA et al., 2006).

Relative to the effect of organic material application on the nutrient availability in soil, Souza et al. (2006) concluded that an increase in pH, associated with the application of OM, reduced the overall phosphorous availability because a fraction of the soluble P adsorbs in the amphoteric fraction of the OM and, partially, in the clay particles. Santos et al. (2001) also reported an increase in the sum of bases when applying organic fertilizers in the soil. The pH increase caused by organic material addition may lead to an overall reduction of micronutrient availability; however, this scenario may only arise if the soil pH is not properly monitored (CONCEIÇÃO et al., 2005; SOUZA et al., 2006).

In regions where sandy soils predominate, it is important to evaluate the dose and frequency of application of both organic and mineral materials, especially because sandy soils are prone to leaching, which may eventually lead to groundwater contamination and salification of the deeper horizons of the soil. This may cause deleterious effects to cultures whose roots penetrate deeper, such as *Citrus* plants, which are an important part of the agricultural production of the Vale do Caí (SONG; LEE, 2010).

4. CONCLUSIONS

The treatments using the solid compost (T1 and T2) induced an increase in the soil porosity (total, macro, and micro), as well as soil pH and EC, which increased proportionally with the applied dose, also reducing the soil bulk density. The treatment using the liquid humic substance (T3) induced a reduction of overall soil porosity, water retention capacity, and EC in the clayey soil. Relative to the sandy soil, the treatment T3 caused an increase of the total porosity, macroporosity, and water retention capacity, whereas it reduced the soil pH and EC.

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