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ORIGINAL ARTICLE

Construction and evaluation of alternative tension infiltrometer in Oxisol under wood ash management[1]

Construção e avaliação de infiltrômetro de tensão alternativo em Latossolo sob manejo de cinza vegetal

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HIGHLIGHTS:
The tension infiltrometer is an alternative for measuring water infiltration in Oxisol.
Wood ash is a soil fertility management alternative that improves soil physical properties.
The method by which wood ash is applied affects soil water infiltration.

ABSTRACT: The tension infiltrometer has the potential to evaluate the effects of applying soil amendments, such as wood ash, on the process of water infiltration into soil. In this context, the aim of this study was to construct and verify the effectiveness of the alternative tension infiltrometer and evaluate water infiltration in Oxisol under pasture cultivation fertilized with incorporated and unincorporated wood ash. To quantify water infiltration in Oxisol under *Urochloa brizantha* grass cultivation, infiltration assessments using the alternative tension infiltrometer were performed under field conditions in triplicate, for a total of 60 measurements. The treatments in the experimental field consisted of two factors: two wood ash application regimes (incorporated and unincorporated) and five wood ash doses (0, 8, 16, 24, and 32 g dm^{-3}). Cumulative infiltration varied with the different application methods and doses of wood ash. The rate of water infiltration was higher in the treatments with unincorporated wood ash application. The proposed tension infiltrometer proved to be effective in quantifying water infiltration in soils under different management conditions.

Key words: biomass ash, soil water infiltration, application regimes, porous membrane

RESUMO: O infiltrômetro de tensão é um equipamento que tem o potencial de avaliar os efeitos da aplicação de corretivos do solo, como a cinza de madeira, no processo de infiltração de água no solo. Nesse contexto, objetivou-se construir e verificar a eficácia do infiltrômetro de tensão alternativo e avaliar a infiltração de água em Latossolo sob cultivo de pastagem adubada com cinza vegetal incorporada e não incorporada. Para quantificar a infiltração de água em Oxisol sob cultivo de capim *Urochloa brizantha*, as avaliações de infiltração utilizando o infiltrômetro de tensão alternativo foram realizadas em condições de campo em triplicata, totalizando 60 medições. Os tratamentos no campo experimental foram constituídos por dois fatores: duas formas de aplicação de cinza de madeira (incorporado e não incorporado) e cinco doses de cinza de madeira (0, 8, 16, 24 e 32 g dm^{-3}). A infiltração acumulada variou com os diferentes métodos de aplicação e doses de cinza de madeira. A velocidade de infiltração de água foi maior nos tratamentos com aplicação de cinza de madeira não incorporada. O infiltrômetro de tensão proposto mostrou-se eficaz na quantificação da infiltração de água em solos com diferentes condições de manejo.

Palavras-chave: cinza de biomassa, infiltração de água no solo, formas de aplicação, membrana porosa

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Introduction

The tension infiltrometer an instrument used to determine the water infiltration into the soil from a circular source under a constant and negative potential. The infiltrometer can be used to measure hydraulic conductivity in the field and sorptivity under near-saturated conditions (Nimmo et al., 2023; Morales-Ortega et al., 2023) to quantify the effect of macropores and preferential pathways on infiltration, among other examples.

The tension infiltrometer alternative has several advantages: it is simple, portable, easy to use in field or laboratory studies, and only requires small volumes of water for measurements. Currently, there are several commercially available models that vary in size, water storage capacity, and purchase cost. The use of an alternative infiltrometer arises from the need to test and analyze the effectiveness of models made from PVC, acrylic, polyethylene, and cotton, which are more affordable than conventional, costly models (Morales-Ortega et al., 2023).

One of the potential uses of a tension infiltrometer is to evaluate the effects of applying soil amendments derived from agro-industrial wastes. The studies by Bonfim-Silva et al. (2022), Oliveira et al. (2023), and Meneghetti et al. (2023) emphasize the importance of soil amendments derived from agro-industrial waste, such as wood ash, as a critical alternative for improving soil properties and mitigating the environmental impacts of improper disposal of these wastes.

When added to the soil, wood ash can contribute to changes in numerous physical, chemical, and biological attributes, such as porosity, water retention, infiltration, pH, salinity, sodicity, microbial diversity and activity, enzymatic activity, metabolic quotient, and basal respiration (Bonfim-Silva et al., 2022; Duarte et al., 2023). However, few studies have specifically related the application of wood ash doses associated with different soil application management practices and their effects on soil water infiltration processes, especially when using a tension infiltrometer.

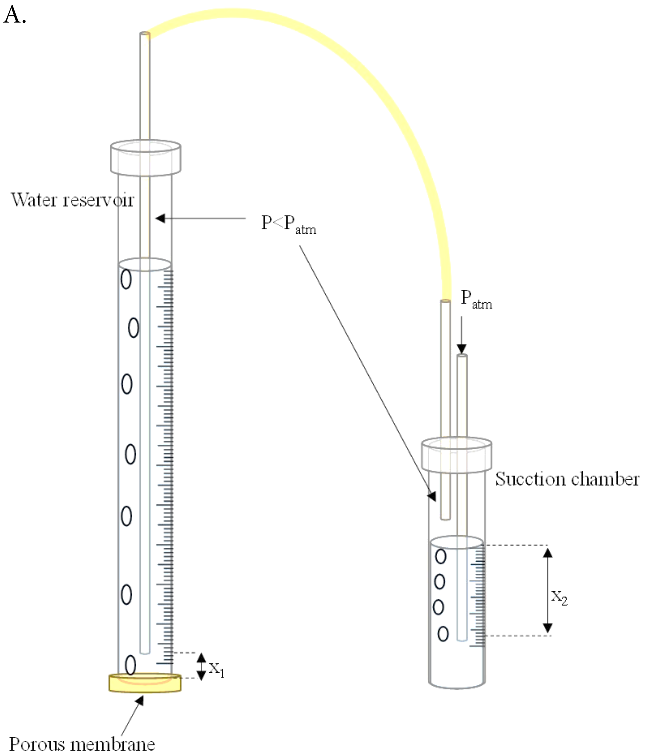
In this context, the tension infiltrometer can potentially evaluate the effects of applying soil conditioners such as wood ash. The hypothesis to be tested is that the alternative tension infiltrometer efficiently quantifies water infiltration in soil under different types of wood ash management. This research aimed to construct and verify the effectiveness of the alternative tension infiltrometer and evaluate water infiltration in Oxisol under pasture cultivation fertilized with incorporated and unincorporated wood ash.

Material and Methods

The infiltrometer equipment was constructed at the Soil Physics Laboratory of the Federal University of Rondonópolis, Mato Grosso state, Brazil (16° 27' 41" S and 54° 4' 52" W, an altitude of 293 m). The tension infiltrometer consists of two compartments connected by a flexible hose. The first compartment is the water reservoir, which has a diameter of 5.0 cm, a height of 40 cm, and a storage capacity of 500 mL of water. The second compartment is the suction chamber, which controls the desired suction on the porous membrane that connects the equipment and the soil. The suction chamber has a height of 25 cm, a diameter of 2.7 cm, and a suction adjustment capacity of 0-15 cm.

Inside the water tank is an acrylic tube with an internal diameter of 0.3 cm and a height of 37 cm, allowing air to pass from the suction chamber to the inside of the water tank. The distance from the bottom of the acrylic tube to the bottom of the equipment is 3.5 cm (X_1 in Figure 1). The upper end of the

A.



B.

Figure 1. Scheme of the alternative tension infiltrometer (A) and the tension infiltrometer built in operation (B)

acrylic tube was connected to the suction chamber by a flexible hose with an internal diameter of 3.0 mm and a length of 70 cm.

The suction chamber has a second acrylic tube, 23 cm long, the upper end was completely open to the atmosphere, and the lower end was submerged in a water column. The function of this tube is to allow air from the atmosphere to enter the suction chamber.

The bottom of the water tank has two porous media, one rigid and the other flexible. The first porous medium is made of PVC and has a basal area, i.e., the area in contact with the soil, of 22.90 cm^2 and is 0.5 cm thick. In this area, 26 holes were drilled, 1.0 mm in diameter, distributed evenly over its surface. The second porous medium, called the membrane, is a commercially available fabric made of polyethylene and cotton, which overlaps the porous medium described above and, therefore, has the same contact area with the soil. The saturated hydraulic conductivity and the soil water retention curve were measured to characterize the hydraulic properties of the porous membrane. As described by Santos et al. (2017), the saturated hydraulic conductivity was determined for soils in general. The water column used was 3.5 cm on average, the membrane area used was 18.85 cm^2, and the water collection time was 10 s on average. A total of 20 replicates were performed. The saturated hydraulic conductivity was 0.07862 cm s^{-1}.

The soil water retention curve of the porous membrane was determined using a 10 × 10 cm sample. The membrane was saturated and then subjected to tensions of -2.5, -5, -7, -15, -20, -30, -40, -50, -60, -70, -80, -90, and -100 cm on the tension table and pressures of 500 and 1500 kPa in the Richards pressure chamber. Once the water extraction had stabilized at each measurement point, the membrane was weighed to determine the moisture content on a mass basis. Subsequently, the Van Genuchten (1980) model was fitted to the experimental data obtained using the SWRC Fit platform (Seki, 2007).

The desired tension in the porous membrane that establishes contact between the infiltrometer, and the soil is set by adjusting the water column in the suction chamber. The tension value can be calculated from the following equation (Eq. 1):

$$h = x_2 - x_1 \tag{1}$$

where:

h - tension in the porous membrane in contact with the soil (cm);

x_2 - distance between the surface of the sheet of water and the bottom base of the acrylic tube in the suction chamber (cm); and,

x_1 - distance between the bottom of the acrylic tube and the bottom of the water tank (cm).

Thus, there will be suction in the porous membrane whenever x_2 is greater than x_1.

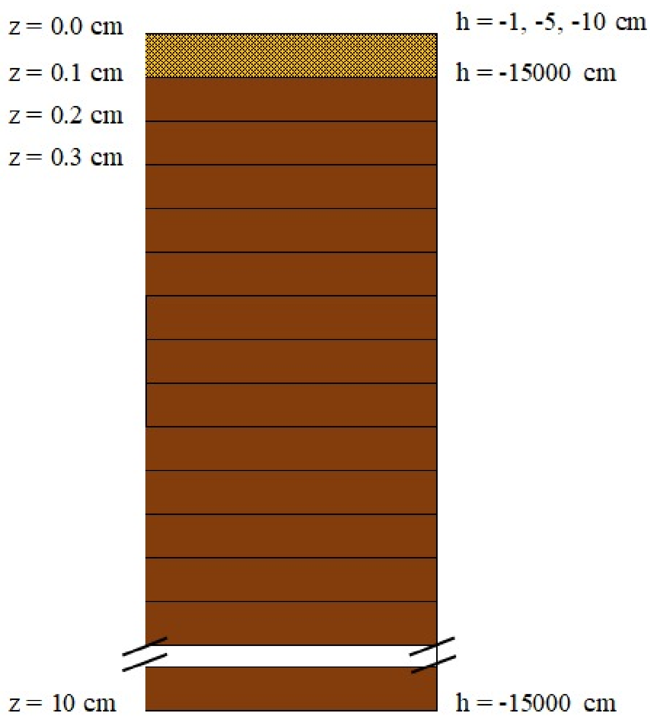
The porous membrane that makes contact between the instrument and the soil must have an enough high hydraulic conductivity to allow water to infiltrate into the soil without any physical limitation caused by the membrane. In addition, the soil surface in contact with the infiltrometer must reach the same tension as the porous membrane in a very short time.

The principle of the alternative tension infiltrometer is to apply a constant load, which can be negative or positive, to the soil by means of direct contact between a circular disc and a membrane. This allows the disc to adhere more closely to the soil to avoid air ingress and leakage, a fact that must be respected during installation, which can lead to errors in the readings.

Numerical simulations of water flow in the soil were performed to evaluate these processes using the Richards model with Hydrus 1D software. For this purpose, the soil profile considered was 10 cm deep, discretized into 101 nodes (Dz = 0.1 cm), with two material types, one representing the porous membrane and the other representing the soil. The first layer of the profile, 0.1 cm thick, represented the porous membrane, and the second layer, from 0.1 to 10 cm, represented the soil (Figure 2).

To calibrate the instrument, a simulation was carried out in which it was possible to check the temporal variation in the tension in the soil layers at 1, 2 and 3 mm below the porous membrane. For calibration, soils of different textures were evaluated from the Hydrus 1D database, which gathers physical data from various soils. All the soil classes available in the software were selected, and their physical characteristics are shown in Table 1.

The tension of the porous membrane used in the simulation was 0.15 m, which was considered constant throughout the infiltration process. This tension was chosen because it is the limit tension used in the equipment. The initial condition adopted for the soils was h = -150 m. The boundary condition for the upper and lower edge of the profile was constant pressure. This condition is essential so that there is no oscillation in the membrane contact that could influence



The top layer represents the porous membrane, 0.1 cm thick, and the other layers represent the soil

Figure 2. Profile used to simulate water flow through the porous membrane

Table 1. Physical properties of the different soil texture classes used to simulate infiltration

Material	θs $cm^3\ cm^{-3}$	θr $cm^3\ cm^{-3}$	α cm^{-1}	n $cm\ d^{-1}$	Ks $cm\ s^{-1}$
Porous membrane	0.97	0.01	0.038	5.13	0.07862
Sand	0.43	0.04	0.145	2.68	0.00825
Loamy Sand	0.41	0.05	0.124	2.28	0.00405
Sandy Loam	0.41	0.06	0.075	1.89	0.00123
Loam	0.43	0.07	0.036	1.56	0.00029
Silt	0.46	0.03	0.016	1.37	6.94E-05
Silt Loam	0.45	0.06	0.020	1.41	0.000125
Sandy Clay Loam	0.39	0.10	0.059	1.48	0.000364
Clay Loam	0.41	0.09	0.019	1.31	7.22E-05
Silt Clay Loam	0.43	0.08	0.010	1.23	1.94E-05
Sandy Clay	0.38	0.10	0.027	1.23	3.33E-05
Silt Clay	0.36	0.07	0.005	1.09	5.56E-06
Clay	0.38	0.06	0.008	1.09	5.56E-05

θs - Saturated moisture content, θr - Residual moisture, α and n - Shape parameters, Ks - Saturated hydraulic conductivity

the equipment's readings and provide greater soil-equipment adherence.

The equipment was tested in the field in the experimental area of the Federal University of Rondonópolis, with geographical coordinates of 16° 27' 41" S and 54° 4' 52" W, with an altitude of 293 m. The soil is classified as an Oxisol (USDA-NRCS Soil Survey Staff, 2014), with 41% sand, 40% clay, and 19% silt, with a clayey texture.

The experimental area is cultivated with *Urochloa brizantha* grass, which is maintained in a pre-existing soil management project using wood ash. The pre-existing project was implemented in 2018, and since the establishment of the experiment, the grass has been maintained in the following years. The wood ash was applied when the experiment was implemented in November 2018 and the fertilization with ash was maintained in November 2019, since then it has not been necessary to reapply the ash in the following agricultural years.

The experiment was conducted under dryland conditions, using only *Urochloa brizantha* grass since the experiment was set up. The average rainfall and temperature during the experiment were 1.88 mm, and 26.49 °C, respectively.

The treatments consisted of a combination of two factors: two application methods of wood ash (incorporated (I) into the soil and unincorporated (NI)) and five doses of wood ash (0, 8, 16, 24, and 32 g dm^{-3}).

A completely randomized design was used, with ten treatments and two replicates, for a total of 20 experimental plots. The infiltration evaluations under field conditions were performed in triplicate, totaling 60 measurements to quantify water infiltration into the soil.

The physical and chemical attributes of the soil in the experimental area were pH ($CaCl_2$) = 3.7; O.M. and V (%) =2.7 and 14.41; P and K (mg dm^{-3}) =1.6 and 42.4; S, Ca, Mg, Al, H+Al, SB, and CEC ($cmol_c\ dm^{-3}$) = 6.1, 0.65, 0.25, 0.95, 6.0, 1.01, and 7.01, respectively, at a depth of 0-20 cm.

The physical and chemical characteristics of the wood ash used as a source of variation were as follows: pH ($CaCl_2$) = 10.67; neutralizing power and relative total neutralizing power (%) = 30.00 and 24.76; N; P_2O_5; K_2O; Ca; Mg; S; Fe and M.M. (g kg^{-1}) = 4.9; 7.9; 32.5; 49.6; 42.0; 6.0; 7.2 and 546.4; particle size: 4.8 mm; particle size: 2.0 mm; particle size: 1.0 mm (%) = 0.48; 3.07 and 10.53 with a density of 0.4 g cm^{-3}, respectively.

The instrument's suction chamber was calibrated to a tension of h = 0 cm to quantify water infiltration into the soil. The water reservoir of the infiltrometer was filled with 500 mL of water, and the change in the amount of infiltrated water was recorded at 30-second intervals. Measurements were taken until 250 mL of water had infiltrated into the soil. On average, each measurement took approximately 30 min. A 2.0 mm layer of sand was added to the soil surface to ensure adequate adhesion between the infiltrometer and the soil.

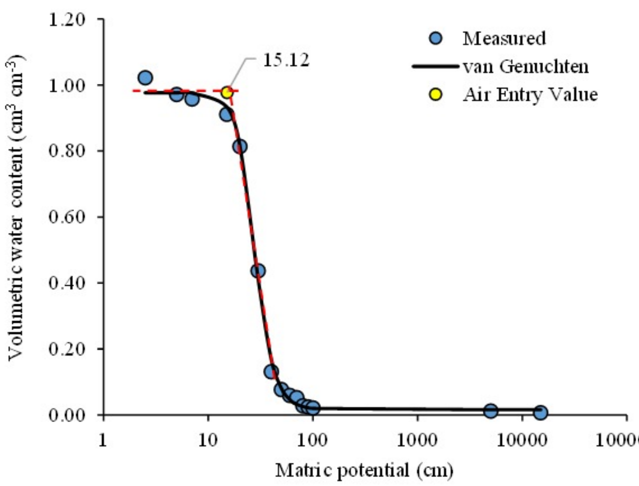
The instrument is installed on the soil surface, ensuring only capsule/membrane contact with the soil. This setup allows for the transfer of fluid (water) from the instrument to the soil, facilitating the quantification of infiltration. The installation process is illustrated in Figure 1.

The model of Kostiakov (1932) was used to describe the infiltration process. The cumulative infiltration over time, the cumulative infiltration, and the infiltration rate as a function of the management of the application of the wood ash and the doses of wood ash, as well as the combination of both factors, were evaluated in isolation.

The data were subjected to the normality of errors test (Shapiro-Wilk) and homoscedasticity test (Bartlett) ($p \leq 0.05$). When regular and homogeneous, the quantitative factors (doses of wood ash) were subjected to the regression test, and the qualitative factors (application management) were subjected to a comparison of means using the Tukey test ($p \leq 0.05$). When there was an interaction between the factors, the effects were split. The SISVAR version 5.7 program (Ferreira, 2019) and Statistica 7 version 7.0 (Statsoft, 2014) were used for the analyses.

Results and Discussion

The representation of the soil water retention curve for the porous membrane used in the proposed infiltrometer is shown in Figure 3. The material has a high-water retention capacity at pressures below 10 cm, i.e., in the saturation zone range. For pressures approximately more significant than 10 cm, there was a marked reduction in water retention in the region commonly referred to as the transition zone (Es-haghi et al., 2023). In terms



The highlighted yellow point represents the air intake value

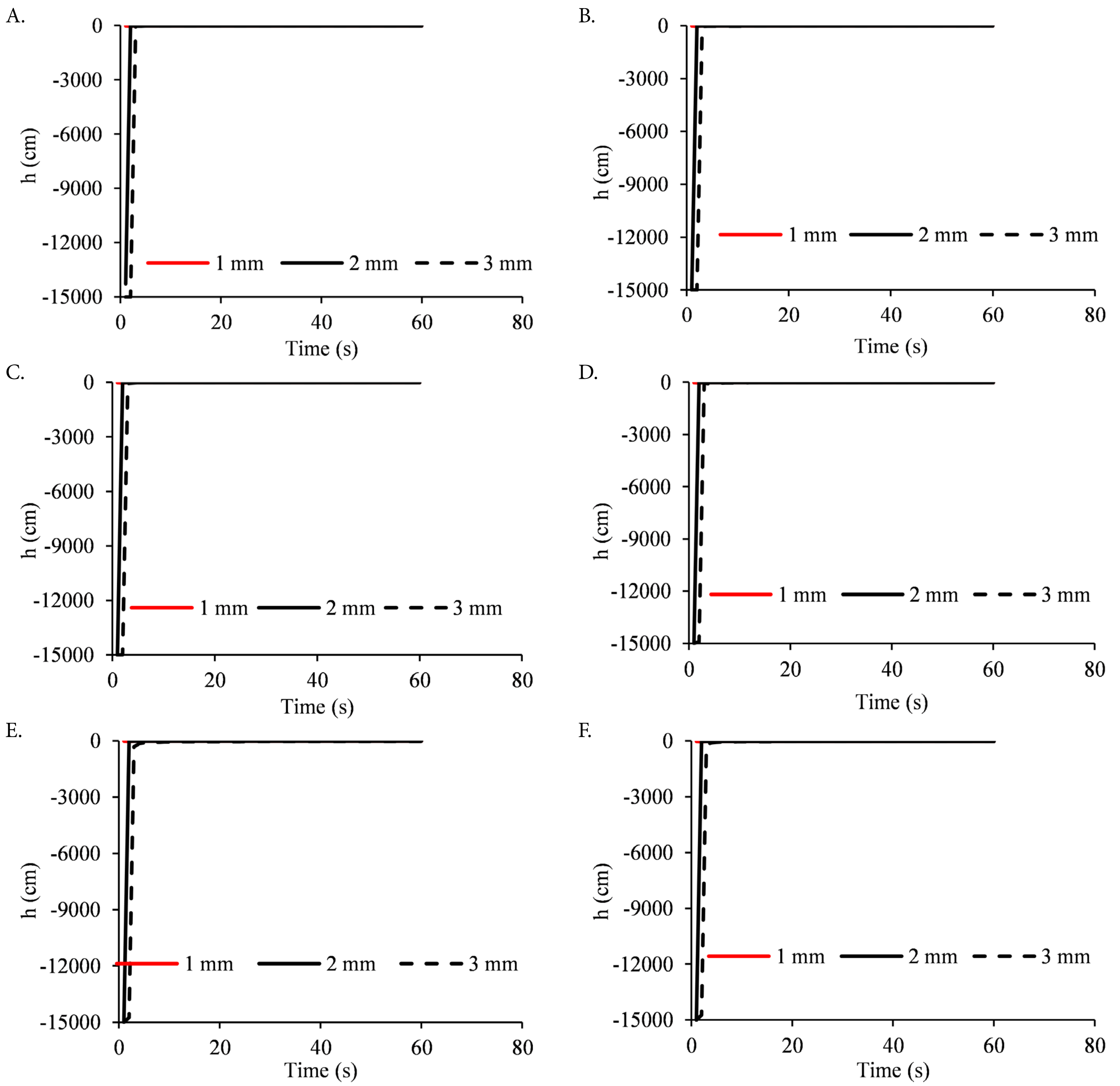
Figure 3. Soil water retention curve of the porous membrane used in the tension infiltrometer

of values, the moisture of the membrane decreased from 1.14 to 0.13 $cm^3 \ cm^{-3}$ when the pressure varied from 10 to 40 cm.

Based on the experimental data of the water retention curve, the air intake value of the porous membrane was determined graphically as the point of intersection of the horizontal tangent line in the saturated portion with the tangent line in the transition portion of the curve (Es-haghi et al., 2023), whose value was found to be 15.12 cm (Figure 3). In the soil, the air intake is characterized as the matric suction at which air begins to enter the largest soil pores during the drying process. In terms of instrument functionality, this would theoretically be the limit, i.e., the highest suction the porous membrane can withstand without air entering its pores. In any case, the air intake pressure in the porous membrane, in terms of suction, must be lower than the suction calibrated in the equipment to ensure that its pores remain saturated during infiltration (Morales-Ortega et al., 2023).

The results of simulating the water tension in the soil at depths of 1, 2, and 3 mm during the infiltration process are shown in Figures 4 and 5. For the soil layer at 1.0 and 2.0 mm below the infiltrometer, the tension after 2 s of simulation is equal to the calibrated tension for the porous membrane, regardless of the soil being evaluated (Figure 5). For the 3.0 mm layer below the infiltrometer, for all soil classes evaluated, the tension after 2 s was close to the initial tension defined for the soils, i.e., h = -150 m. Even after 60 s of simulation, the simulated tensions in the 3.0 mm layer did not match the tension determined for the instrument (h = 15 cm) for most soils. The differences were generally greater for the finer-textured soils (Figures 4 and 5).

For the 3.0 mm layer, the differences observed between the tensions can be attributed to the soil physical attributes, which at this distance from the porous membrane affect with the movement of water and, consequently, the variation of the



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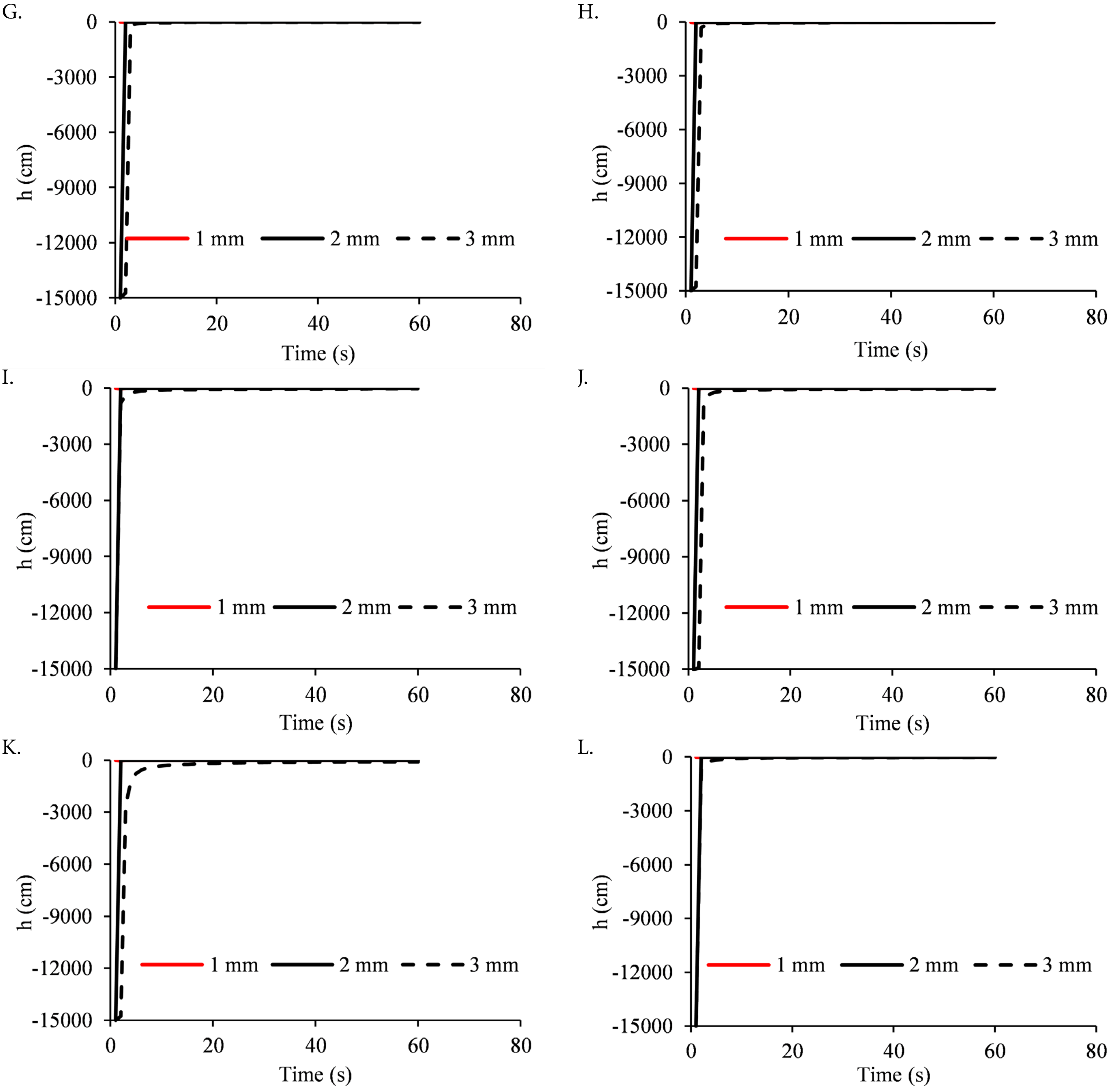


Figure 4. Simulation of the temporal variation of water tension at different soil depths during the infiltration process using Hydrus 1D software for the following soil texture classes (USDA-NRCS Soil Survey Staff, 2014): (A) Sandy, (B) Loamy Sandy, (C) Sandy Loam, (D) Loam, (E) Silt, (F) Silt Loam, (G) Sandy Clay Loam, (H) Clay Loam, (I) Silt Clay Loam, (J) Sandy Clay, (K) Silt Clay, (L) Clay

tension (Figures 4 and 5). On the other hand, the equality of tensions at the 1.0 and 2.0 mm depths, proves that the porous membrane has sufficient hydraulic properties for the soil to quickly acquire the tensions calibrated for the equipment (Figures 4 and 5).

The cumulative infiltration and Kostiakov equation fit coefficients are shown in Figure 6. The fitting of the Kostiakov model obtained a coefficient of determination (R^2) of 0.99 for all treatments, i.e., regardless of the application management and the dose of wood ash applied, the data show that the model accurately explains the cumulative infiltration. These results corroborate Almeida et al. (2018), Oliveira et al. (2018), and Suryoputro et al. (2018) when they state that the Kostiakov model can estimate infiltration rates in soils under different management types with high coefficients of determination.

In studying the performance of infiltration models under different soil managements in a tropical climate, Atta et al. (2022) stated that the Kostiakov model had the highest accuracy with the highest R^2 values ranging from 0.9965 to 0.9967.

Cumulative infiltration varied over the different application methods and doses of wood ash (Figure 6). The application of ash incorporated into the soil (I) resulted in lower values of cumulative infiltration over time, since for the dose of 32 g dm^{-3} the infiltration reached 7.19 cm in 0.4 hours, while for the doses of 0 and 24 g dm^{-3}, it reached 8.91 cm in 0.5 hours (Figure 6A).

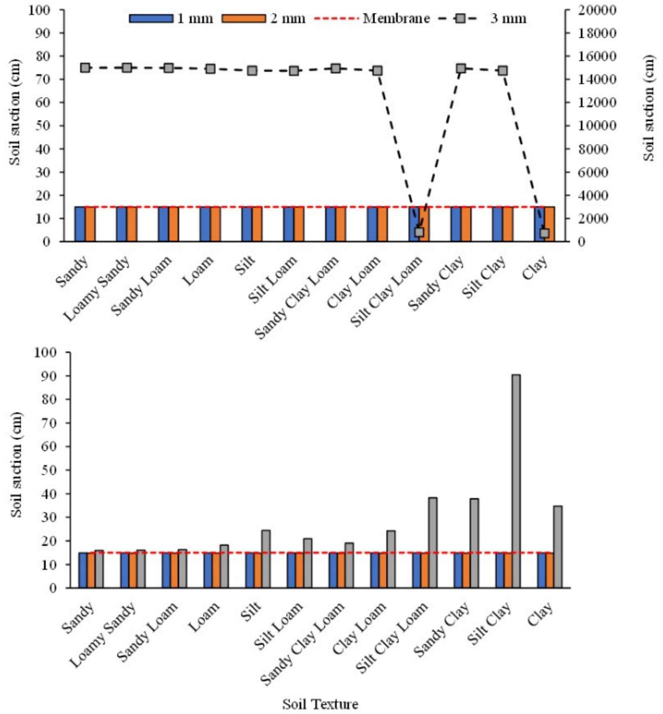


Figure 5. Soil suction at depths of 1, 2, and 3 mm after 2 s (A) and 60 s (B) of infiltration

Under unincorporated (NI) management, the highest cumulative infiltration values were observed at doses of 8, 16 and 32 g of ash dm^{-3}, accompanied by the shortest times, corresponding to 8.44, 7.90, and 9.27 cm for the times of 0.34, 0.46 and 0.36 hours, respectively (Figure 6B).

It should also be noted that the parameters "k" and "n" of the Kostiakov model obtained by the best fit of the measured data differed between the treatments that included ash doses applied incorporated (Figure 6A) and unincorporated (Figure 6B). The justification for these results in the unincorporated management is that in the soil cultivated with pasture, there is a large amount of biopores from biological activity, combined with the maintenance of the soil structural properties promoted by the addition of wood ash, such as high porosity and low soil bulk density. Martins & Santos (2017) state that biopores have a strongly influence on water infiltration into the soil, since they are long and continuous, and thus therefore highly effective in the transmission of water and air transmission in the soil, providing allowing greater infiltration of water into the soil.

The application management directly influences the reactive processes of the wood ash on the soil properties, which is reflected in the different infiltration rates within the management for each ash dose. The association of wood ash with pastures favors the physical and hydrological properties of Oxisols (Duarte et al., 2020; Duarte et al., 2023; Silva Filho et al., 2023).

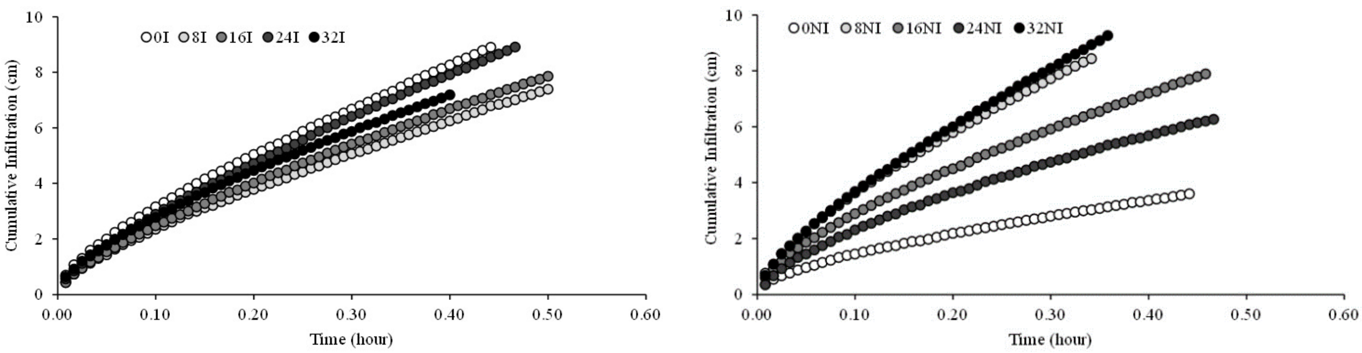
The comparison of the 0.0 g dm^{-3} dose of wood ash with the other doses in each of the treatments for cumulative infiltration adjusted to the Kostiakov model is shown in Table 2. There was a difference between the doses compared to the zero dose and within the treatments at $p \leq 0.05$ according to the F test.

The differences observed reflect the dynamics of management versus doses of ash, resulting in different infiltration curves for each management within each dose of ash compared to the 0.0 dose (g dm^{-3}) (Table 2). Prazeres et al. (2021) stated that water infiltration in the soil is strongly influenced by management, especially by the type of soil mobilization with a harrow, corroborating what was observed in this study.

Table 2. Comparison between cumulative infiltration curves adjusted to the Kostiakov model ($I = K t^n$)

Management	Ash dose (g dm^{-3})	F test	p
Incorporated	8	10139.744	≤0.05
	16	8162.507	≤0.05
	24	376.190	≤0.05
	32	2164.408	≤0.05
Unincorporated	8	185993.0251	≤0.05
	16	129995.312	≤0.05
	24	63604.169	≤0.05
	32	206899.513	≤0.05

A. B.



Management	Ash (g dm^{-3})	k	n	R^2
I	0	15.51	0.693	0.99
	8	12.03	0.713	0.99
	16	12.91	0.720	0.99
	24	15.47	0.730	0.99
	32	13.22	0.671	0.99

Management	Ash (g dm^{-3})	k	n	R^2
NI	0	5.83	0.606	0.99
	8	17.60	0.686	0.99
	16	13.13	0.659	0.99
	24	10.34	0.651	0.99
	32	19.23	0.718	0.99

Figure 6. Cumulative infiltration over time in Oxisol as a function of the ash doses applied incorporated - I (A) and unincorporated - NI (B) with the equations fitted by the Kostiakov model

It is well known that the formation of macropores, soil voids, channels, and effective water transport pathways, changes in soil structure, and different types of land use can be other components that tend to explain changes in the processes governing water infiltration in the soil (Atta et al., 2022; Mamkagh et al., 2022; Abdel-Sattar et al., 2023). However, wood ash has potential as a soil amendment, as recently demonstrated in studies conducted by Romdhane et al. (2021) and Moragues-Saitua et al. (2017); with the application of ash to different soils, changes in saturated hydraulic conductivity, soil water retention, and water infiltration were observed. It is important to note that the positive effects of adding different doses of wood ash from plant biomass can improve the productivity of the crops to be grown in these soils.

The summary of the analysis of variance for cumulative infiltration (Ia) as a function of application management and wood ash doses is shown in Table 3. There was a significant effect at the $p \leq 0.01$ using the F test, of wood ash doses and the interaction between wood ash doses and Incorporated (I) and Unincorporated (NI) application management factors for Ia (Table 3). The mean cumulative infiltration was 9.74 cm.

Brasil et al. (2020) noted that, depending on its characteristics, wood ash can contain a large amount of organic matter (16.6%), making it a recognized physical soil amendment. Therefore, the addition of wood ash to the soil provides organic matter that allows for greater aggregation and cohesion between particles, making the soil more susceptible to water retention and benefiting infiltration (Klein & Klein, 2014).

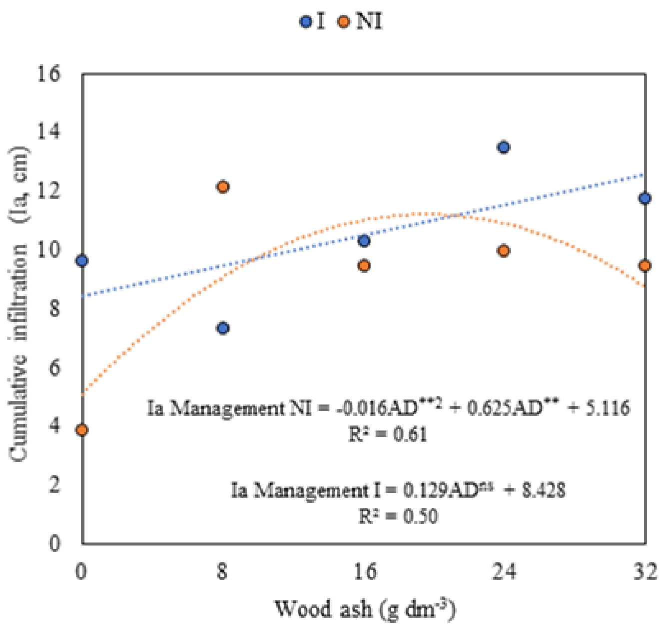
Liu et al. (2022) reported that when biochar is applied at depths greater than 10 cm, it directly affects the process of water infiltration in the soil, and when incorporation occurs in the top layers (0-10 cm) of the soil, there is greater cumulative infiltration compared to incorporation at depths of 10-20 and 20-30 cm, respectively.

Wood ash has small particles, which causes an increase in the number of effective pores in the soil, which consequently leads to an increase in water infiltration in the soil as well as in the water holding capacity of the soil due to the greater volume of micropores compared to macropores (Novak et al., 2016; Oliveira et al., 2023).

The interactions between the application management factors and wood ash dose for the variable cumulative infiltration in the Oxisol are shown in Figure 7. With the combination of wood ash and incorporated management (I),

Table 3. Summary of the analysis of variance for cumulative infiltration (Ia) of water in the soil under different application managements and doses of wood ash in an Oxisol.

Sources of variation	Degrees of freedom	F-statistics
Block	1	3.33^{ns}
Application management (AM)	1	0.32^{ns}
Ash doses (AD)	4	4.32^{**}
AM × AD	4	5.66^{**}
Error 1	1	-
Error 2	48	-
Overall average	-	9.74
CV1 (%)	-	55.61
CV2 (%)	-	31.60



I - incorporated; NI - unincorporated

Figure 7. Cumulative infiltration in Oxisol in function of wood ash doses in two application managements

there was no difference between the treatments in terms of cumulative infiltration. However, as the dose of ash increased, there was an increase in accumulated infiltration, with an increase of approximately 0.129 cm for every 1 g dm^{-3} of ash incorporated into the soil (Figure 7).

According to the regression equation for the effect of the interaction between the dose of wood ash and unincorporated management, a quadratic mathematical model was found, with the maximum cumulative infiltration occurring at a dose of 19.56 g dm^{-3} of wood ash (Figure 7). In the case of unincorporated management, in which wood ash was applied by hand, there was a decrease in the amount applied and an increase in water infiltration through the soil, which can be explained by the fact that the soil was less disturbed and the soil particles were sealed with ash.

Oliveira et al. (2023) concluded in their study that with the incorporated application, as the dose of wood ash increased, there was a reduction in the soil bulk density of the Oxisol studied. This reduction in density has a decisive influence on the increase in water infiltration in the soil, confirming what was observed in this study.

Given the different types of infiltrometers used to quantify water infiltration in the soil, as well as the equations used, it can be inferred that the alternative tension infiltrometer constructed is a viable option for measuring soil water infiltration, with a fit considered excellent by the Kostiakov equation, with a coefficient of determination greater than 0.99. It is also clear that when tested under different management conditions and wood ash doses, this instrument showed that it could be used.

The application management and the different doses of ash applied to the Oxisol influence the processes that govern water infiltration in the soil, which is reflected in different infiltration curves for each management within each dose of ash applied.

Conclusions

1. The proposed tension infiltrometer is effective and affordable for measuring water infiltration in soil under the tested management conditions.

2. The addition of wood ash to the surface favors water infiltration in a clay-textured Oxisol, regardless of the dose used, although the increase is not linear.

3. With regard to the infiltration process, the addition of wood ash in an unincorporated form is preferable.

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