ABSTRACT
The objective of this study was to evaluate the influence of biochar saturation doses on the cumulative loss of water in a Yellow Latosol typical of Central Amazonia. The experiment was conducted in a greenhouse of the National Institute of Research of the Amazon - INPA, in Manaus-AM. Biochar was used from the pyrolysis of brown urchins and a secondary forest soil. A completely randomized design with five biochar doses (0, 20, 40, 60 and 80 t ha\(^{-1}\)) was used with four replicates, each experimental unit consisting of a plastic vessel with 2500 g of soil with biochar. The observed variables were the amount of water required for soil saturation and the cumulative loss of water in seven periods (24 h, 48 h, 72 h, 96 h, 120 h, 144 h and 168 h). The water measurements required for saturation were based on dry soil and, while losses were calculated based on the subtraction of the saturated soil mass and the wet mass of each period. The biochar doses did not significantly influence the amount of water required for saturation of the studied soil. Attenuated water losses were observed with the application of 20 and 40 t ha\(^{-1}\) of biochar. The higher doses of 60 and 80 t ha\(^{-1}\) of biochar promoted the greatest accumulated losses of soil water. 

KEYWORDS: Humidity, soil, pyrogenic carbon.
biochar a partir da pirólise de ouriços de castanha e um solo de floresta secundária. Adotou-se um delineamento inteiramente casualizado, com cinco doses de biochar (0, 20, 40, 60 e 80 t ha\(^{-1}\)) com quatro repetições, sendo cada unidade experimental constituída por vaso plástico com 2500 g de solo com biochar. As variáveis observadas foram à quantidade de água necessária para a capacidade de campo e a perda acumulativa de água em sete períodos (24 h, 48 h, 72 h, 96 h, 120 h, 144 h e 168 h). As medições da capacidade de campo tiveram como base o solo seco e sua saturação completa, enquanto as perdas foram calculadas com base na subtração da massa solo na capacidade de campo e a massa úmida de cada período. As doses de biochar não influenciaram significativamente a capacidade de campo do solo estudado. Foram observadas perdas de água atenuadas com a aplicação de 20 e 40 t ha\(^{-1}\) de biochar. As doses mais elevadas de 60 e 80 t ha\(^{-1}\) de biochar promoveram as maiores perdas acumuladas de água do solo.

**PALAVRAS-CHAVE**: Umidade, solo, carbono pirogênico.

**INTRODUCTION**

Biochar known through studies in the Amazonia Dark Earth, has been evidenced in the literature as a direct contributor in the chemical, physical and biological aspects of the soil (ARCHANJO et al., 2014; LIMA et al. 2016). Due to its polycyclic aromatic chemistry, its use in soils has promoted immobilization of inorganic and organic pollutants, increased microbiological activity and greater availability of water and nutrients (LEHMANN et al., 2011).

Due to the release of volatile compounds of the biochar, micro, meso and macropores, respectively, smaller than 2.00 nm, between 2.00 nm – 50.00 nm and greater than 50.00 nm originate, which interfere in the increase of their surface area, increasing water storage in their spaces (ARCHANJO et al., 2014). This effect was verified with the use of biochar in a sandy texture plintite soil by Carvalho et al. (2014), where they obtained an increase of about 1% of water available to the plants at each T ha\(^{-1}\) of biochar.

According to Abel et al. (2013), the increase in the availability of water with the use of biochar is linked to a decrease in the soil density that ranged from 1.00 to 5.00%, which promotes the elevation of the number of soil pores and can be useful in soils with high tendency to compaction, such as occurred in the Amazonian oxisoil and ultisool. According to Ulyett et al. (2014) and Hagemann et al. (2016), the porous nature of biochar may influence the increase of water retention in soils, especially in sandy soils, which due to the presence of coarser granulometry, the loss of water is more pronounced.

Some studies have found an increase in the water available to the plants, but it is not means an increase in productivity (CARVALHO et al., 2014), while others observed the increase of water retention in soils with the application of biochar (SUN, LU, 2014). Other studies have demonstrated the lack of positive results in this aspect (MAJOR et al., 2012; JEFFERY et al., 2015), while others have observed limitations in water availability (TEIXEIRA et al., 2017).

The investigation of contradictory results induces the continuous study in questions related to this. Thus, our objective with this work was to verify the influence of the biochar doses on the amount of water required for the saturation and the loss of water in domestic conditions, using the yellow oxisoil in the central region of the Amazon.

**MATERIAL AND METHODS**
The present study was carried out in the V8 Campus / agronomic sciences department of the National Institute for Amazonian Research - INPA (3 ° 5’29”S and 59 ° 59’37” W) in the Manaus - AM. The climate of Manaus is classified as Am (Tropical Humid and subhumid) with average annual temperature of 27.4 ºC (PEEL et al., 2007).

A completely randomized design was used, consisting of five doses of biochar made from Brazil nut (0, 20, 40, 60 and 80 t ha⁻¹), totaling five treatments, four repetition and 20 experimental units. The biochar was obtained through the biocarbonization of the meso and exocarp of Brazil nuts shells collected of the company Agropecuária Aruanã SA. The process of pyrolysis was done in the furnace of refractory brick of 20 kg of biomass capacity of the Cellulose and Charcoal Laboratory of the Coordination of Research on Forest Products (CPPF) of INPA. The nuts shells were subjected to a carbonization temperature of 500 ºC for 30 minutes and subsequent cooling for 24 h. Then the biochar was sieved in a 2.00 mm mesh.

Subsequently, the biochar was homogenized with the soil and placed in the pots. The oxisoil was collected in August 2014 from the subsurface layer (20-40 cm) of a secondary forest with approximately 30 years old of the Experimental Station of Tropical Fruits of INPA (02º 32’12”S 60º 02’22” W). The chemical and physical soil analysis were done in the Soils and Plants Thematic Laboratory (LTSP) of INPA. The result of the analysis was: pH = 3.9; K (cmol, dm⁻³) = 0.02; Ca (cmol, dm⁻³) = 0.05; Mg (cmol, dm⁻³) = 0.08; Al (cm⁻³, dm⁻³) = 0.90; P (mg dm⁻³) = 0.99; Fe (mg dm⁻³) = 251.4; Zn (mg dm⁻³) = 1.13; Mn (mg dm⁻³) = 0.57; H + Al (cm⁻³, dm⁻³) = 1.65; T (cmol, dm⁻³) = 1.80; t (cmol, dm⁻³) = 1.05; v (%) = 8.33; m (%) = 85.7; Clay (g kg⁻¹) = 418; Sand (g kg⁻¹) = 432; Silt (g kg⁻¹) = 150. The soil texture was classified as sandy-loam or medium-textured. The average soil studied is 1.03 g cm⁻³. The permanent wilting point was not determined in this study due to the lack of plants as an object.

The experimental units consisted of pots with 2.5 kg of capacity, were the mixture soil and biochar was added. The average greenhouse temperature (31ºC) during the seven days of evaluation were monitored through digital thermometer. The calibration of the vessels with the soils was carried out with the addition of a digital scale, discounting their weight. Subsequently, 2.5 kg (2.500 g) of the soil plus biochar was weighed and saturated with water until percolation or run-off occurred. After this period, the pots were submitted to a period of 10 hours of continuous natural drainage with the same soil type (Oxisoil).

The first measure was established 10 hours after the drainage stoppage, the soil wet mass was measured after 24, 48, 72, 96, 120, 144 and 168 h, based on the amount of water required for saturation at zero hour (Table 1). The loss of water was estimated according to the following equation, based on the methodology of Casasroli and Lier (2008):

\[ PA(t) = (MSat - MU(t)) \]

Being:

PA (t): Loss of water (g) according to times 24, 48, 72, 96, 120, 144 and 168 h;

MSat: Soil mass saturated;

MU (t): Wet soil mass (g) according to the times 24, 48, 72, 96, 120, 144 and 168 h.
The data were submitted to analysis of variance by the Assistat program 7.7 and significant means were compared by the Tukey test at 5% probability. In addition, regression analyzes were performed for the studied hours of water loss.

RESULTS AND DISCUSSION

As observed in Table 1, the amount of water required for soil saturation ranged from 805 to 839 cm³ of water. There was no significant difference between the saturation water and the increase of the doses of biochar in the vessels. There was no significance (p> 0.05) in the regression analysis (Figure 1), however, there is a trend of water elevation required for soil saturation and bio-carbon doses up to 60 T ha⁻¹.

### TABLE 1. Water required for saturation of atypical Yellow Oxisoil of Amazon submitted the addition of biochar.

<table>
<thead>
<tr>
<th>Biochar (t ha⁻¹)</th>
<th>Dry weight (g)**</th>
<th>Saturated weight (g)</th>
<th>Saturation Water (cm³)***</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.500</td>
<td>3.305</td>
<td>805 a</td>
</tr>
<tr>
<td>20</td>
<td>2.500</td>
<td>3.318</td>
<td>818 a</td>
</tr>
<tr>
<td>40</td>
<td>2.500</td>
<td>3.340</td>
<td>840 a</td>
</tr>
<tr>
<td>60</td>
<td>2.500</td>
<td>3.365</td>
<td>865 a</td>
</tr>
<tr>
<td>80</td>
<td>2.500</td>
<td>3.339</td>
<td>839 a</td>
</tr>
</tbody>
</table>

**C. V. 1,26

* Means followed by the same letters were not significant by the Tukey test at 5%.
** Coefficient of variation. *** Weight of soil only

![Regression analysis of the biochar on the substrate and the water required for soil saturation](image_url)

FIGURE 1. Regression analysis of the biochar on the substrate and the water required for soil saturation

We observed a significant effect, except for 24 h, of biochar doses on accumulated water losses in all evaluated periods (48 h, 72 h, 96 h, 120 h, 144 h and 168 h) (Table 2). At 24 h of observation, even without significance, it was the period that the water losses, either by evaporation or percolation were more accentuated, ranging from 64 cm³ to 71.5 cm³. According to Teixeira et al. (2017), the values of available water and readily available water plants are higher in biochar produced in the range of 500 °C to 550 °C, temperature used in the present work.
For the evaluated periods of 48, 72 and 96 h, accumulated water loss developed a similar pattern in response to all biochar applied (table 2). In both cases, the doses of 20 and 40 t ha\(^{-1}\) of biochar provided the lowest water losses, comparing with the control (0 t ha\(^{-1}\) of biochar) and also with the highest doses, 60 and 80 t ha\(^{-1}\) of biochar. The increase biochar particles in the substrate seems to directly influence the loss of water in the soil. For wood and bamboo biochars, Teixeira et al. (2017) verified from 64 to 70% of macropores (> 50 nm), being these responsible for the volume of water occupied when saturated, it could be an explanation for the behavior observed for the biochar of Brazil Nut shells.

**TABLE 2.** Cumulative loss of water by evaporation or percolation for seven days in Amazonian Oxisoil plus biochar doses.

<table>
<thead>
<tr>
<th>Evaluation Period</th>
<th>Biochar (t ha(^{-1}))</th>
<th>24 h</th>
<th>48 h</th>
<th>72 h</th>
<th>96 h</th>
<th>120 h</th>
<th>144 h</th>
<th>168 h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm(^{-3})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>*64.0 a</td>
<td>130.5 bc</td>
<td>198.0 bc</td>
<td>255.0 bc</td>
<td>294.0 bc</td>
<td>332.0 bc</td>
<td>364.0 b</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>62.0 a</td>
<td>126.5 c</td>
<td>194.0 c</td>
<td>248.5 c</td>
<td>287.5 bc</td>
<td>325.5 bc</td>
<td>358.5 b</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>63.0 a</td>
<td>125.0 c</td>
<td>192.5 c</td>
<td>248.5 c</td>
<td>282.5 c</td>
<td>322.5 c</td>
<td>356.0 b</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>71.5 a</td>
<td>146.0 a</td>
<td>216.5 a</td>
<td>272.0 a</td>
<td>314.5 a</td>
<td>353.0 a</td>
<td>389.0 a</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>70.5 a</td>
<td>141.0 ab</td>
<td>208.0 ab</td>
<td>264.0 ab</td>
<td>302.5 ab</td>
<td>339.5 ab</td>
<td>373.5 ab</td>
<td></td>
</tr>
<tr>
<td><strong>C.V</strong></td>
<td>8.49</td>
<td>4.29</td>
<td>2.52</td>
<td>2.18</td>
<td>2.41</td>
<td>2.24</td>
<td>2.32</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letters were not significant by the Tukey test at 5%. ** Coefficient of variation.

According to Carducci et al. (2011), typical tropical soils such as the oxisoil has a bimodal distribution of the pores, that is, they have a good infiltration character of water transmission through the pores mainly due to their textured classes, varying from loamy to very clayey. In this way, it is hypothesized that the biochar in high amounts (> 60 t ha\(^{-1}\)) damages the natural functioning of Amazonian soils and that in doses below 40 t ha\(^{-1}\), do not promote a clearly necessary.

Authors such as Novak et al. (2012), Carvalho et al. (2014) and Sun and Lu (2014) evidenced the increase in available water in the soil, as well as the improvement in its retention with biochar application. Studies conducted by Major et al. (2012) and Jeffery et al. (2015) did not show significant results with the application of biochar in the soil as an alternative of water use efficiency. It is believed that the influence of the use of biochar in the increase of water availability is related to the applied dose and the morphological characteristics of the soil, such as mineralogy and granulometry (TEIXEIRA et al., 2017). It has been shown that the soils most responsive to the application of biochar are those with textures that vary from sandy-loam to sandy, due to high retention by biochar (GUL et al., 2015; TEIXEIRA et al., 2017).

There was similar effect of water loss after 120 and 144 h evaluation. For 0 and 20 t ha\(^{-1}\) of biochar, the losses were significantly equal and the lowest losses observed were in the application of 40 t ha\(^{-1}\). As in the other evaluated periods, the highest losses were concentrated in the application of doses above 60 t ha\(^{-1}\) of biochar. For 168 h of evaluation, there was a similar effect of accumulated loss of water by pots to 0, 20 and 40 t ha\(^{-1}\) of biochar and the highest losses of 60 t ha\(^{-1}\). Such a result, especially at the end of observations (168 h), may indicate that application of biochar, even at low doses, does not promote satisfactory water effects.
When observing figure 2, we can see the quadratic tendency in all evaluated periods of cumulative water loss. There was no significant regression between any of the evaluation periods studied (24 h, 48 h, 72 h, 96 h, 120 h, 144 h and 168 h).

**FIGURE 2.** Regression analysis of cumulative water loss (Cm$^{-3}$) with increasing doses of biochar in the substrate as a function of the number of hours (24 h, 48 h, 72 h, 96 h, 120 h, 144 h and 168 h)
In all the evaluated periods, it is possible to notice the decrease of the cumulative loss of water until the application of 40 T ha⁻¹ (Figure 2). Such behavior can be reinforced by studies by Abel et al. (2013), in which the addition of 1 to 5% of biochar the substrate promotes an increase of the pores and can increase the points of loss of water by evaporation of the soil. At the higher doses (> 3% in the substrate - 60 T ha⁻¹) a stable water loss behavior was observed, with the lowest values being observed in all evaluated periods. The increase of the water retention in such conditions can be explained by the increase in the volume of water trapping points with the increase of the occupation in the solid phase of the soil, provoking, among others, the smaller leakage of water molecules through the pores (ULYETT et al. al., 2014).

According to Gray et al. (2014) and Jeffery et al. (2015), hydrophobicity, that is, repulsion by water molecules by newly produced biochar may indicate the cause of many results that do not point to a beneficial effect in their use for this purpose as well as in this work, such as the increase in water retention. However, it is possible that this characteristic is attenuated with the breakdown of hydrophobic compounds with the *aging* of the biochar (TEIXEIRA et al., 2017). Even with contradictory results, the addition of biochar in the soil still denotes promising responses, such as better soil structuring and decreased soil density (BUBICI et al., 2016; TEIXEIRA et al., 2017). In addition to increased crop productivity and soil fertility (CARVALHO et al., 2014).

**CONCLUSION**

The application of biocarbon to yellow oxisols typical of Amazonia did not result in significant changes in the amount of water required for saturation of this soil under greenhouse conditions. The loss of water by evaporation or percolation was attenuated with the application of 20 and 40 t ha⁻¹ of biochar, while the doses of 60 and 80 t ha⁻¹ of biochar allowed the cumulative losses of water.

**REFERENCES**


