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HYDROPHILIC POLYMER CHANGES THE WATER DEMAND IN THE IMPLEMENTATION OF A DWARF CASHEW ORCHARD

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KEYWORDS

Anacardium occidentale L., climate change, adaptation, soil amendment, biochar.

ABSTRACT

Important losses of dwarf cashew seedlings during the establishment of orchards in the Brazilian semiarid are related to the relatively short rainy season. This study aimed to evaluate biochar and hydrophilic polymer as soil amendments to increase water retention and reduce plant death in the first year. An experiment was conducted at the Curu Station, Paraipaba, CE, Brazil, using the clone BRS 226. The experimental design consisted of randomized blocks, with amounts of 0.5, 1.0, 2.0, and 4.0 kg of cashew wood biochar and 20, 40, 60, 80 g of hydrophilic polymer applied per pit, as well as a control treatment (no soil amendment). Seedlings were submitted to an irrigation regime to avoid water stress (5 L water seedling^{-1} when the tensiometer installed at a depth of 0.15 m reached 60 kPa). The variables of plant development number of leaves, plant height, stem diameter, and canopy diameter were evaluated up to 374 days after transplanting to the field. The analysis of variance showed no treatment effect on plant development. However, minimum water consumption was observed when 29.56 g of hydrophilic polymer was applied per pit, providing 100.0% seedling survival.

INTRODUCTION

The introduction of dwarf cashew was essential to reduce the deforestation, with contributions to the environment and restructuring of the Caatinga biome domain (Alencar et al., 2018). Cashew is a native species to the Northeast region of Brazil considered tolerant to water stress, but seedling losses that reach up to 50% can be observed when planting orchards in years of irregular precipitation. Despite being a drought-tolerant species, water is considered one of the main limiting factors for the cashew crop (Carr, 2014). Soil and water conservation techniques in areas with limited irrigation structure may increase cashew yield and, consequently, producer income.

The cashew crop is commonly developed on Quartzipsamment soils, which have low cation exchange capacity and water retention (Xavier et al., 2013). Measures for soil and water conservation in cashew fields, such as the use of buried coconut shell, increase crop yield (Rejani & Yadukumar, 2010) due to increased soil moisture retention. According to Sajeev et al. (2014), the use of soil and water conservation technologies has a high correlation with cashew production in India.

Biochar is the product from the incomplete combustion of organic materials, and its addition to agricultural soils has been proposed to increase the water retention capacity, mitigate the effects of climate change by increasing soil carbon sequestration and reducing greenhouse gas emissions and improve soil fertility (Karhu et al., 2011). Elshaikh et al. (2017) reported positive effects of biochar on the tolerance of okra plants to soil salinity, while Pimenta et al. (2019) reported that the use of biochar from cashew wood resulted in an increased pH and potassium, phosphorus, and sodium contents. Kammann et al. (2011) reported an increase in soil-water retention capacity when using biochar, giving plants a high tolerance to drought.

In addition, Novotny et al. (2015) reported increased water retention for most of the different types of tested biochars. Omondi et al. (2016) pointed out an increase in available water as the most relevant effects of adding biochar to soils. Likewise, Lim et al. (2016) indicated the effect of reducing hydraulic conductivity in coarse-textured soils, Moragues-Saitua et al. (2017), Batista et al. (2018), and Villagra-Mendoza & Horn (2018) reported the effect of biochar porosity on soil water retention, while Gonzaga et al. (2019) reported an increase in water use efficiency.

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One of the strategies reported to increase water use efficiency is the deficit irrigation in dense planting systems (Mangalassery et al., 2019), but Güereña et al. (2019) reported that the positive effects of biochar are conditioned to the absence of water stress. Mao et al. (2019) reported that biochar addition increased water retention capacity in hydrophobic soils with low total organic carbon content. Verheijen et al. (2019) confirmed an increase in water retention for sandy and sandy loam soils. Danso et al. (2019) reported increased water productivity in corn grown under the application of biochar made from rice husk. Therefore, the use of biochar to improve soil physical-hydraulic characteristics has become an alternative for fruit crop producers.

The hydrophilic polymer is another soil amendment that has been used to retain water in the soil. Sarvas et al. (2007) reported that hydrophilic polymer application in the preparation of pine seedlings caused an improvement in the survival rate by 19%, with the best performance when it was applied in the pit. Marques et al. (2013) reported that the use of hydrophilic polymer at a dose of 2 g per polyethylene bag as a substitute for irrigation provided coffee seedlings of the same quality as those irrigated. Noumura et al. (2019) applied this polymer to papaya seedlings and observed better development. Also, Kraisig et al. (2018) obtained maximum yield when testing this product in the corn/oat system.

Periodic supply of cashew firewood can be found in the producing regions, which is related to the pruning required by the crop. This material could be used by producers due to the potential benefits reported in the literature. Thus, this study aimed to evaluate the application of cashew wood biochar and hydrophilic polymer as water retention agents and the increase of plant survival in the implementation of cashew orchards.

MATERIAL AND METHODS

This study was carried out from January 2016 to January 2017 at the Curu experimental field, belonging to Embrapa Tropical Agroindustry, located in the municipality of Paraipaba, CE, Brazil. The regional climate is Aw (tropical with a dry winter), according to Köppen classification, and C1 (dry subhumid), according to Thornthwaite classification (Muniz et al., 2017). The annual precipitation is around 1,000 mm, and the rainy season is concentrated from February to May.

The result of the soil analysis in the experimental area showed a medium to sandy texture at the 0–30 cm layer (805 g kg^{-1} of sand, 76 g kg^{-1} of clay, and 119 g kg^{-1} of silt) and a medium texture at the other layers, with characteristics of a Ultisol (Embrapa, 2013). The maximum organic matter content was 6.4 g dm^{-3}, pH varied from 5.6 to 6.3 between the layers, cation exchange capacity from 31.3 to 64.8, and maximum sum of bases of 62% at the most superficial soil layer.

Seedlings of the clone BRS 226 of dwarf cashew with 120 days of age from sowing or 60 days after grafting were prepared at the Pacajus Experimental Station belonging to Embrapa Tropical Agroindustry. Pits with a circumference of 0.40 m and depth of 0.40 m were drilled using a drill attached to the Massey Ferguson 275 tractor. These pits were fertilized with 80 g pit^{-1} of dolomitic limestone, 400 g pit^{-1} of single superphosphate, 50 g pit^{-1} of potassium chloride, and 50 g pit^{-1} of FTE BR 12. Also, the seedlings received 130 g pit^{-1} of urea and 100 g pit^{-1} of potassium chloride split into two monthly applications from 45 days after planting. A total of 216 cashew seedlings of the clone BRS 226 were planted with a spacing of 8 m between rows and 4 m between plants, totaling 12 rows with 20 plants per row of 50 m.

The orchard was implemented under a randomized block design, with nine treatments and four replications with six plants per plot. The treatments T1, T2, T3, and T4 corresponded to the application of cashew wood biochar at planting time, with amounts of 0.5, 1.0, 2.0, and 4.0 kg per pit, respectively. The treatments T5, T6, T7, and T8 corresponded to the application of the Hydroplan® hydrophilic polymer, also during planting time, at doses of 20, 40, 60, and 80 g per pit, respectively. Moreover, the treatment T9 corresponded to the control without the application of biochar or hydrophilic polymer.

The result of the chemical analysis of the cashew wood biochar is shown in Table 1. Water retention capacity, determined in a Hainnes funnel at the field capacity (10 kPa), was 0.53 and 0.57 g g^{-1} for particle size diameters of 4 and 2 mm, respectively (Gondim et al., 2018). Both the biochar and the polymer were applied dry and at the pit.

TABLE 1. Chemical analysis of the cashew wood biochar.

Macronutrient (g kg^{-1})						Micronutrients (mg kg^{-1})				(%)		dS/m
N	P	Mg	Na	S	K	Cu	Fe	Zn	Mn	C_{total}	pH	EC
3.5	1.2	4.0	1.4	1.6	7.3	2.0	363	16	42	62.5	7.26	0.32

After planting, cashew seedlings were subjected to a rescue irrigation regime, in which water was applied with a tank coupled to a tractor. An amount of water of 5 L plant^{-1} was estimated each time the tensiometer installed at 0.15 m depth reached 60 kPa to avoid water stress, considering an ETo of 49 mm week^{-1}, Kc of 0.48, efficiency of 50%, and plants occupying an area of 0.1 m^2. The tension of 60 kPa corresponded to 0.15 cm^3 cm^{-3} of water content in the soil, while the field capacity was 0.38 cm^3 cm^{-3}.

Monthly precipitations (mm) from January 20, 2016, to January 31, 2017, at the experiment site were concentrated from February to May (rainy season). Climate variables were measured by a Campell® HOBO U30 automated weather station and consisted of precipitation (mm), maximum and minimum temperatures (°C), relative air humidity (%), solar radiation (MJ m^{-2} day^{-1}), wind speed (km day^{-1}). The total rainfall during the seedling development was 1,085.5 mm, while the reference evapotranspiration, estimated with the climate variables measured by the automated weather station using the Penman-Monteith method, was 1,451 mm, with the need for water supply in the orchard.

In addition to seedling survival, the biometric variables evaluated consisted of the number of leaves per plant (NLPP), plant height (PH), stem diameter (SD), and canopy diameter (CD). Five plants were evaluated per plot. The variables NLPP and PH were evaluated monthly during the first six months and every two months for the remaining period. Moreover, the variables SD and CD were evaluated at the end of the experiment, i.e., at 374 days after transplantation (DAT).

Analyses of variance were performed using the GLM procedure of the statistical software SAS/STAT® version 9.3 to evaluate the effect of treatments on the response variables. The water demand for each treatment was monitored by the number of irrigations, considering the water from the accumulated precipitation, which was the same for all treatments (1,085.5 mm). The free software R version 3.6.3 was used to adjust regression models to evaluate the effects of doses of the applied soil amendments (biochar or hydrophilic polymer) on the volume of water used for irrigation.

RESULTS AND DISCUSSION

The means of the biometric characteristics of seedlings from 60 to 374 days after transplanting (DAT) to the field for different treatments are shown in Tables 2 and 3. A significant difference was observed only for the number of leaves per plant at 90 and 120 DAT (Table 2). No statistical difference was found after this period (F-test, p>0.05). The number of leaves varied from 9 to 13 at 60 DAT (CV = 16.6%) and from 187 to 304 at 374 DAT (CV = 27.8).

TABLE 2. Means of the number of leaves of seedlings from 60 to 374 days after transplanting under different treatments.

DAT / Number of leaves	Biochar (kg pit^{-1})				Hydrophilic polymer (g pit^{-1})				Control	
	0.5	1.0	2.0	4.0	20	40	60	80	-	CV(%)
60^{ns}	11	12	10	9	13	11	13	12	11	16.6
90*	21^{a}	20^{a,b}	15^{b}	13^{b}	21^{a}	19^{a,b}	22^{a}	18^{a,b}	20^{a,b}	19.2
120*	25^{b}	23^{b}	24^{b}	23^{b}	32^{a}	26^{b}	34^{a}	27^{ab}	27^{ab}	16.8
150 ^{ns}	45	51	44	42	55	47	62	46	49	10.2
180 ^{ns}	66	72	58	60	77	58	83	70	61	10.8
240 ^{ns}	88	82	76	91	105	79	122	93	103	13.0
270 ^{ns}	96	108	99	106	120	99	160	122	128	13.9
330 ^{ns}	139	132	118	124	164	120	204	153	163	18,9
374 ^{ns}	216	187	237	230	265	230	304	301	259	27.8

^{ns} No significance for statistical analysis using the SAS System®.

Plant height varied according to the treatments from 23.9 to 25.8 cm (CV = 6.9%) and 70.5 to 76.6 cm (CV = 11.5%) from 60 to 374 DAT (Table 3), respectively.

TABLE 3. Means of seedling height (cm) from 60 to 374 days after transplanting under different treatments.

DAT /Height (cm)^{ns}	Biochar (kg pit^{-1})				Hydrophilic polymer (g pit^{-1})				Control	
	0.5	1.0	2.0	4.0	20	40	60	80		CV(%)
60 ^{ns}	24.0	25.4	23.9	23.9	24.6	25.6	24.0	25.8	24.3	6.9
90^{ns}	28.3	32.4	29.2	28.7	31.8	32.8	32.1	32.7	31.4	12.9
120 ^{ns}	35.2	37.8	34.3	33.7	36.6	35.9	39.3	35.3	37.1	9.7
150 ^{ns}	46.8	50.0	45.6	44.8	48.7	47.9	50.6	45.2	49.4	5.1
180 ^{ns}	54.9	58.0	56.7	57.6	59.4	58.3	62.6	54.7	57.2	6.1
240 ^{ns}	65.3	63.9	63.4	66.5	65.8	63.7	67.9	59.6	66.3	4.9
270 ^{ns}	63.7	61.8	62.9	66.6	66.1	66.6	75.0	61.4	70.1	5.9
330 ^{ns}	69.5	68.2	67.8	66.0	71.6	68.3	75.1	62.2	72.0	4.8
374 ^{ns}	70.9	71.7	73.2	71.2	71.4	70.5	74.9	76.6	70.9	11.5

^{ns} No significance for statistical analysis using the SAS System®.

Stem diameter and canopy varied from 38.0 to 45.7 cm (CV = 10.4%) and canopy 81.3 to 114.6 cm (CV = 15.4%), respectively at 374 DAT (Table 4).The survival rates (Table 4) obtained from the different treatments of this study ranged from 70.8 to 100.0% (CV = 10.3%), which is considered satisfactory compared to the results found by Serrano et al. (2015) in the semiarid region of Piauí in an eight-year-old BRS 226 orchard under the rainfed regime. These authors observed survival rates from 75 to 86%, with a mean of 79.63% (CV = 16.1%), depending on the used rootstock. In the present study, most of the observed values were higher, which can be attributed to the irrigations, as the time of exposure of plants to water stress was minimized (Table 5).

TABLE 4. Means of biometric characteristics and survival of seedlings at 374 days after transplanting under different treatments.

Biometric characteristics	Biochar (kg pit^{-1})				Hydrophilic polymer (g pit^{-1})				Control	
	0.5	1.0	2.0	4.0	20	40	60	80	-	CV(%)
Stem diameter (mm)^{ns}	38.0	39.4	40.1	41.6	42.2	40.7	45.1	45.7	41.1	10.4
Canopy (cm)^{ns}	86.6	81.3	85.9	94.1	93.4	89.9	114.6	103.4	91.1	15.4
Survival (%)	91.7	87.5	87.5	70.8	100.0	95.8	83.3	100.0	95.8	10.3

^{ns} No significance for statistical analysis using the SAS System®.

The adjustment of the regression model that describes the relationship between the dose of biochar (kg) and the volume of water applied per plant (L) during the 12 months of irrigation was not significant (p>0.05). Therefore, the reduction in water consumption by the additive effect of inputs could not be consistently explained (Table 5). Thus, further experiments with a high number of treatments or replications can be planned, considering the costs associated with increased sampling. Vinh et al. (2015) applied rice husk biochar to six-year-old cashew trees and reported an increase in soil moisture only at the application depth (0.20 m). In this case, the desired effect may require a new application as seedlings deepen their root system.

TABLE 5. Number of irrigation operations and annual water volume applied per treatment.

	Biochar (kg pit^{-1})				Hydrophilic polymer (g pit^{-1})				Control
Variable	0.5	1.0	2.0	4.0	20	40	60	80	-
Water volume (L)	70	70	90	150	55	55	125	150	120
Irrigation number	14	14	18	30	11	11	25	30	24
Cost/ha (R$1.00 in 18.09.01)*	700.00	700.00	900.00	1,500.00	550.00	550.00	1,250.00	1,500.00	1,200.00

(*) Based on the cost of R$ 100.00 per hour, including tractor driver.

A quadratic regression model (R^2 = 0.99, p = 0.01054, Figure 1) was adjusted between the amount of hydrophilic polymer (zero to 60 g) and the water volume applied during the 12 months of irrigation. The minimum water consumption (46 L plant^{-1}) corresponded to the dose of 29.5 g pit^{-1} of hydrophilic polymer per plant. The control treatment, without hydrophilic polymer, had water demand similar to the dose of 60 g of the hydrophilic polymer, but higher than the demands for doses of 20 and 40 g pit^{-1}. Water demand increased together with higher polymer doses of 29.5 g pit^{-1}, possibly because the moisture is retained in the polymer and less available to plants at the root zone. The treatment corresponding to the dose 80 g was excluded from the adjusted model because part of the applied polymer was expelled to the soil surface during the experiment due to intense rainfall, suggesting an excessive amount. Therefore, the expelled amount started to not respond to its additive effect due to this occurrence.

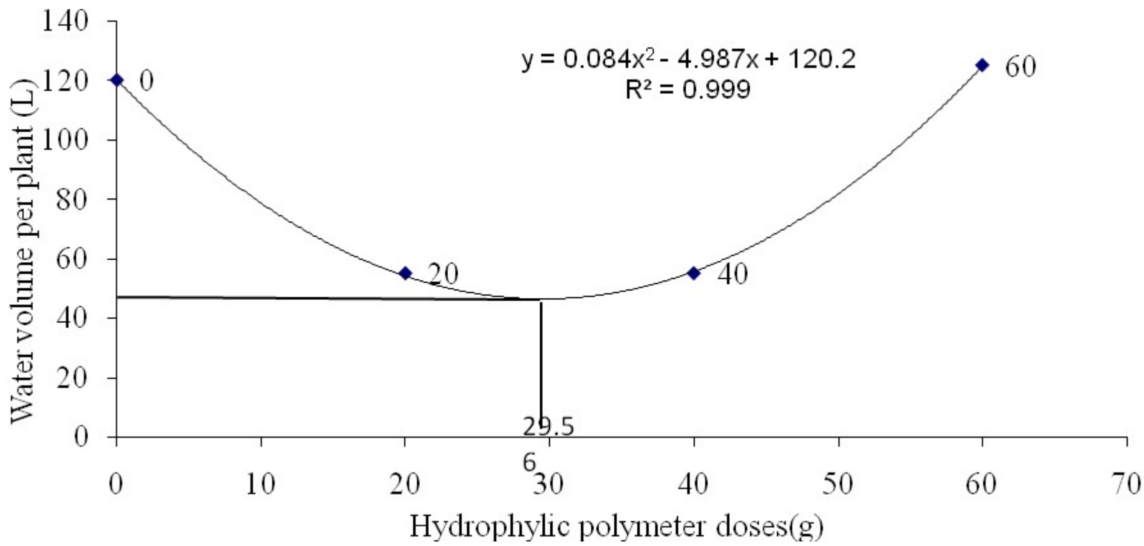


FIGURE 1. Adjusted quadratic model (p = 0.01054) and p of the t-test of equation coefficients (x^2: 0.01054), (x: 0.01116), and (intercept: 0.0057) to describe the relationship between the dose of hydrophilic polymer (kg) and volume of water applied per plant (L) in 12 months of rescue irrigation in Paraipaba, CE, Brazil.

Several studies have been developed with seedlings and plants on the application of high doses of hydrophilic polymers, but they have not found the expected positive effects. Nomura et al. (2019) worked with papaya seedlings grown in plastic bags and reported a positive effect on the biometry of plants when using 4 and 6 g of the hydrophilic polymer. Its increased concentration led to a decrease in the evaluated parameters, while a higher concentration interfered negatively with seedling growth. Tatagiba et al. (2019) reported that the polymer negatively affected the rooting of eucalyptus cuttings and survival of plants as the water depth applied on the substrate decreased, while the increasing hydrophilic polymer dose showed no increase in the substrate moisture. Kraisig et al. (2018) demonstrated an optimal level of concentration and decreased performance due to an increase in the polymer dose, explained by regression and surface response. Dranski et al. (2013) reported that doses above the recommended had a reduction effect on seedling growth under the conditions of western Paraná. Gervásio & Frizzone (2004) reported that excellent results obtained under laboratory conditions, mainly in terms of absorption and reabsorption, are not the same when using the soil amendment mixed with the substrate. The activity of hydro-absorbent polymers is reduced for water retention when added to an organic substrate, which may be due to the lack of free water in the substrate, limiting its expansion.

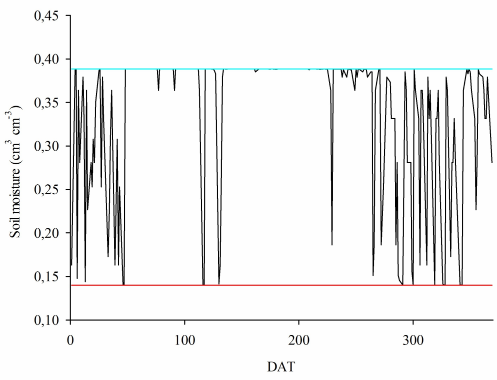
The number of irrigation operations per treatment was lower in treatments with 20 and 40 g of polymer, demonstrating that treatments with lower demand of water volume (55 L) had fewer irrigation operations, i.e., 11 irrigations (Table 5). The lowest annual operations cost of using rescue irrigation represents approximately 46% of the total spent on the control treatment. This cost reaches R$ 1,716.00 annually because it is currently recommended to apply 25 L water week^{-1} to each seedling, being higher than all the studied treatments. In this case, the annual consumption represents 800 L water seedling^{-1} in eight months of irrigation in the case where precipitations around the mean occur during the rainy season (February to May).

Variations in the soil moisture content of all treatments at the 0–0.30 m soil layer are shown in Figure 2, resulting from readings of tensiometers installed at a depth of 0.15 m. The critical moisture of 60 kPa was adopted to start rescue irrigation of 5 L plant^{-1} in the nine applied treatments over the 374 days after transplanting (DAT). Soil moisture values on the Y-axis varied from 0.15 (60 kPa) to 0.38 cm^3 cm^{-3} at the field capacity, equaling the minimum soil moisture content that occurred in each treatment. Treatments with the highest frequency in which soil water content reaches 0.15 cm^3 cm^{-3} are related to higher water demand and, therefore, more frequent irrigation operations.

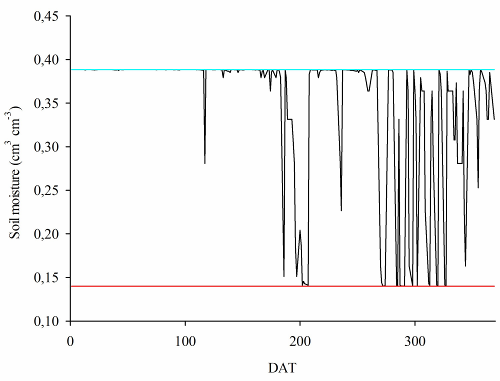
Although soil moisture tension did not exceed 60 kPa on most days, as planned, soil moisture varied between the different treatments, notably in treatments with 4 kg of biochar and 80 g of polymer (Figure 2), which corresponded to the treatments with the highest doses of biochar and polymer, respectively. In this sense, these treatments had their moisture close to 60 kPa more frequently, corroborating with the thesis that soil amendments at high amounts retain water and become it less easily available to plants, thus requiring a higher frequency of rescue irrigation (Table 5).

Treatments with 0.5 kg of biochar and 20 g of polymer demanded the least number of irrigation operations (Table 5), with the lowest levels of biochar and hydrophilic polymer applied, respectively, being able to maintain moisture available to plants for a longer time. The treatment with 40 g of polymer provided higher available soil moisture with the same amount of water than the treatment with 20 g of polymer, but with higher amounts of soil amendments. Treatments with 2.0 and 4.0 kg of biochar, 60 and 80 g of hydrophilic polymer, and the control demanded a higher irrigation frequency to maintain the moisture tension below 60 kPa relative to the treatments of 0.5 and 1.0 kg of biochar and 20 and 40 g of polymer (Table 5 and Figure 2).

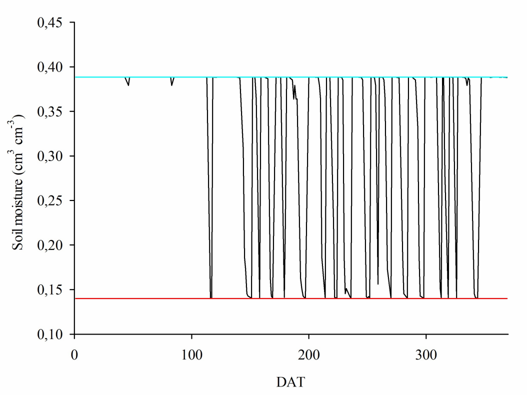
Both biochar and polymer remained active in terms of their water retention capacity throughout the monitoring period (Figure 2), which can be very useful in a semiarid region that has a dry period from seven to eight months. The obtained results showed that doses of 20 and 40 g of hydrophilic polymer favor the soil moisture conservation, which may minimize the mortality of cashew plants in the first year after planting in the field.



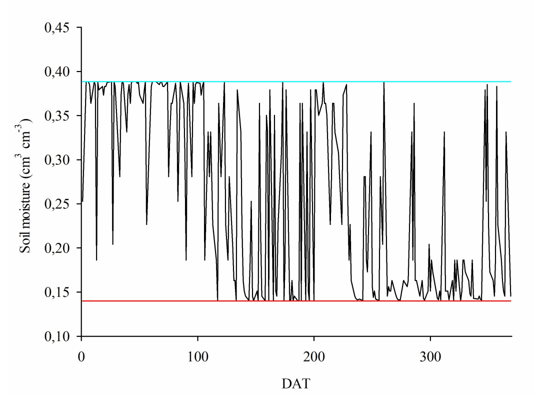
A. 0.5 kg biochar per pit



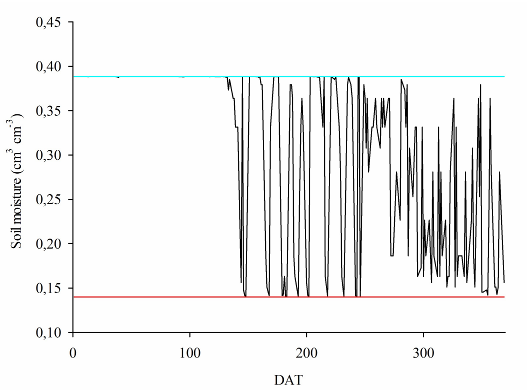
B. 1.0 kg biochar per pit



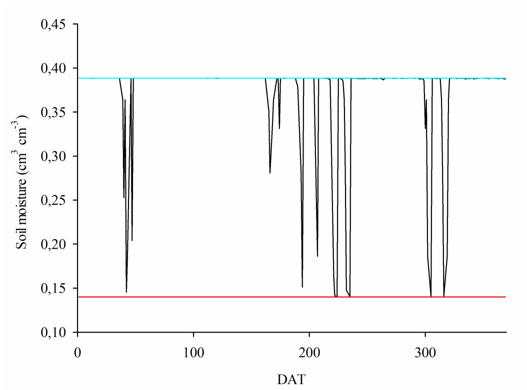
C. 2.0 kg biochar per pit



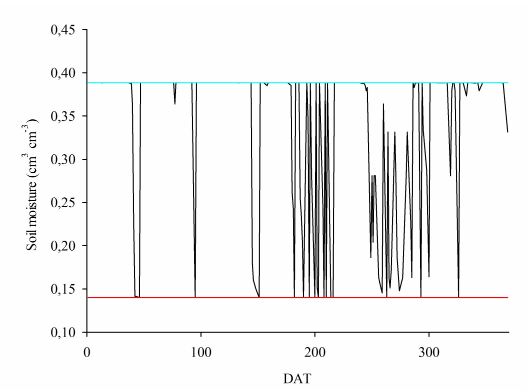
D. 4.0 kg biochar per pit



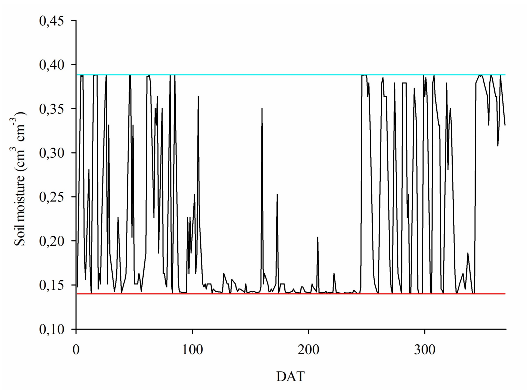
E. 20 g hydrophilic polymer per pit



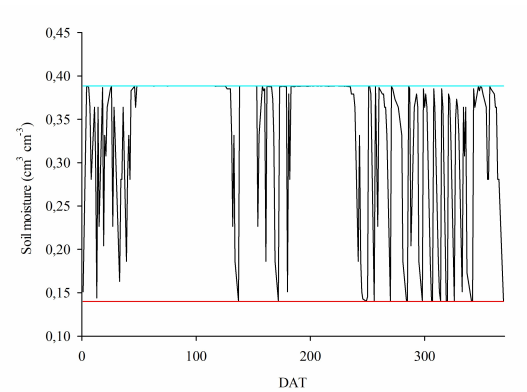
F. 40 g hydrophilic polymer per pit



G. 60 g hydrophilic polymer per pit



H. 80 g hydrophilic polymer per pit



I. Control

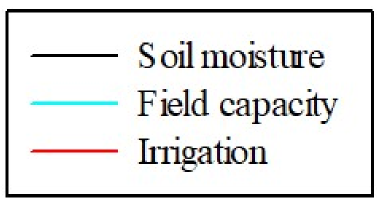


FIGURE 2. Effect over time of different doses of biochar and hydrophilic polymer on the variation of soil moisture content (cm^3 cm^{-3}) at a depth of 0.15 m for different treatments. A. 0.5, B. 1.0, C. 2.0, and D. 4.0 kg of biochar pit^{-1}; E. 20, F. 40, G. 60, and H. 80 g of hydrophilic polymer pit^{-1}; and I. Control up to 374 DAT in Paraipaba, CE, Brazil.

CONCLUSIONS

Biochar and hydrophilic polymer application showed no influence on the cashew seedling development during the first year after planting in the field.

The dose of 29.56 g pit^{-1} of polymer is indicated for maximizing water retention, representing a lower number of irrigation operations in the field and reducing the associated costs and higher level of plant survival.

There is a need for further research regarding the cashew wood biochar to enable consistent and substantiated indications.

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