

Effects of peat bog humic substances and organic compounds in water retention of substrates

Efeito de substâncias húmicas extraídas da matéria orgânica de turfeiras e de composto orgânico de resíduos da indústria têxtil na retenção de água

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Abstract: Peat bogs and organic compounds present high water retention capacity due to the presence of humic substances. This study aimed to quantify water retention of substrates composed by humin and humic acids extracted from peat bog and organic compound of textile industry waste. Firstly, sand was sieved and divided into fine and medium texture sand. After, the sand was blended in with both humin and humic acids, extracted from peat bogs and organic compounds, to compose further tested substrates. For that, the following proportions were performed: 100% humic substances; 75% humic substances plus 25 % sand; 50 % humic substances and 50% sand; 25% of humic substances with 75 % sand; and 100% sand. Humin is the most prevalent humic substance in both analyzed materials. There were no differences were found in water retentions for substrates with 100% fine and medium sand. Humic acids showed higher water retention when compared to humins. Additionally, humic substances extracted from peat bogs showed higher water retention related to those from organic compounds. We must highlight the substrate with 75 % humic substances and 25% sand, which the highest water retentions. Finally, humic acids and the humin exhibit hydrophilic properties and have potential to develop a sustainable organic water-absorbent.

Keywords: Soil organic matter, humin; humic acids; hydrophilic properties.

Resumo: As turfeiras e os compostos orgânicos apresentam elevada capacidade de retenção de água, devido à presença das substâncias húmicas. Objetivou-se quantificar a retenção de água por substratos constituídos por humina e ácidos húmicos extraídos da matéria orgânica de turfeiras e de composto orgânico de resíduos da indústria têxtil. O fracionamento da matéria orgânica foi realizado de acordo com o método preconizado pela Internacional Humic Substances Society (IHSS). A areia foi separada por peneiramento em areia fina e areia média, que foram misturadas com as duas substâncias húmicas, humina e ácidos húmicos, provenientes de turfeira e de composto, para confecção dos substratos testados, nas seguintes proporções: 100 % de substância húmica; 75 % de substância húmica e 25 % de Areias; 50 % de substância húmica e 50 % de Areias; 25 % de substância húmica e 75 % de Areias e 100% de Areias. A tensão com que a água estava retida nos substratos foi determinada com o auxílio do extrator de Richards nas tensões de retenção de água de 0 (capacidade máxima de retenção de água); 10; 100; 300; 500 e 700 kPa em três repetições. Os dados foram submetidos à análise de variância e suas médias foram testadas pelo teste Tukey ($p < 0,05$). A humina é a substância húmica que predomina amplamente no composto orgânico de resíduos de indústria têxtil e na turfeira. Não foram encontradas diferenças significativas na retenção de água entre os substratos com 100 % de areia fina e areia média. Os ácidos húmicos apresentaram maior retenção de água em relação às huminas e as substâncias húmicas extraídas de turfeira apresentaram maior retenção de água em relação às extraídas do composto. O substrato com areia em sua composição que apresentou as maiores retenções de água em todas as tensões foi o composto por 75 % de substâncias húmicas e 25 % de areia fina. Os ácidos húmicos e a humina apresentam hidrofília e tem potencial para o desenvolvimento de um hidrorretentor orgânico sustentável.

Palavras-chave: matéria orgânica do solo, humina, ácidos húmicos, hidrofília.

INTRODUCTION

Water retention capacity in soil is related to soil density, texture, organic matter content, predominant type of mineral clay, among other aspects (MICHELON et al., 2010). Hence, soil organic matter promotes particle aggregation (COSTA et al., 2006), increasing soil porosity, aeration and water holding capacity (BAYER & MIELNICZUK, 2008).

Peat bogs are formed by organic soils that develop and accumulate in environments with nearly 90% water and 10% solid matter of fibers, roots, leaves, flowers and seeds (IPCC, 2001.; CAMPOS et al., 2012), which may hold an water amount of four to eight times of the dry matter weight (CAMPOS et al., 2011).

In Minas Gerais State, the Espinhaço Mountains were mapped 14,287.55 ha of peat lands occupying a volume of 170,021,845.00 m³ peat bogs, what stores 6,120,167.00 tons of organic matter and 142,138,262.00 m³ of water (SILVA et al., 2013b).

The organics compounds are materials partially or totally humified (GUERRA et al., 2008; KIEHL, 1985), showing a high water retention capacity. Humic substances are prevalent in peat bog organic matter and organic compound.

The humic substances are materials are formed by humin (insoluble) fulvic acids (soluble in both acidic and alkaline), and humic acids. The last one represent the most stable reactive fraction of humified organic material, being insoluble in strongly acidic means (CANELLAS et al., 2001) and can hold up to twenty times the own mass in water (CANELLAS et al. 2005b).

In a study carried out in tropical peat bogs, Campos et al. (2011), found that humic substances tend to have different behavior in relation to water retention. In less decomposed peat bog layers, with high humin levels (Hu), retained more water than those layers in a more advanced decomposition stage with smaller amounts of humin; what suggests the humic substance influence on water retention. Humic acids (HA) showed an opposite behavior; so there is a possibility of a negative influence on water retention.

Therefore, from hypothesis that humin and humic acids influence on water retention, this study aimed to quantify water retention of substrates made by these two humic substances and extracted from organic matter of peat bogs and organic compound from textile industry waste.

MATERIAL AND METHODS

The experiment was conducted in laboratory and were used humin and humic acids extracted from organic matter of two materials: organic compound from textile industry waste and peat bogs.

The textile industry has two factories, one in Diamantina city and another in Gouvea a neighboring town, in which the monthly waste production goes around 10 tons and stored in open air. These correspond to sweeping material residues such as fibers, cotton and synthetic fabrics, which are classified as low toxicity (Class I) in accordance with Brazilian Association of Technical Standards (ABNT) standard regulation n°10,004.

Peat bogs were collected in the environmental protection area (EPA) of Pau-de-Fruta, in Diamantina (MG).

Organic compound was obtained from an open-environment composting yard at the Forest Species Propagation Center (CIPEF) in UFVJM. The mass to be decomposed (pile) underwent a slow decomposition process, in which remained naturally fermenting for approximately 180 days. Inoculants, which came into spontaneous fermentation (KIEHL, 1985), were added; as long as animal manure (cattle and quail) and woodstove sweeping ash. During that period, the pile received about three turnings a week to aerate and activate fermentation; moreover, it was sieved four times (4 mm sieve), removing parts that have not been decomposed yet.

Compound and peat bog decomposition stage was determined according to von Post scale (EMBRAPA, 2013). Before starting humic substance fractionating process, materials were sieved through a 0.1-mm sieve to remove all non-decomposed organic material. Then, chemical analysis was performed (EMBRAPA, 1999) for all evaluated materials (**Table 1**).

Table 1. Chemical and physical attributes of natural materials of peat bogs and organic compound

	pH H ₂ O	P -mg dm ⁻³	K ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H+Al -cmol _c dm ⁻³	S	t	T	m --%	V ---	Sand dag kg ⁻¹
OC	6,9	987	853	9,0	5,4	0,1	3,0	16,6	16,7	19,6	1	85	45
PB	4,3	4,6	56,9	0,2	0,1	5,6	43,1	0,5	6,1	43,6	93	1	38

OC - organic compound, PB – peat bogs, pH H₂O - relation 1:2,5; P e K⁺ - Mehlich-1 extractor; Ca²⁺, Mg²⁺ and Al³⁺ - KCl 1 mol L⁻¹ extractor; H+Al - calcium acetate 0,5 mol L⁻¹ extractor; S: Sum of Bases; t: effective cation-exchange capacity of soils; T: cation exchange capacity at pH 7; m: Aluminum saturation V: Base saturation.

Organic matter fractioning was made according to method recommended by the International Humic Substances Society (SWIFT, 1996), based on differential solubility of humic substances in alkaline and acidic means.

The material was fractionated into humin (Hu) and humic acids (HA), which remained cold at 4° C until experiment assembly. Moisture was measured through gravimetric method (EMBRAPA, 1997) to obtain Hu and HA dry mass. Hu was sieved through a 0.053-mm sieve to remove minerals, since finer fractions (silt and clay) hardly occur in both material. HA were purified with HF solution + HCl 0.5% (Schnitzer, 1982) for 24 h and centrifuged at 5,000 g. Purified samples were washed with HCl 0.1 mol L⁻¹ and transferred into 100-mL cellophane bags. Sample dialysis was performed in deionized water, which was changed three times a day until there was no conductivity raise higher than 1 µS, one hour after thereof being exchanged.

The sand was separated by sieving in medium sand (0.25 – 0.5 mm - MS), fine sand (0.1 – 0.25 mm - FS), which were mixed with Hu and HA, from peat bogs (P) and organic compound (C), to produce the tested substrates:

- **Experiment 1** - Treatments (P): substrates with 100% of Hu; substrates with 75% Hu and 25% FS; substrates with 50% Hu plus 50% FS; substrates with 25% Hu and 75% FS and substrates with 100% FS;
- **Experiment 2** - Treatments (P): substrates with 100% of Hu; substrates with 75% Hu and 25% MS; substrates with 50% Hu and 50% MS; substrates with 25% Hu and 75% MS and substrates with 100% MS;
- **Experiment 3** - Treatments (C): substrates with 100% of Hu; substrates with 75% Hu and 25% FS; substrates with 50% Hu and 50% FS; substrates with 25% Hu and 75% FS and substrates with 100% FS;
- **Experiment 4** - Treatments (C): substrates with 100% of Hu; substrates with 75% Hu and 25% MS; substrates with 50% Hu and 50% MS; substrates with 25% Hu and 75% MS and substrates with 100% MS;
- **Experiment 5** - Treatments (P): substrates with 100% of HA; substrates with 75% HA and 25% FS; substrates with 50% HA and 50% FS; substrates with 25% HA and 75% FS and substrates with 100% FS;
- **Experiment 6** - Treatments (P): substrates with 100% of HA; substrates with 75% HA and 25% MS; substrates with 50% HA and 50% MS; substrates with 25% HA and 75% MS and substrates with 100% MS;
- **Experiment 7** - Treatment (C): substrates with 100% of HA; substrates with 75% HA and 25% FS; substrates with 50% HA and 50% FS; substrates with 25% HA and 75% FS and substrates with 100% FS;
- **Experiment 8** - Treatment (C): substrates with 100% of HA; substrates with 75% HA and 25% MS; substrates with 50% HA and 50% MS; substrates with 25% HA and 75% MS and substrates with 100% MS.

Substrates were placed in PVC rings with 40 mm diameter and 30 mm height, covered on the bottom with nylon net protection to avoid material loss. Then, they were saturated for 48 hours, weighed to obtain moisture saturation point. Subsequently, samples were placed in Richards extractor distributed on three porous plates, which were set one upon the other inside the extractor (EMBRAPA, 1997).

To determine substrate mass added to each ring, we calculated Hu and HA densities (0.5 t m⁻³) and fine and medium sand (2 t m⁻³).

All substrates were stabilized in water retention at tension 0 (maximum water holding capacity); 10; 100; 300; 500 and 700 kPa in three repetitions. After the stabilization, we determined the amount of water retained for each tension by the gravimetric method.

Once saturated and adjusted in extractor plates, samples were subjected to the first tension (10 kPa) until reach equilibrium, i.e., when the extractor stop to remove water. Then, extractor was opened and substrates weighed; and the samples were again accommodated on plates inside extractor to another tension test (100 kPa) that was also applied up to stabilization. Therefore, this procedure was followed until the last working tension (700 kPa). By the end of the experiment, the substrates were dried at 105° C to constant weight to get dry matter. From these samples, we performed calculations to determine water content retained in each working tension. The total test time inside the Richards extractor lasts for 90 days, until stabilization at the highest tension of 700 kPa.

Treatments were statistically analyzed in three groups:

- G1: composed entirely of sand, where sand grain size effects were tested (fine and medium), at tensions (0, 10, 100, 300, 500 and 700 kPa) and the interaction between the two effects;
- G2: consisted of only the substrates, in which we tested the humic substance source effects (peat bog and organic compound), humic substance type effects (humic acids and humin), at the varied tensions and the interactions among these three effects;
- G3: in which we tested the effects of G1 and G2 combinations, and their levels, including effects of sand/ substrate ratio (25%, 50% and 75%). Data of the three groups were subjected to variance analysis and averages tested by Tukey test (p <0.05).

We performed 12, 24 and 144 treatments for G1, G2 and G3, respectively, totaling 180 treatments in the entire experiment. For statistical evaluation we applied a randomized block design (RBD) with three

replications, where plates of Richards extractor were the blocks (**Table 2**). The RBD was used to analyze the influence of plates and tension inside the extractor.

Table 2. ANOVA for an experiment in a randomized block design with three repetitions and 180 treatments conducted in Richards extractor

Source of variation	Degrees of freedom	Mean square	F
Blocks	2	Q ₁	Q ₁ /Q ₂₀
Treatments (All)	179	Q ₂	Q ₂ /Q ₂₀
Only sand (G1)	11	Q ₃	Q ₃ /Q ₂₀
Fine sand	1	Q ₄	Q ₄ /Q ₂₀
Tension	5	Q ₅	Q ₅ /Q ₂₀
Interaction	5	Q ₆	Q ₆ /Q ₂₀
Only Substrate (G2)	23	Q ₇	Q ₇ /Q ₂₀
Origin of Substrate	1	Q ₈	Q ₈ /Q ₂₀
Type of Substrate	1	Q ₉	Q ₉ /Q ₂₀
Tension	5	Q ₁₀	Q ₁₀ /Q ₂₀
Interaction	16	Q ₁₁	Q ₁₁ /Q ₂₀
Substrate and sand (G3)	143	Q ₁₂	Q ₁₂ /Q ₂₀
Particle size of sand	1	Q ₁₃	Q ₁₃ /Q ₂₀
% sand	2	Q ₁₄	Q ₁₄ /Q ₂₀
Origin of Substrate	1	Q ₁₅	Q ₁₅ /Q ₂₀
Type of Substrate	1	Q ₁₆	Q ₁₆ /Q ₂₀
Tension	5	Q ₁₇	Q ₁₇ /Q ₂₀
Interaction	133	Q ₁₈	Q ₁₈ /Q ₂₀
Among groups (G1, G2 e G3)	2	Q ₁₉	Q ₁₉ /Q ₂₀
Residue	358	Q ₂₀	
Total	539		

RESULTS AND DISCUSSION

Organic compound and peat bog layer were classified as fibrous and slightly decomposed material. Hu largely predominated for both materials (**Table 3**). Peat bog and Hu, which came from peat bog organic matter, presented higher levels of C comparing to the compound, which, in its turn, presented humic acids with higher amounts of C (**Table 4**).

Table 3. Organic carbon as humic acids and humin of organic compound and peat bog

Source material	Organic carbon (%) as	
	Humic acids	Humin
Compound	12,65	78,86
Peat bog	10,81	86,05

Table 4. Carbon content of the organic compound, peat bogs and their humic substances

Element	Source Material		Humic substances			
	Compound	Peat bogs	Compound		Peat bogs	
			HA	Hu	HA	Hu

C* (%)	25,41	30,26	42,76	18,10	37,33	30,43
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* Determined by the elemental analyzer CHNS. HA: Humic acids; Hu: humin

Peat bog material had strong water pH; however, it was almost neutral to the compound material. Nutrient levels of P, K, Ca and Mg, as well as SB and V values were much higher to the compound compared to peat bog, since compound was enriched with manure and ash during fermentation process (**Table 1**). Peat bog is formed by organic material accumulation of plants adapted to oligotrophic environments, which are saturated with water at all times, and low nutrient content (SILVA et al., 2009b). Value "T" was much higher for peat bog than it was for compound (**Table 1**), due to quality and organic matter content, as well as decomposition stage (**Table 4**). Increasing negative charges had a great contribution of organic matter by carbon content (CANELLAS et al. 2008), which complexes H⁺ and Al⁺³ ions (CANELLAS et al. 2005b).

There was no effect of blocks, corresponding to plate position inside extractor, which shows that pressure inside was homogeneous. There were no differences in water retention between substrates with 100% fine and medium sand (G1). However, there was differences between 100% humin and humic acids, and between humic substances from compound and peat bog (G2) substances, in which humic acids and peat bog presented higher water retention average (**Table 5**).

Table 5. Average water retention by the substrates with 100% of sand (G1), 100% of humin and humic acids, originated of peatland and organic compost (G2) and by the substrates composed of 25, 50 and 75% of humin and humic acids, with the two particle sizes of sand, of two source materials (G3)

	Average water retention (dag kg ⁻¹)					
	Particle sizes of sand		Origin of substrate		Type of substrato	
	Fine sand	Medium sand	Peat bogs	Compound	Humic acids	Humin
G ₁	11,36 a	6,68 a	-	-	-	-
G ₂	-	-	313,45 a	267,87 b	377,44 a	203,89 b
G ₃	51,52 a	47,52 b	49,67 a	49,26 a	49,53 a	49,41 a

Means followed by the same letter in the same row do not differ by the F test (p <0.05). Means were counterstained in the lines as follows: (Fine sand x medium sand); (Peatland x Compost); (Humic acids x Humin). Number of samples: G1 = 36; G2 = 72; G3 = 432.

When water retention was verified in all tensions, substrates at different sand and humic substance ratios, sand grain size, substrate types and sources (G3), we have just found significant differences between fine sand that retained more water than medium grain (**Table 5**).

Fine sand fraction retained an amount of 70% more water than the medium sand did (**Table 5**), since smaller particles have higher specific surface and tend to retain more water, as its higher expression of capillary (LIBARDI, 2010).

The largest amount of organic carbon in peat bogs (**Table 3**) is directly related to higher levels of organic colloids (CANELLAS et al., 2005a) and high surface areas (SILVA FILHO & SILVA, 2011); therefore promoting greater water retention compared to the compound. Peat bogs can hold from 4 to 8 times the own weight in water amount (KIEHL, 1985), acting as sponge-like material, storing large volumes of water during rainy periods and releasing slowly during the rest of year (INGRAM, 1983; CAMPOS et al., 2012). Campos et al. (2011) had more than 900 dag kg⁻¹ of water retention at maximum water holding capacity in surface layers of peat bog used as source material for this research. Castilhos et al. (2008) did not find raise in water retention for lawns treated with humic substances, while Selim & Mosa (2012) reported positive effects of humic substances on water retention in soils.

The greater water retention of substrates composed by 100% HA compared to 100% Hu (**Figures 1 and 2**) may be related to non-polar components present in humin and the improved polarity of humic acids. Humin includes organic matter tightly attached to organomineral compounds, coal, non-polar components and undecomposed plant remains (BREEMEN & BUURMAN, 2002).

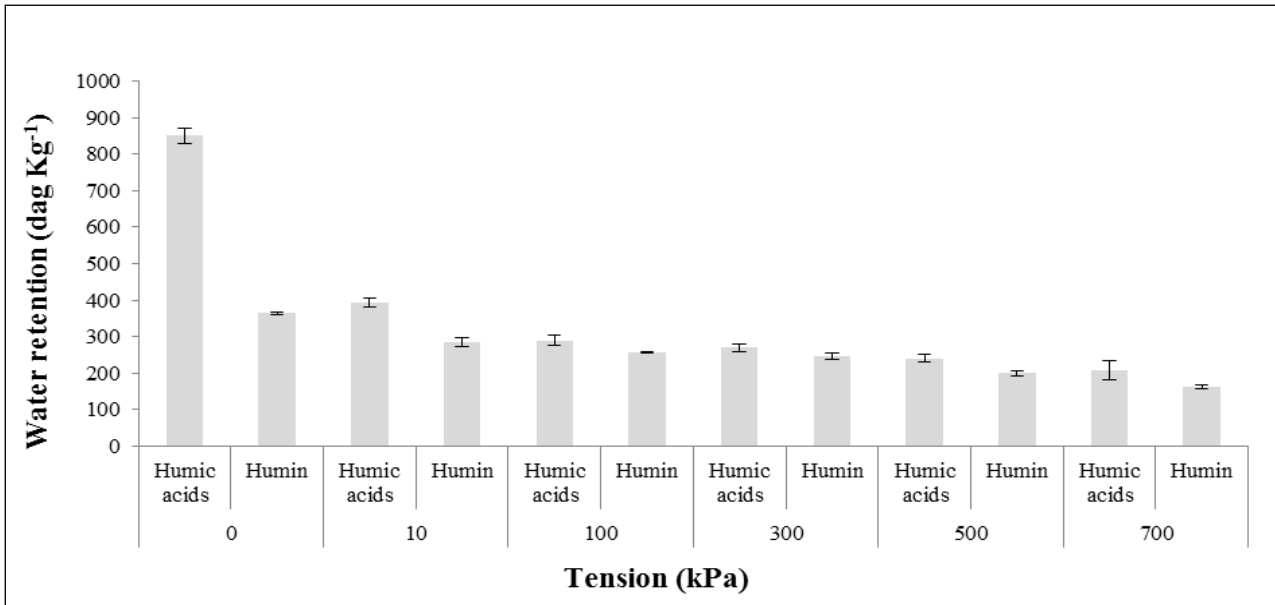


Figure 1. Water retention (kPa) by substrates with 100% of humic substances of peatland.

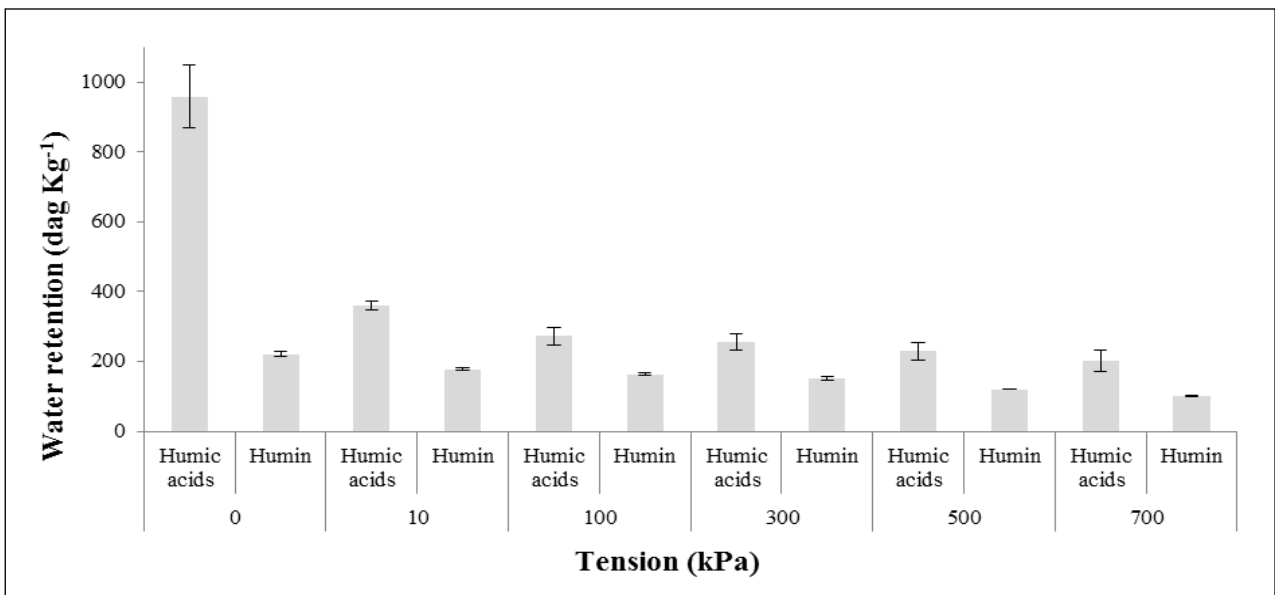


Figure 2. Water retention (kPa) by substrates with 100% of humic substances of organic compost.

According to Rosa et al. (2008), humic acids index of polarity is higher in systems that preserve organic matter, such as peat bogs; this higher polarity increases attraction between HA and H₂O molecules, increasing water retention. Campos et al. (2011), studied peat lands of the Espinhaço Meridional Mountains in MG, found that the less decomposed layers (fibrous), with higher Hu levels, more they retained water than layers at advanced decomposition stage. Nevertheless, in intermediate stage layers, where HA levels were higher, lower retentions were found. In this study, pure humic substances extracted from peat bog organic matter and residue from textile industry waste were used, having high water retention by HA.

Substrates with sand that presented the highest water retention were those with 75% Hu or HA and 25% FS (Figures 3, 4, 5 and 6). As and retains less water (Table 5), we can highlight again water retention capacity by humic substances, which can reach over 958 dag kg⁻¹ (Figure 2).

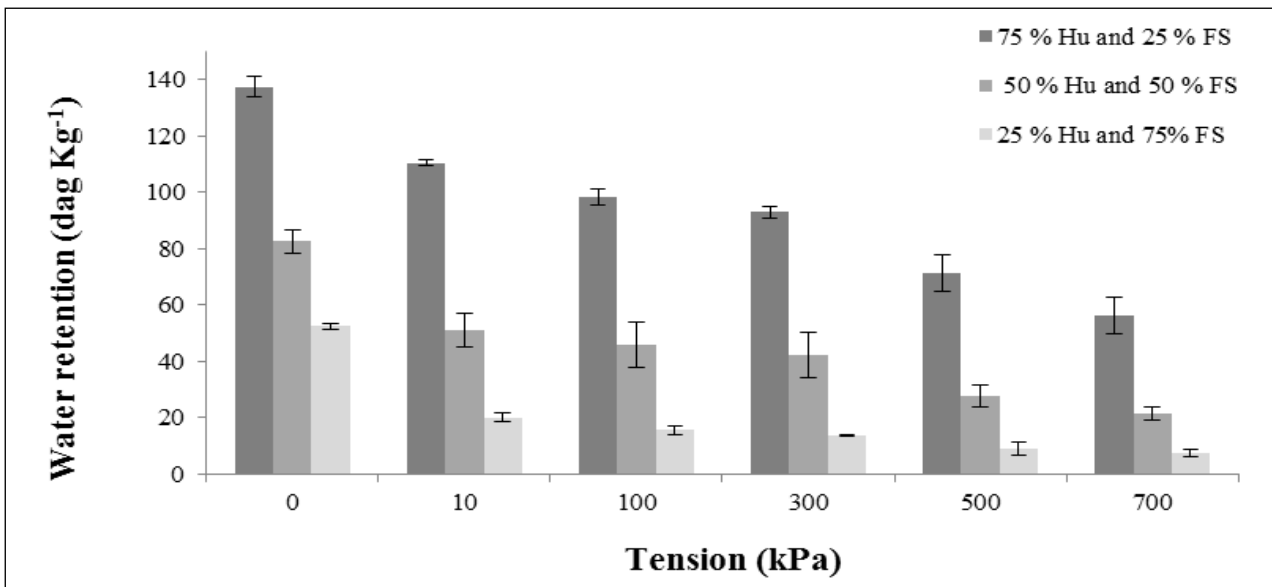


Figure 3. Water retention (kPa) by substrates with humin (Hu) of peatland and fine sand (FS).

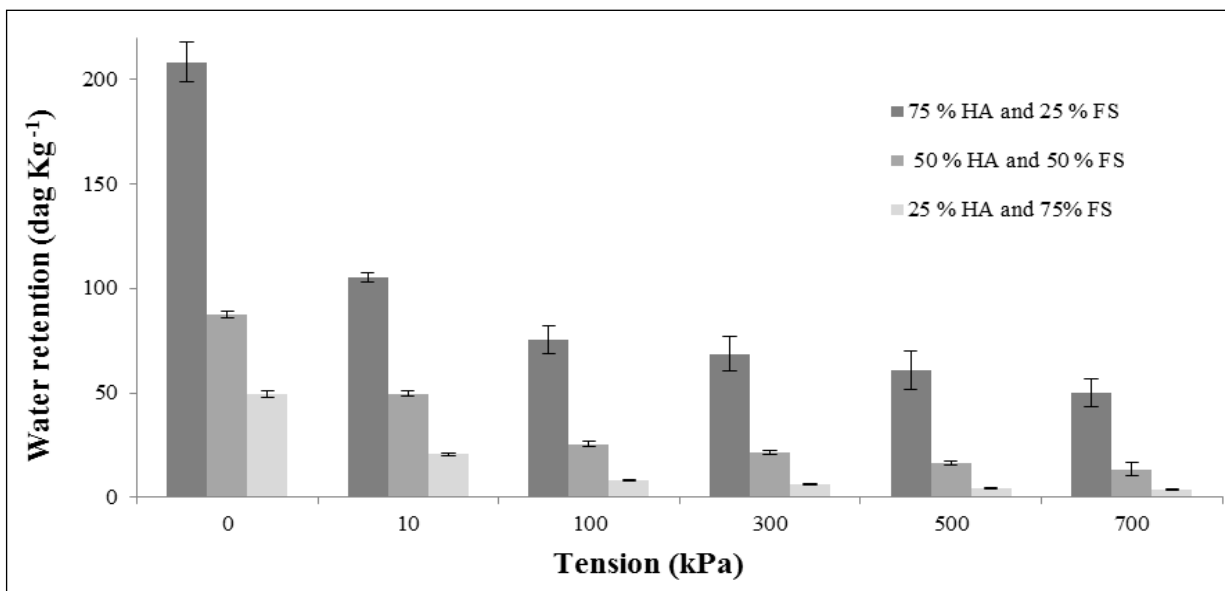


Figure 4. Water retention (kPa) by substrates with humic acids (HA) of peatland and fine sand (FS).

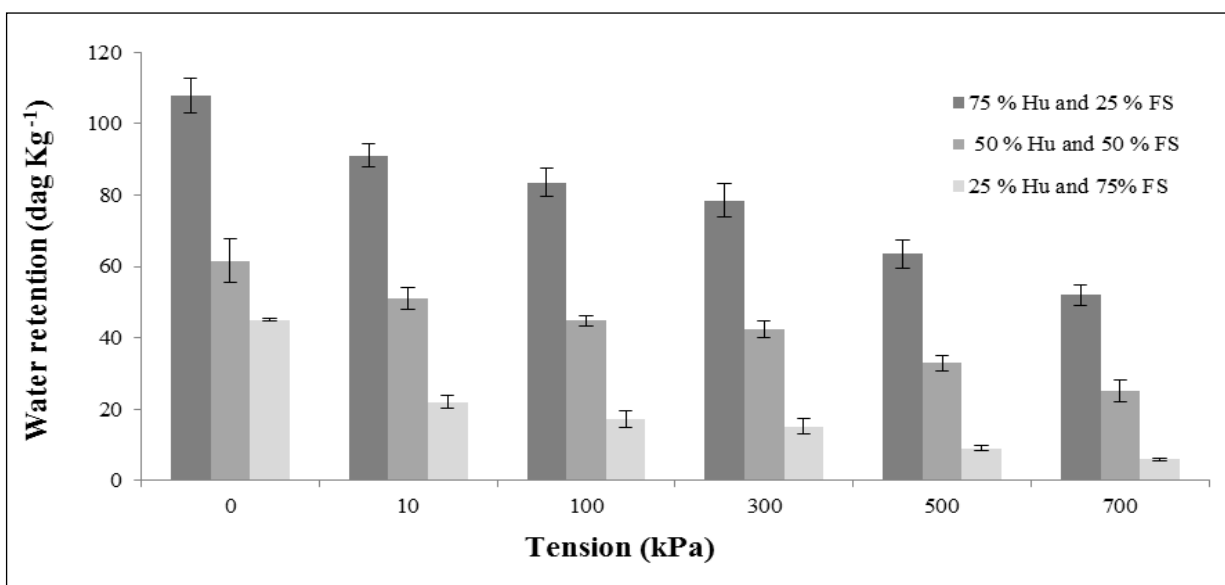


Figure 5. Water retention (kPa) by substrates with humin (Hu) of organic compost and fine sand (FS).

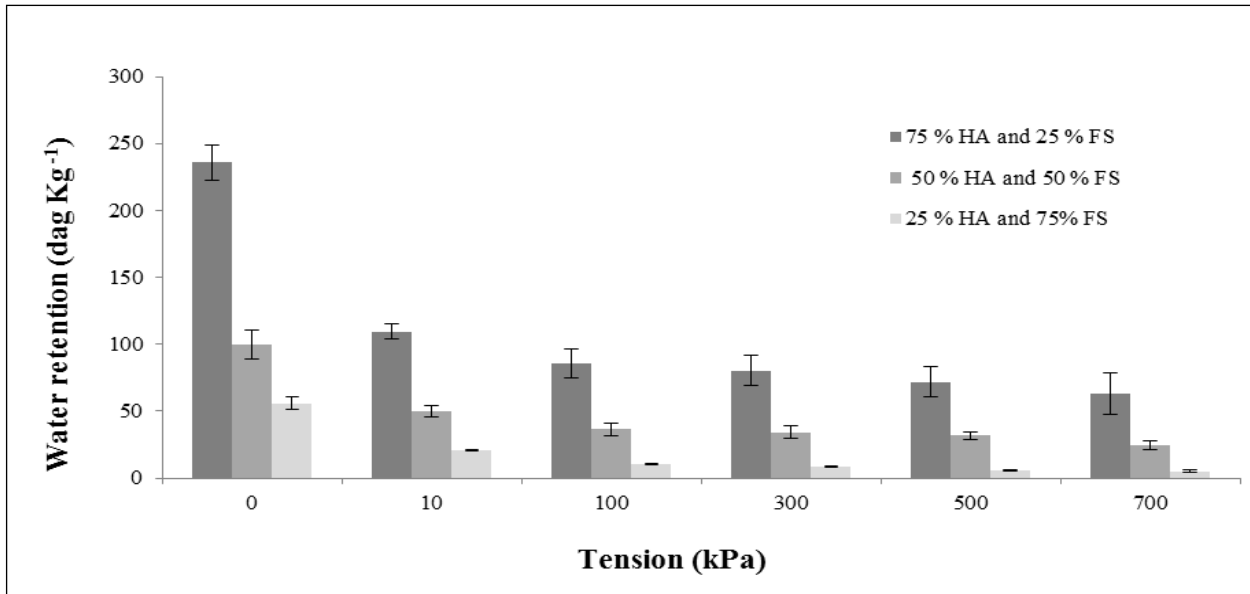


Figure 6. Water retention (kPa) by substrates with humic acids (HA) of organic compost and fine sand (FS).

Studied humic substances, both from organic compound and peat bog, retain large amounts of water; and thus, both have potential to be an organic water holder. In other words, a product that can be used to provide seedlings water in nursery and field by replacing gel based water-absorbent.

On average, substrates prepared with HA and sand showed same water retention compared to those prepared with Hu and sand (G3 - **Table 5**). The humin is the most appropriate humic substance for the development of organic water-absorbent, since both sources present humin concentration about 7 times higher than humic acids content (**Table 1**).

Peat bogs are normally located in environmentally protected areas and have an important role in carbon cycle, water storage and as paleoenvironmental change indicator (CAMPOS et al., 2011 and 2012; HORÁK et al., 2011; MARTINELLI et al., 2009, SILVA et al., 2009a, b; RIELEY et al., 2008; REEVE et al., 2000; INGRAM, 1983).

Organic composts are an alternative to reuse or recycling materials, promoting the noble use to materials that would be deposited on landfills, what consequently reduces environmental risks, benefiting natural resource conservation, since consumption and the need to meet demands of population have generated large amounts of waste.

Thus, the Hu, extracted from organic compound, is the material that has greater feasibility to continue these studies and, after testing other species in the field, develop a sustainable organic water-absorbent.

CONCLUSION

Humin is the humic substance prevalent in organic compound of textile industry waste and in peat bogs.

The highest water retention at 0, 10, 100, 300, 500 and 700 kPa tensions was obtained by 100% humic acid substrates than 100% humin.

Sand substrate that had the highest water retention was the one with 75% humic substances and 25% fine sand.

Humic acids and humin increased the water retention of substrates and have potential to be basis for a sustainable organic water-absorbent.

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