WATER RETENTION IN A PEATLAND WITH ORGANIC MATTER IN DIFFERENT DECOMPOSITION STAGES(1)

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SUMMARY

Peatlands are ecosystems formed by successive pedogenetic processes, resulting in progressive accumulation of plant remains in the soil column under conditions that inhibit the activity of most microbial decomposers. In Diamantina, state of Minas Gerais, Brazil, a peatland is located at 1366 m asl, in a region with a quartz-rich lithology and characteristic wet grassland vegetation. For this study, the peat area was divided in 12 transects, from which a total of 90 soil samples were collected at a distance of 20 m from each other. The properties rubbed fiber content (RF), bulk density (Bd), mineral material (MM), organic matter (OM), moisture (Moi) and maximum water holding capacity (MWHC) were analyzed in all samples. From three selected profiles of this whole area, samples were collected every 27 cm from the soil surface down to a depth of 216 cm. In these samples, moisture was additionally determined at a pressure of 10 kPa (Moi_{10}) or 1500 kPa (Moi_{1500}), using Richards' extractor and soil organic matter was fractionated by standard procedures. The OM decomposition stage of this peat was found to increase with soil depth. Moi and MWHC were highest in layers with less advanced stages of OM decomposition. The humin levels were highest in layers in earlier stages of OM decomposition and with higher levels of water retention at MWHC and Moi_{10}. Humic acid contents were higher in layers at an intermediate stage of decomposition of organic matter and with lowest levels of water retention at MWHC, Moi_{10} and Moi_{1500}.

Index terms: Histosol, fibric, hemic, sapric, humic substances.

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RESUMO: *RETENÇÃO DE ÁGUA EM UMA TURFEIRA COM MATÉRIA ORGÂNICA EM DIFERENTES ESTÁDIOS DE DECOMPOSIÇÃO*

Turfeiras são ecossistemas formados por sucessivos processos pedogenéticos, resultando em acúmulo em sucessão de restos vegetais em locais que apresentam condições que inibem a atividade da maioria dos microrganismos decompositores. Em Diamantina – MG, uma turfeira de 81,7 ha é encontrada em uma área de 1.366 m de altitude, com litologia predominantemente quartzítica e vegetação típica de campo úmido. Para a realização deste estudo, a área da turfeira foi dividida em 12 transectos e, dentro destes, a cada 20 m, foi feita uma coleta de solo (90 amostras). Em todas as amostras, foram analisados os teores de fibras esfregadas (FE), densidade do solo (Ds), material mineral (MM), matéria orgânica (MO), umidade (Um) e capacidade máxima de retenção de água (CMRA). Em três perfis, foram coletadas amostras de solo a cada 27 cm, até a profundidade de 216 cm. Nessas amostras, foi determinada, adicionalmente, a umidade após drenagem sob tensão de 10 kPa (U_{10}) e 1.500 kPa (U_{1500}), em extrator de Richards, e foi feito o fracionamento da matéria orgânica. O grau de decomposição da matéria orgânica da turfeira aumenta com o aumento da profundidade. A Um e a CMRA são mais elevadas em camadas com estádio menos avançado de decomposição da MO. Os maiores teores de humina estão relacionados com as camadas que apresentam estádio menos avançado de decomposição da matéria orgânica e com a maior retenção de água na CMRA e U_{10}. Os maiores teores de ácidos húmicos estão relacionados com as camadas que apresentam estádio intermediário de decomposição da matéria orgânica e com as menores retenções de água na CMRA, U_{10} e U_{1500}.

Termos de indexação: Organossolo, fíbrica, hêmica, sáprica, substâncias húmicas.

INTRODUCTION

Peatlands are ecosystems resulting from the successive accumulation of plant remains at sites where local conditions inhibit the decomposing activity of microorganisms, i.e., areas of excess moisture, low pH, lack of oxygen, and low temperatures (Moore, 1997). Peatlands are common in the Serra do Espinhaço Meridional (SdEM), where 112,233 ha of soils were mapped in four Conservation Units by Silva et al. (2009a), of which 12,814 ha are peatlands associated with other soils, located at the sources of important rivers – the Jequitinhonha, Araçuaí, Pardo, and Vermelho rivers.

There is a peatland near Diamantina, MG, in the protected area Pau-de-Fruta, close to the source of the Pedras river, which provides water for a population of about 40,000 people. Campos (2009) reported that this peat bog covers 81.7 ha and its volume is 595,000 m^3, 83.7 % of which represent the maximum stored water volume. Organic matter decomposition ranges from the sapric (more decomposed) to the fibric stage (less decomposed), according to von Post's organic matter decomposition scale (Embrapa, 2006).

A peatland is a heterogeneous substrate with physical properties that vary depending on the botanical characteristics of the source vegetation of its organic matter, the decomposition degree and the content of inorganic elements, all of which may affect its water storage capacity (Ingram, 1983; Reeve et al., 2000; Silva et al., 2009a,b).

Water dynamics in peatland environments are directly affected by the balance between matric forces and capillarity, which are forces that act against gravity. This means that peatlands have a high water holding capacity; they behave as a "sponge" by storing large water volumes in the rainy season and releasing this water gradually during other periods of the year (Ingram, 1983; Moore, 1997; Price & Schlotzhauer, 1999).

Rycroft et al. (1975a,b) and Brandyk et al. (2003) have shown that the water content in Northern hemisphere peat bogs varies inversely with the decomposition degree of peat, which in turn increases with depth. This variation occurs mainly because of decreases in porosity and increases in density that result from the subsidence process – a swelling and shrinkage, resulting from wet and dry seasons and anaerobic microorganism activity in peatlands (Brandyk et al., 2003).

Although the importance of this ecosystem for biodiversity, water dynamics, and carbon sequestration has been recognized domestically and internationally (DOCE, 1992; Brasil, 1996), few studies have been published on its water holding capacity, particularly in tropical regions.

The hypothesis that the water holding capacity of peat bogs decreases as the decomposition state of organic matter increases (Rycroft et al., 1975a,b; Brandyk et al., 2003) has been tested by relating the peat water holding capacity with physical and chemical properties and the decomposition stage of organic matter of a tropical peatland in the Serra do Espinhaço Meridional.

MATERIAL AND METHODS

Location and characterization of the study area

The studied peatland covers an area of 81.7 ha in the conservation unit Pau-de-Fruta (APA Pau-de-Fruta), 6 km away from the city of Diamantina, MG state. This protected area belongs to the water treatment company of Minas Gerais (Companhia de Saneamento de Minas Gerais, or COPASA), and covers 1,700 ha, of which 668 ha drain into this peatland which is also the headwaters of the Pedras river, the water supplier of the urban population of Diamantina. The bog has a total volume of 595,000 m^3, of which 498,015 m^3 represent the amount of water it retains (Campos, 2009).

The site consists of a depression at 1,366 m asl, covered with typical wet grassland vegetation and sparse patches (islands of shrub and tree species) of seasonal forests (Ribeiro & Walter, 1998; Silva et al., 2009b). Saadi (1995) described the site as a hydromorphic depression containing peatlands overlying riverine or colluvial sands and gravel, surrounded by quartzitic rock outcrops associated with hematite phyllites.

The temperature is mild in the region throughout the year; the annual mean is 18.9 °C, ranging from 16.0 °C in the coldest month (July) to 21.2 °C in the warmest month (January). The mean annual rainfall is 1,351.2 mm, with two well-defined seasons: a rainy season from November to March (mean rainfall – 223.19 mm), and a drier season from June to August (mean rainfall – 8.25 mm) (Neves et al., 2005).

Sampling

Twelve transects were defined, representative in spatial variations (width and depth) and the decomposition stage of organic matter. Samples were collected every 20 m with a 50 mm diameter PVC sampler (Campos et al., 2010) in each transect. Ninety points were sampled from the surface to the mineral substrate.

Three representative profiles of the area (P1, P2, and P3) (Figure 1) were sampled every 27 cm according to the homogeneity of layers to a depth of 216 cm (interface with the mineral substrate) and classified based on the Brazilian Soil Classification System (Embrapa, 2006) - Table 1).

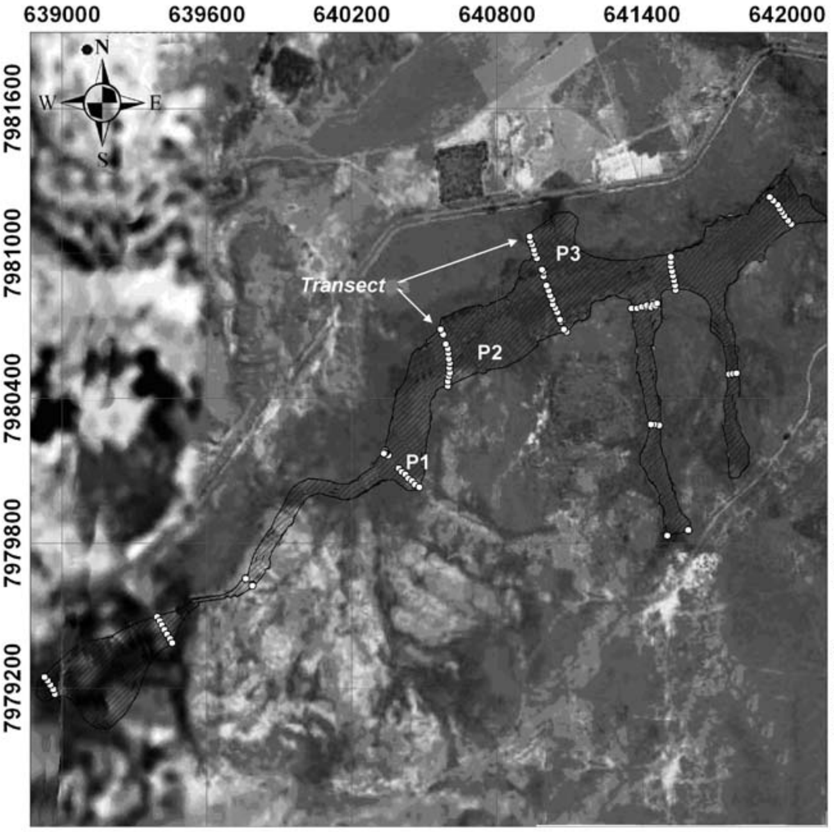

Figure 1. Location of sampled points in the transects and the profiles that were described and sampled in the peatland conservation unit Pau-de-Fruta, Diamantina – MG.

Table 1. Location, depth, altitude, and classification of sampled profiles

Profile	UTM Coordinates		Depth	Altitude	Classification
	S	W			
			cm	m	
P1	640455	7980139	216	1355	Typic Haplosaprists
P2	640835	7980614	216	1352	Typic Haplosaprists
P3	641435	7980943	216	1350	Typic Haplosaprists

Peatland characterization

The rubbed fiber content (RF), soil density (Bd), mineral material (MM), and organic matter (OM) were analyzed in all samples in three replicates according to the procedures available at Embrapa (2006) described below for analysis of organosols.

The rubbed fiber content was determined in a known soil volume (2.5 cm^3), measured in a graduated syringe. This soil volume was transferred to a sieve (100 mesh) and washed with tap water until the percolated liquid became clear. Next, the fibers were rubbed between the thumb and first finger under an intermittent water jet until the resulting fluid was colorless. This material was again transferred to the syringe to measure the volume. The rubbed fiber percentage was calculated as the ratio between the initial and the end volumes multiplied by one hundred (Embrapa, 2006).

The soil density was measured by drying known volume samples (2.5 cm^3) in an oven during 24 h at 105 °C and weighing the resulting volume. The soil density is the mass of the dried mass at 105 °C divided by 2.5 cm^3. The mineral mass of the oven- dried samples (at 105 °C) was determined by burning the material in a muffle furnace at 400 °C for 24 h, and weighing the resulting mass. The mineral material was calculated by dividing the sample mass incinerated at 400 °C by the dried mass at 105 °C and multiplied by one hundred.

Samples of known weight were oven-dried at 105 °C for 24 h and incinerated in a muffle furnace at 600 °C for 6 h, followed by drying in a dessicator to measure the mass. The organic matter content was calculated as the difference between the sample mass after oven-drying and the sample mass incinerated in the muffle furnace.

The organic matter of all samples of profiles 1, 2, and 3 was fractionated in fulvic acids (AF), humic acids (HA) and humin (H), according to the method proposed by the International Humic Substances Society (IHSS), available in Canellas et al. (2005).

Maximum water holding capacity and soil moisture

The gravimetric moisture (Moi) and maximum water holding capacity (MWHC) were detremined immediately after sampling, as described by Monteiro & Frighetto (2000). The samples were air-dried, sieved (2 mm mesh), water-saturated for 24 h, and placed in a Richards extractor at tensions of 10 kPa (Moi_{10}) and 1,500 kPa (Moi_{1500}) to determine the moisture content and gravimetric moisture (Richards, 1965).

Statistical analysis

The hypotheses about the effects of profiles (three levels) and depths (eight levels) in relation to the variables rubbed fiber, mineral material, organic matter, soil density, maximum water holding capacity (MWHC), gravimetric moisture, Moi_{10}, and $Moi_{1,500}$ were verified using the F test; the error was the interaction between two effects in question. The Tukey test ($p < 0.05$) was applied to compare the means of profiles and depths for these variables.

The degree to which independent variables (mineral material, rubbed fiber, gravimetric moisture, and soil density) determined a dependent variable (organic matter) was estimated using stepwise multiple linear regression based on 90 observations. A similar procedure was applied for gravimetric moisture (as a dependent variable) and mineral material, rubbed fiber, organic matter, and soil density (as independent variables).

Parameters were also estimated in quadratic regression models for the variables MWHC, Moi_{10}, and Moi_{1500} (dependent) and the variables H, HA, and FA(independent). A regression equation was obtained for each combination of dependent and independent variables. The significance of the model was measured using the F test, based on the ratio between the mean square of the regression and the mean square of deviations. The lowest point on the resulting curves was calculated by applying the first derivative of the regression equations. The correlation coefficient was calculated by comparing the observed values of the dependent variable with the estimated values. The significance of r was estimated using Student's t test ($p < 0.05$).

RESULTS AND DISCUSSION

Of the 90 sample points, 8.3 % were classified as Organossolo Háplico Fíbrico típico; 25 % were Organossolo Háplico Hêmico típico and 66.7 % were Organossolo Háplico Sáprico típico (Embrapa, 2006) (Table 2). By the US Soil Taxonomy these Histosols were classified as Hydric Haplofibrists, Hydric Haplohemists and Typic Haplosaprists, respectively (Estados Unidos, 1975).

Figure 2 shows the variations in organic matter as a function of the variables bulk density, mineral material, rubbed fiber, and gravimetric moisture. The dispersion of points and estimated correlations indicates that increases in organic matter are related with decreases in soil density and mineral material, and increases in rubbed fiber and gravimetric moisture (Figure 2). The relationship among these variables is also shown in the regression equation: OM = 82.473 + 0.004Moi + 0.190RF – 0.704MM – 10.307Bd, (R^2 = 0.89** and n = 90 observations), where organic matter varies positively with gravimetric moisture and rubbed fiber, and negatively with mineral material and soil density.

Table 2. Transects, number of sampled points, mean values of chemical and physical properties of the peatland

Transec	No. of Points	Color by pyrophosphate	von Post(1)	Moi	RF(2)	MM(3)	OM(4)	Bd(5)
		Munsell		dag kg^{-1}				g cm^{-3}
1	12	10YR 4/3	Sapric	471.73	13.43	49.63	50.37	0.35
2	4	10YR 2/1	Sapric	355.90	11.75	51.47	48.53	0.44
3	2	10YR 4/6	Hemic	90.35	30.00	80.04	19.96	0.41
4	3	10YR 3/3	Hemic	51.83	2.00	83.86	16.14	0.75
5	5	10YR 3/3	Sapric	35.80	2.50	87.00	13.00	0.89
6	10	10YR 3/3	Sapric	693.49	16.25	42.39	57.61	0.25
7	16	10YR 2/2	Sapric	729.77	21.00	44.80	55.20	0.25
8	10	10 YR 2/1	Sapric	721.25	9.60	37.84	62.16	0.16
9	10	10 YR 7/1	Fibric	623.07	19.00	47.01	52.99	0.43
10	8	10 YR 2/2	Sapric	645.86	15.25	33.76	66.24	0.23
11	8	10 YR 2/1	Sapric	194.71	18.00	66.71	33.29	0.60
12	2	10YR 7/3	Hemic	235.10	11.00	85.69	14.31	1.11
Mean	7.5			404.07	14.15	59.18	40.82	0.49

(1) Organic matter decomposition scale proposed by von Post (Embrapa, 2006). (2) Rubbed fibers. (3) Mineral material . (4) Organic matter. (5) Bulk density.

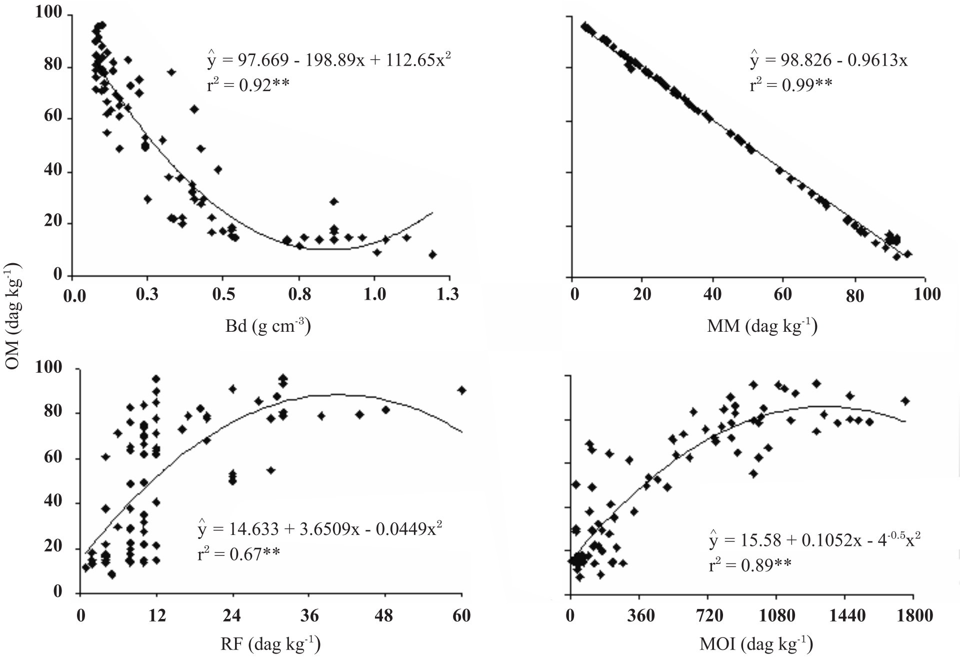

Figure 2. Content of organic matter (OM) in the peat bog and its relation with: bulk density (Bd); mineral material (MM); rubbed fibers (RF); moisture (Moi), and the respective regression equations and correlation coefficients in the peatland of the conservation unit Pau-de-Fruta, Diamantina, MG.

Figure 3 shows the variations of gravimetric moisture as a function of the variables soil density, rubbed fiber, mineral material, and organic matter. The dispersion of points and estimated correlations indicates that gravimetric moisture correlates positively with rubbed fiber and organic matter, and negatively with soil density and mineral material (Figure 3). The regression equation: Moi = 603.141 + 10.370RF – 4.570MM + 3.045OM – 434.606Bd, (R^2 = 0.72** and n = 90 observations) also shows that gravimetric moisture varies positively with rubbed fiber and organic matter, and negatively with soil density and mineral material.

The three study profiles are typical haplic sapric organosols, which represent 66.7 % of the organosols in the peatland. However, the two surface layers are fibric, the two intermediate layers are hemic, and the four deeper layers are sapric (Embrapa, 2006) (Table 3); it was thus possible to compare the study variables in layers at different stages of OM decomposition.

The sodium pyrophosphate color analysis (Munsell) revealed that chroma and value are higher in more superficial layers, tending to decrease with depth (Table 3); in deeper layers, peatlands are darker than at the surface. This is used as an indicator of the decomposition stage of organic matter – darker colors indicate more advanced stages of decomposition (Reeve, 2000; Embrapa, 2006; Campos et al., 2010).

Rubbed fiber content did not vary among profiles, but was higher in surface layers, and decreased as depth increased and the decomposition stage of organic matter advanced (Table 3). However, the total organic matter content – although varying among profiles – did not vary significantly as depth increased, corroborating data of Silva et al. (2009a) in peatlands of the SdEM, and of Brandyk et al. (2003) in peat bogs in the Northern hemisphere.

Soil density did not vary among profiles, but was statistically higher in deeper layers of the profiles, which were classified as sapric (Table 3). The reason is that organic matter was in more advanced stages of decomposition and subsidence, a common finding in organic soils (Ingram, 1983; Moore, 1997). Brandyk et al. (2003) suggested additional factors, e.g., the weight of water and soil in surface layers, and swelling and shrinkage caused by dry and wet seasons, all of which increase soil density in deeper layers.

The mineral material content did not vary among profiles, but was higher in deeper layers (Table 3), which were classified as sapric and closer to the inorganic basal substrate. Päivänen (1973), Okruszko (1993), and Zeitz & Ilnicki (2003) reported similar results.

The MWHC varied among profiles; it was higher in the two surface layers, and decreased with depth (Table 4), corroborating data presented by Silva et al. (2009b) and Ingram (1983). Päivänen (1973) and Ingram (1983) suggested that this is a common feature

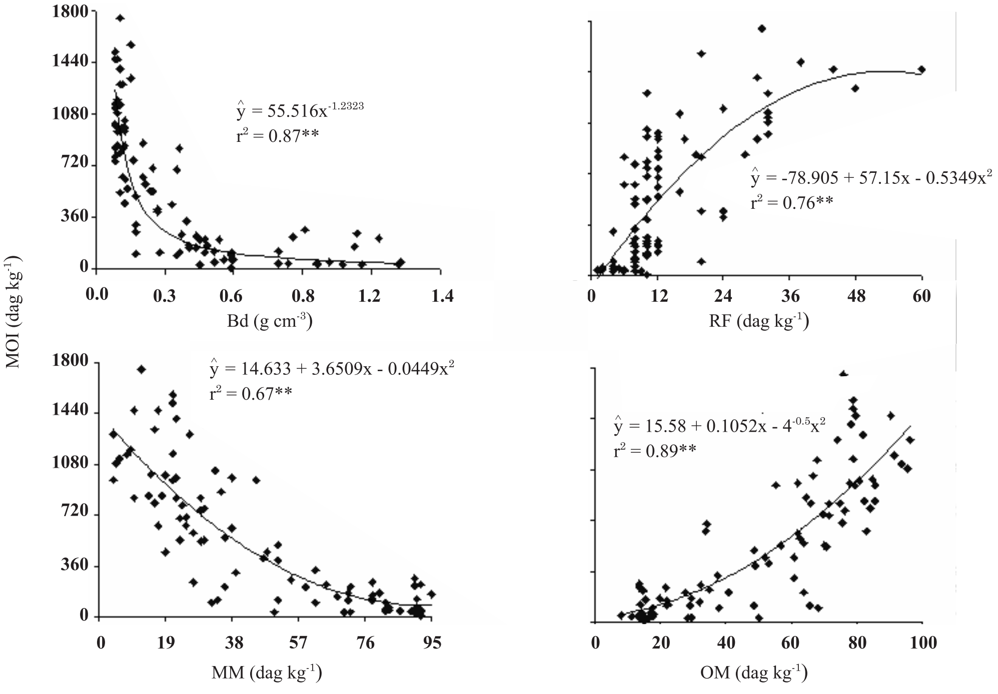

Figure 3. Moisture content (Moi) and its relations with: bulk density (Bd); rubbed fibers (RF); mineral material (MM); organic matter (OM) and the respective regression equations and correlation coefficients in the peatland conservation unit Pau-de-Fruta, Diamantina, MG.

Table 3. Physical and chemical properties of three peatland profiles in the conservation unit Pau-de-Fruta, Diamantina, MG

Layer	Color(1)	von Post(2)	RF(3)	MM(4)	OM(5)	Bd(6)
cm				dag kg^{-1}		g cm^{-3}
		Profile 1 - Typic Haplosaprists				
0–27	10 YR 4/4	Fibric	60	28.0	76.2	0.10
27–54	10 YR 4/4	Fibric	65	28.1	77.2	0.13
54–81	10 YR 3/4	Hemic	42	30.0	72.1	0.16
81–108	10 YR 3/3	Hemic	48	18.7	71.9	0.09
108–135	10 YR 3/2	Sapric	33	30.0	70.0	0.10
135–162	10 YR 3/4	Sapric	33	31.4	91.4	0.11
162–189	10 YR 3/1	Sapric	20	55.0	79.1	0.16
189–216	10 YR 3/3	Sapric	17	56.9	78.6	0.26
Mean			39.7 A	34.7 A	75.3 B	0.14 A
		Profile 2–Typic Haplosaprists				
0–27	10 YR 4/5	Fibric	55	23.8	76.2	0.12
27–54	10 YR 4/4	Fibric	53	23.6	76.4	0.13
54–81	10 YR 4/4	Hemic	46	27.3	76.2	0.12
81–108	10 YR 4/4	Hemic	44	27.7	76.7	0.12
108–135	10 YR 4/2	Sapric	35	33.8	74.5	0.13
135–162	10 YR 4/2	Sapric	33	35.9	73.3	0.15
162–189	10 YR 3/1	Sapric	22	44.9	76.7	0.15
189–216	10 YR 3/2	Sapric	20	47.0	77.6	0.18
Mean			38.5 A	33.0 A	67.0 A	0.14 A
		Profile 3–Typic Haplosaprists				
0–27	10 YR 4/4	Fibric	67	30.1	75.3	0.08
27–54	10 YR 4/4	Fibric	58	28.3	76.5	0.11
54– 81	10 YR 4/3	Hemic	55	29.4	77.9	0.1
81– 108	10 YR 4/2	Hemic	43	35.8	76. 4	0.09
108–135	10 YR 3/2	Sapric	48	37.9	74.6	0.16
135–162	10 YR 3/1	Sapric	37	42.0	81.9	0.17
162–189	10 YR 3/1	Sapric	16	49.6	77.6	0.28
189–216	10 YR 3/2	Sapric	21	47.7	74.5	0.26
Mean			43.1 A	37.6 A	62.4 A	0.14 A
		Layer mean				
0–27		Fibric	60.7 a	27.3 b	73.0 b	0.10 b
27–54		Fibric	58.7 ab	26.7 b	73.3 b	0.12 b
54–81		Hemic	47.7 bc	28.9 b	71.1 b	0.13 b
81–100		Hemic	45.0 bcd	27.4 b	69.3 b	0.10 b
108–135		Sapric	38.7 cd	33.9 b	66.1 b	0.13 b
135–162		Sapric	34.3 cd	36.4 b	63.9 b	0.14 ab
162–189		Sapric	19.3 e	49.8 a	50.2 ab	0.16 ab
189–216		Sapric	19.3 e	50.5 a	49.5 a	0.23 a

(1) Color: color evaluated in sodium pyrophosphate. (2) von Post: organic matter decomposition scale according to von Post (Embrapa, 2006). (3) RF: rubbed fibers. (4) MM: mineral material. (5) OM: organic matter. (6) Bd: bulk density. Means followed by the same uppercase letter in columns and means of layers with the same lowercase letters in columns did not differ by Tukey´s test ($p < 0.05$).

of peatlands, and is caused mainly by the presence of two hydraulically separate layers: a more active surface (fibric) layer that contains a complex system of pores formed by living roots and poorly decomposed fibers in which water is mainly retained by matric forces and capillarity, and less active deeper (sapric) layers where organic matter is more decomposed and soil density and higher mineral material content reduce the water holding capacity.

No significant differences among profiles and layers were observed in samples under a tension of 10 kPa (Moi_{10}). However at 1,500 kPa (Moi_{1500}), differences were observed among profiles; furthermore, all layers differed statistically from the deepest (sapric) layer, which had the lowest Moi_{1500} content (Table 4). It should be noted that the samples for analyses of Moi_{10} and Moi_{1500} were air-dried and sieved (2 mm mesh), which may alter the water holding capacity. Studies by Waniek

Table 4. Hydric parameters, decomposition stage of organic matter (von Post), and content of C-humic substances in three peatland profiles in the conservation unit Pau-de-Fruta

Layer	MWHC(1)	Moi_{10}(2)	Moi_{1500}(3)	von Post	Organic carbon		
					H(4)	HA(5)	FA(6)
cm	dag kg^{-1}				dag kg^{-1}		
			Perfil 1 – Typic Haplosaprists				
0–27	1727.8	269.6	182.	Fibric	67.0	24.6	8.4
27–54	951.5	199.7	149.2	Fibric	67.8	25.1	7.1
54–81	677.5	157.2	95.2	Hemic	48.2	43.6	8.2
81–108	724.9	143.0	85.7	Hemic	46.8	44.4	8.8
108–135	838.2	119.6	57.3	Sapric	46.9	42.8	10.3
135–162	835.7	118.5	52.3	Sapric	50.8	38.6	10.6
162–189	1196.1	138.1	63.7	Sapric	54.1	35.6	10.3
189–216	910.4	108.0	41.2	Sapric	58.3	31.5	10.2
Mean	982.8 A	156.7 A	90.82 AB		55.0 A	35.8 A	9.3 A
			Perfil 2 – Typic Haplosaprists				
0–27	1125.9	256.8	194.9	Fibric	63.1	30.5	6.4
27–54	882.6	177.5	152.6	Fibric	637	30.1	6.3
54–81	788.6	192.1	136.5	Hemic	61.5	31.9	6.6
81–108	686.4	120.8	79.4	Hemic	50.9	42.6	6.5
108–135	685.1	110.4	78.1	Sapric	48.6	44.8	6.6
135–162	537.5	119.2	68.2	Sapric	58.0	35.1	7.0
162–189	596.4	221.3	113.6	Sapric	58.4	33.4	8.2
189–216	564.0	197.2	97.2	Sapric	57.2	32.4	10.3
Mean	733.3 B	174.4 A	115.1 A		57.7 A	35.1 A	7.2 B
			Perfil 3 – Typic Haplosaprists				
0–27	1197.9	128.5	67.4	Fibric	64.3	26.2	9.5
27–54	880.2	129.7	57.9	Fibric	58.5	33.8	7.7
54–81	715.2	125.4	57.0	Hemic	52.3	38.9	8.9
81–108	680.6	103.3	46.8	Hemic	46.7	43.8	9.5
108–135	814.2	171.6	79.2	Sapric	40.1	50.9	9.1
135–162	854.6	172.7	81.2	Sapric	60.0	29.8	10.1
162–189	765.2	161.5	74.8	Sapric	57.1	30.5	12.4
189–216	635.6	128.5	49.1	Sapric	55.8	31.0	13.3
Mean	817.9 AB	140.2 A	64.2 B		54.4 A	35.6 A	10.1 A
			Layer mean				
0–27	1350.5 a	218.3 a	148.1 a	Fibric	64.8 a	27.1 b	8.1 b
27–54	904.8 ab	169.0 a	119.9 ab	Fibric	63.3 a	29.7 b	7.0 b
54–81	727.1 b	158.2 a	96.2 a b	Hemic	54.0 ab	38.1 ab	7.9 bc
81–108	697.3 b	122.4 a	70.6 a b	Hemic	48.2 b	43.6 a	8.3 bc
108–135	779.1 b	133.9 a	71.5 a b	Sapric	45.2 b	46.1 a	8.7 abc
135–162	742.6 b	136.8 a	67.2 a b	Sapric	56.3 a	34.5 b	9.2 abc
162–189	852.5 b	173.7 a	84.0 ab	Sapric	56.6 a	33.2 b	10.3 ac
189–216	703.3 b	144.5 a	62.5 b	Sapric	57.1 a	31.6 b	11.3 a

(1) MWHC: Maximum water holding capacity. (2) H: Humin. (3) HA: Humic acids. (4) FA: Fulvic acids. Means followed by the same uppercase letter in columns and means of layers with the same lowercase letters in columns did not differ by Tukey´s test ($p < 0.05$).

et al. (1999) in peatlands in the Northern hemisphere showed that dried peat can become hydrophobic, particularly more decomposed (sapric) peat.

The highest humin content was found in more superficial and less decomposed layers (fibric layers), where the values of rubbed fiber, gravimetric moisture, and maximum retention capacity were also higher (Table 4). In peatlands, this organic matter fraction is less water-soluble and tends to concentrate in surface layers where horizontal water flow is stronger (Cunha et al., 2005). However, the humin content increases again in deeper layers, possibly because of organo-mineral complexes, due to a high affinity with mineral particles (Steverson, 1994; Canellas et al., 2000; Valladares, 2003; Silva & Mendonça, 2007).

Based on the significance of the regression model as applied to humin content and the MWHC, Moi_{10} and Moi_{1500}, and measured in the F test and the correlation coefficient (Figure 4), it may be suggested that humin tended to positively affect the observed values of hydric parameters in the study. The polynomial regression model that best adjusted to humin, the MWHC, and Moi_{10} and Moi_{1500}, was the quadratic model (Figure 4), making it possible to infer that higher humin values tend to be related with increased MWHC, Moi_{10} and Moi_{1500}, (Table 4).

At the surface – where the peatland is fibric; the humin, the MWHC, Moi_{10} and Moi_{1500} were higher (Table 4). In the 81–108 cm layer, the MWHC and Moi_{10} were lowest, Moi_{1500} among the lowest, and humin the lowest *of all studied layers* (Table 4). On the regression curve, the minimum points were 694.3 (MWHC), 128.7 (Moi_{10}), and 61.5 dag kg^{-1} (Moi_{1500}), which is close to true values. In deeper sapric layers, the Moi_{1500} reaches its lowest values, and humin and mineral material values increase again (Tables 3 and 4). Brandyk et al. (2003) and Silva & Mendonça (2007) suggested that increased polymerization of humic substances and their interaction with the mineral fraction of soils may decrease the soil water holding capacity to the point when it becomes hygrophobic. This effect appears to be more pronounced when water is retained at higher energy levels – at higher tension (Moi_{1500}). This is due to a high content of polyphenol-rich aliphatic long chain carbonic compounds derived from lignin and cellulose (Silva & Mendonça, 2007).

The levels of humic acids were inverse to humin contents and were highest in the intermediate layers of the three profiles. Based on the significance of the regression model for humic acid content, the MWHC, Moi_{10} and Moi_{1500} (obtained with the F test and the correlation coefficient) (Figure 4), it may be suggested that humic acids tend to negatively affect the hydric parameters in the study. The regression model that best adjusted to the humic acid content and the MWHC, Moi_{10} and Moi_{1500}, was the quadratic model (Figure 4). It was observed that in general, a higher humic acid content tended to be related with lower MWHC, Moi_{10} and Moi_{1500} (Table 4).

The MWHC, Moi_{10} and Moi_{1500} were higher at the surface, where the peatland is fibric and the humic acid content is low. In the 81–108 cm layer, the MWHC and the Moi_{10} were lowest, the Moi_{1500} among the lowest, and humic acids the highest *of all studied layers* (Table 4). The minimum points on the

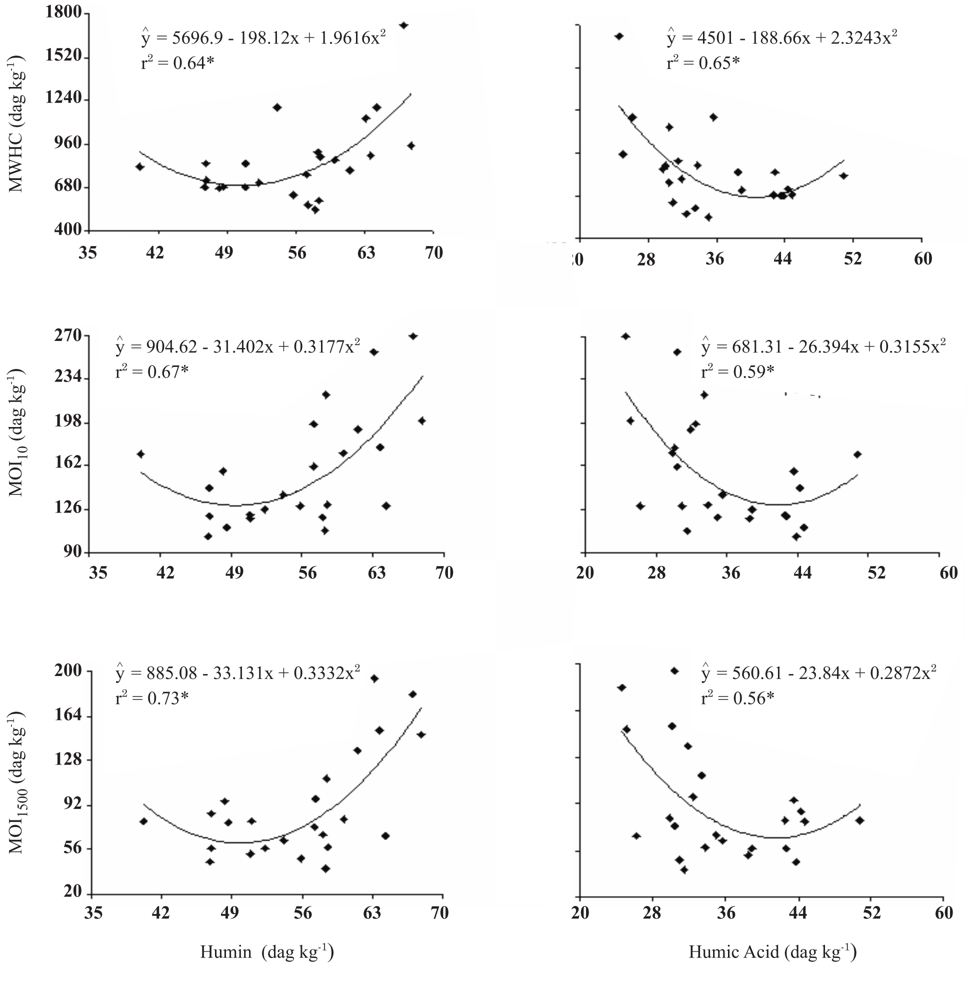

Figure 4. Maximum water holding capacity (MWHC), moisture at 10 kPa (Moi_{10}), moisture at 1500 kPa (Moi_{1500}), their relations with C-humin (H) and C-humic acids (HA) and the respective regression equations and correlation coefficients in the peatland conservation unit Pau-de-Fruta, Diamantina, MG. All regression equations were significant by the F test ($p < 0.05$ or $p < 0.01$).

regression curve are 671.6 (MWHC), 129.3 (Moi_{10}), and 65.9 dag kg^{-1} (Moi_{1500}). In soils with high organic matter content, water – a polar molecule – may be repelled by compounds with apolar carbon chains, which are common components of humic acids (Silva & Mendonça, 2007).

The content of fulvic acids was higher in deeper layers (Table 4). The humic acid content in surface layers is lower because of its water solubility; this fraction is soluble in acid and alkaline media, and may easily be transported by water flow (Canellas et al., 2000; Silva & Mendonça, 2007). There were no significant correlations between fulvic acid content and the MWHC, Moi_{10} and Moi_{1500}.

As this is not an experimental study, and since regression analysis was applied to check possible trends in the relationships among humic substances of a natural material (peat) and hydric parameters, there was no intention to adjust the models and/or to make predictions based on regression equations. Thus, only the different tendency of MWHC of humic substances at 10 kPa and 1,500 kPa was observed (Figure 4). Experimental research is needed to increase knowledge about the behavior of humic substances in terms of water retention.

All hydric parameters in this study (Tables 2 and 4) demonstrated the "sponge-like" behavior of peat bots (Ingram, 1983; Moore, 1997; Price & Scholtzhauer, 1999), which hold large water volumes. These parameters also show that fibric layers, which are less decomposed, hold more water than hemic – and especially sapric – layers in more advanced stages of decomposition, corroborating the model proposed by Rycroft et al. (1975a,b) and Brandyk et al. (2003).

CONCLUSIONS

1. The gravimetric moisture and maximum water holding capacity are higher in layers with less advanced stages of organic matter decomposition, which in turn is more advanced in deeper layers of peatlands.

2. The rubbed fiber content and organic matter were positively correlated; the mineral material correlated negatively with gravimetric moisture.

3. The humin content is highest in layers with less advanced stages of organic matter decomposition; the humic acid content is highest in layers with intermediate stages of organic matter decomposition.

4. Humic substances tend to behave differently in relation to the maximum water holding capacity at 10 kPa and 1,500 kPa.

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