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THE INFLUENCE OF SOIL TEXTURE AND ORGANIC MATTER ON THE RETENTION CURVES AT SOIL MOISTURE IN THE HUMIC CALCARIC REGOSOL OF THE OVCHE POLE REGION, NORTH MACEDONIA

SUMMARY

This paper is a result of field and laboratory research of the soils (Rendzina Calcaric Regosol) in Ovche Pole region in the Republic of North Macedonia. The field research of the soils has been done according to methods described by Mitrikeski & Mitkova (2013). In laboratory, the following analyses have been carried with the soil samples: hygroscopic moisture, mechanical composition (soil texture), pH value of the soil solution, humus content and content of carbonates. The soil texture and chemical properties of the soils have been determined by standard methods described by Mitrikeski & Mitkova (2013). The soil moisture retention at pressures of 0.33, 6.25 and 15 bars was determined by bar extractor (Townend, et al., 2001; ICARDA 2001; Marinčić, 1971). The average content of physical sand and clay fractions was 59.50% and 40.50% respectively. The average content of individual soil separates is: coarse sand 20.85%, fine sand 38.65%, silt 18,29% and clay 22.21%. The content of humus in horizon Ap ranges from 1.87 to 2.2 with an average of 2.1% and this percentage decreases with depth in all examined profiles. In horizon Amo is 1.36%, in AC horizon 0.89% and the smallest is in parent material C, 0.69%. The moisture content of the soil at 0.33 bar is high in all horizons. The highest retention has horizon Amo 31.25% (higher content of humus and clay). The horizons AC, Ap and the parent material C have similar values (26.74%, 26.72 and 24.51%). The wilting point is not high (average 15.71% in Amo horizon). The results suggested a positive correlation in horizon Amo between the moisture retention at 0.33 and 15.00 bars and the content of physical clay and clay, as well as high negative correlation between the moisture retention at 0.33 and 15.00 bars and the content

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of sand. The retention curves in all horizons are almost horizontal at 2 bars in all the studied cases. The greatest decline of the retention curves occurs at lower pressures (< 1 bar). Gradual changes in the retention forces can be noticed coming with the change of moisture without jumps. This shows that the division of the soil moisture in different forms cannot be justified with the retention curve because the decrease of the amount of water does not have big jumps under different tensions.

INTRODUCTION

Rendzina Calcaric Regosol, formed by the weathering of the carbonate rocks of various geological formations, are inter-zonal soils developed in the subboreal, boreal, as well as in some regions of the subtropical zones. Their characteristic features are the occurrence of the fragments of the parent material in the surface level and neutral or abasic reaction of the soil in a solution with a high content of calcium (Dobrzañski et al., 1987; FAO/UNESCO, 1997; Pranagal et al., 2005).

The hydrous and physical relations, in addition to the mineralogical composition of the soil, are also influenced by the mechanical content, the content of organic matter etc. (Hillel 1980). Maclean and Yager (1972), Jamison and Kroth (1958), Shaykewich and Zwarich (1968) as well as Heinonen (1971) studied the influence of organic matter and the mechanical composition over the retention of moisture in several different soils in the USA, Europe and Asia. In the research of Hollist et al. (1977), it is confirmed that the soil moisture retention in Western Midland (Great Britain) depends mainly on the organic matter and mineralogical composition of soil. According to Filipovski (1996), Markoski et al. (2013, 2016) the retention of moisture at different tensions is strongly correlated with the content of humus, clay, silt and the mineralogical composition of the clay.

The hydrophysical properties of soils, the water retention and the water permeability in the saturated and unsaturated zone, not only affect the water balance but also have a dominant influence on the conditions of growth and development of plants. They determine the availability of water to plants and leaching of nutrients dissolved to the deeper layers of the soil (Coquet et al., 2005; Hillel, 1998, Kutilek and Nielsen, 1994; Witkowska-Walczak et al., 2000). The knowledge of the hydrophysical properties of the soil is therefore essential in the interpretation and prediction of changes of the vegetation cover, which occur as a result of a natural succession.

The intensity of the impact of the mechanical composition and organic matter on the retention of soil moisture depends on the share of certain fractions of soil separates and the percentage of organic matter. Particles of clay, due to the large inner and outer active surface, high cation exchange capacity (CEC) and mineralogical composition, represent the most active fraction of the mechanical composition of the soil (Škorić, 1991; Markoski et al., 2015).

In our research, the main emphasis was on the dependence and impact of organic matter and mechanical composition on the retention of water in the surveyed Rendzina Calcaric Regosol. Due to the stated importance of the mechanical composition and organic matter of the other properties of soil, this paper investigates the impact on retention of soil moisture at different points of tension, ranging from 0.33 up to 15 bars, which correspond to the water constant, which is called permanent wilting point (PWP). The remaining moisture above 15 bars is unavailable to plants (Bogdanović 1973; Markoski et al., 2013; Markoski et al., 2015; Markoski et al., 2016).

MATERIAL AND METHODS

The influence of the mechanical composition and organic matter of the soil to the retention curves of soil moisture has been investigated in the Rendzina Calcaric Regosol spread around the in Ovche Pole region in Republic of North Macedonia (Figure 1).

Figure 1. Study area of the Ovche Pole region in Republic of North Macedonia

In this region seven basic pedological profiles were excavated and 28 soil samples were taken for further analysis. We analysed: the mechanical composition of the soil, determined by dispersing the soil using a 1 M solution of $Na_4P_2O_7$ x 10 H_2O. The fractioning of mechanical elements was carried out using the International Classification; the textured classes with the American Triangle, described by Mitrikeski and Mitkova (2013); Determinates in mechanical composition and chemical properties in soils with standard methods described by Bogdanović et al (1966), Mitrikeski & Mitkova (2006); Džamić et.al. (1996).

The determination of moisture retention at a pressure of 0.33 bar, 0.5 bar and 1 bar, was performed applying pressure with a Bar extractor. To determine the retention of soil moisture at higher pressures, the method of Richards (1982), Porous plate extractor, 4.0 bar 6.25 bar and 15 bar was applied, described by Townend et al. (2001; ICARDA 2001; Marinčić, 1971). There has been

descriptive statistics (average value, standard deviation and variation coefficient were determined) of the mechanical composition, chemical properties and constants of soil moisture in Microsoft Excel. The correlation between retention of moisture, mechanical composition and humus is determined using the computer program Microsoft Excel.

RESULTS AND DISCUSSION

The mechanical composition and organic matter of the soil are of great importance to physical, physical-mechanical and chemical properties of the Rendzina Calcaric Regosol. The mechanical composition and physical properties of Rendzina Calcaric Regosol mostly depend on the nature of the substrate and the content of humus.

On the basis of the analysed mechanical composition (Table 1), it may be noted that the average content of physical sand and physical clay fractions is 59.50% and 40.50% respectively. The average content of individual soil separates is: coarse sand 20.85%, fine sand 38.65%, silt 18.29% and clay 22.21%. The content of humus in horizon Apca ranges from 1.87 to 2.2 with an average of 2.1% and this percentage decreases with depth in all examined profiles. In horizon Amoca is 1.36%, in ACca horizon 0.89% and the smallest is in parent material C 0.69%.

Table 1. Mechanical composition of Rendzina Calcaric Regosol

Hor.	N	> 2 [mm]		0.2 – 2 [mm]		0.02 – 0.2 [mm]		0.02 – 2 [mm]		0.002 – 0.02 [mm]		< 0.002 [mm]		< 0.02 [mm]	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
Ap$_{ca}$		25.27	5.79	35.18	6.91	60.44	10.34	35,18	6.91	14.03	2.20	25.41	8.46	39.56	10.34
Amo$_{ca}$		20.18	9.87	33.22	3.90	53.40	12.57	33,22	3.90	17.44	6.99	29.16	8.12	46.60	12.57
ACca	7	18.07	12.76	40.16	11.90	58.23	13.00	40,16	11.90	21.10	9.96	20.67	8.94	41.77	13.00
Cca		19.16	16.63	46.06	13.21	65.93	18.61	46,06	13.21	20.59	15.37	13.49	8.41	34.07	18.61

According the American classification on textured classes, the Amo horizon of examined soils falls within texture class: clay loam; the transitional AC horizon falls within the sandy clay loam, and the substrate C falls within the clay loam. The presented data on the mechanical composition of Rendzina Calcaric Regosol are similar to the data for this soil type as presented by (Filipovski, 1996; Kalicka, et al. 2008).

Besides the mechanical properties, the retention of soil moisture in the Rendzina Calcaric Regosol is strongly influenced by the chemical properties. The average values of the chemical properties are shown in Table 2.

Table 2. Chemical properties of Rendzina Calcaric Regosol

Hor.	N	pH in H_2O		Humus [%]		N [%]		P_2O_5 [mg/100 g soil]		K_2O [mg/100 g soil]		$CaCO_3$ [%]	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
Ap_{ca}	7	7.47	0.75	2.1	0.13	0.12	0.01	17.83	8.78	30.31	7.58	3.52	3.62
Amo_{ca}		7.79	1.0	1.36	0.21	0.1	0.01	7.73	6.07	17.67	5.98	6.47	7.2
ACca		8.48	0.89	0.89	0.25	0.03	0.03	4.88	3.6	13.48	5.68	16.67	11.91
Cca		8.73	0.91	0.69	0.19	0.02	0.02	4.74	4.51	8.59	2.52	19.2	16.0

These properties in the surveyed Rendzina Calcaric Regosol depend on the properties of the substrate (parent material) and its mechanical and mineralogical composition and content of carbonates in it and of the intensity of pedogenetic processes (accumulation of humus and translocation of $CaCO_3$).

For the content of organic matter, it is of great importance for Rendzina Calcaric Regosol to be under natural (grassland or forest) vegetation. The average content of humus in the humus accumulative horizon Apca is 2.1%, in the transitional horizon Amoca - 1.36%, ACca – 0.89 % and it is the lowest in the substrate C, with average of 0.69%. According to Filipovski (1996) the average content of humus in the horizon Amo analysed for 481 profiles of Rendzina Calcaric Regosol in Macedonia is 2.63%.

The retention of water in the soil is the result of two forces: adhesion (attraction of water molecules by soil particles) and cohesion (water molecules attract each other). Adhesion is much stronger than cohesion. The force with which water is retained in the soil is called capillary potential and is closely related to water content. Free water in the soil has capillary potential equal to zero, a condition when all the soil pores, capillary and non-capillary, are filled with water. Soil water potential can be determined indirectly by recourse to measurements of soil water content and soil water release or soil moisture characteristic curves that relate volumetric or gravimetric content to soil water potential. The measurement of water potential is widely accepted as fundamental to quantifying both the water status in various media and the energy of water movement in the soil-plant-atmospheric continuum (Livingston, N. J, 1993). In the research of Markoski, et al. (2009) it was confirmed that by reducing the moisture content in the soil, the value of the capillary potential is increasing.

For assessment of soil moisture by means of capillary potential, quantified by Schofield, quoted by Vucić (1987), he suggested pF values, where the force of water in the soil was expressed by the height of the water column in cm (1 bar =

1063 cm water cm^{-2}). The pF values are affected by the change of the mechanical composition and, according to the same author, the greater the share of the smaller fractions, the greater the pF values, especially at a pressure of 0.33 bars.

In our research, the water retention capacity (WRC) was established in laboratory conditions using pressure of 0.33 bars, and was expressed in mass percentage. Its average values per horizons are shown in Table 3.

Tabela 3. Soil moisture retentions of Rendzina Calcaric Regosol

Hor.	N	0.33 bar		0.5 bar		1 bar		4 bar		6.25 bar		15 bar	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
Ap_{ca}		23.60	5.50	21.74	5.52	19.80	5.41	17.29	5.29	15.81	4.49	13.81	4.24
Amo_{ca}		25.89	7.00	24.74	6.54	22.35	6.11	19.55	6.41	17.35	5.22	15.71	5.08
ACca	7	23.22	6.62	21.95	6.80	19.64	6.29	16.57	5.97	14.63	5.18	12.65	4.66
Cca		19.51	6.77	18.12	6.57	15.94	5.74	12.80	5.43	10.95	4.75	9.22	4.32

From the data presented in the Table 3, it can be seen that water retention capacity has the highest percentage in the Amo horizon of 25.89% due to the higher content of clay, colloid and organic matter, followed by the transitional AC horizon with a similar value of 23.22% and in the substrate C of 19.51%.

In all horizons of the examined Rendzina Calcaric Regosol, high values were obtained for moisture of wilting point. In the Amo horizon where the highest retention of moisture was observed at a pressure of 15 bars, high average value of physical clay fraction 46.60 % is shown.

The influence of mechanical and organic matter composition on the retention of moisture in the surveyed Rendzina Calcaric Regosol best expresses the high correlation between moisture retention at 0.33 (r=0.62) and 15.00 bars (r=0.98) in relation with the content of clay and retention of 0.33 and 15 bars at the silt fraction (r=0.75 and r=0.25) presented in Table 4. Similar values were obtained by Žic (1976), Rajkai, et al. (1996) and Markoski, et al. (2009), who found that soils with heavier mechanical composition have greater moisture retention, where the correlation coefficient ranges from r=0.75 to r=0.77. High correlation exists between the content of humus and retention moisture from 0.33 to 15 bars (r=0.83 and r=0.87).

In contrast, a high negative correlation is established between moisture retention and the composition of coarse and fine sand. Markoski (2008) found a positive correlation between physical clay content and moisture retention at tensions of 0.33 and 15 bars (r=0.948; r=0.828), and the highest negative correlation (r=-0971 i.e. r=-0.912) between the total sand content and moisture retention at same tensions.

Table 4. Correlation between soil texture humus and soil moisture retention

Fraction	Soil moisture retention					
	0.33	0.5	1	4	6.26	15
Clay	0.62	0.74	0.86	0.99	0.99	0.98
Silt	0.75	0.71	0.56	0.13	0.19	0.25
Coarse sand	-0.49	-0.84	-0.93	-0.99	-0.99	-0.99
Fine sand	-0.60	-0.76	-0.87	-0.99	-0.99	-0.98
Humus	0.83	0.50	0.66	0.93	0.90	0.87

If tension of soil moisture is measured, and for each tension, content of moisture is measured, expressed in volume percentage and the data obtained are applied to the coordinate system for each horizon, retention curves will be obtained. They reflect the ratio between attracting forces (tension) and the amount of moisture in the soil.

The knowledge of the essence of the retention and retention curves of Rendzina Calcaric Regosol is of great importance to the availability of water for the plant and the movement of water in the soil. Matula et al. (2007) emphasize that soil hydraulic characteristics, especially the soil water retention curve, are essential for many agricultural, environmental, and engineering applications. Their measurement is time-consuming and thus costly.

The data in the following graphs (1, 2, 3, 4, 5, 6 and 7) show lowering of the retention curves, which is most significant at lower pressures. The influence of mechanical composition on the retention of soil moisture can be seen from all graphs, where there is a large retention in humus accumulative horizon due to the amount of clay and humus compared to other horizons.
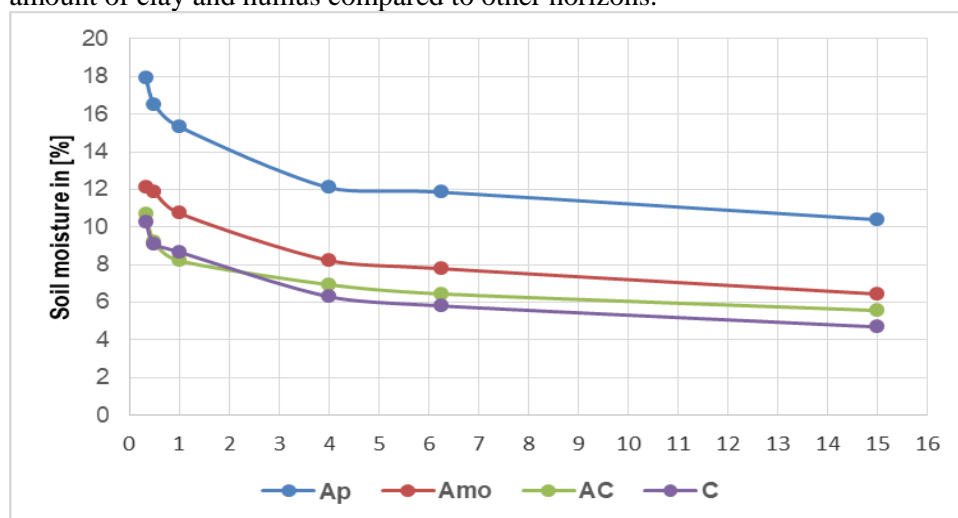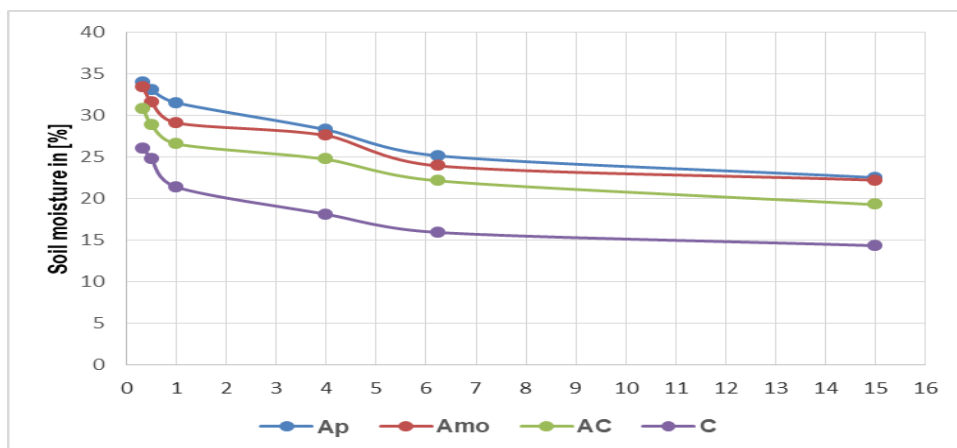

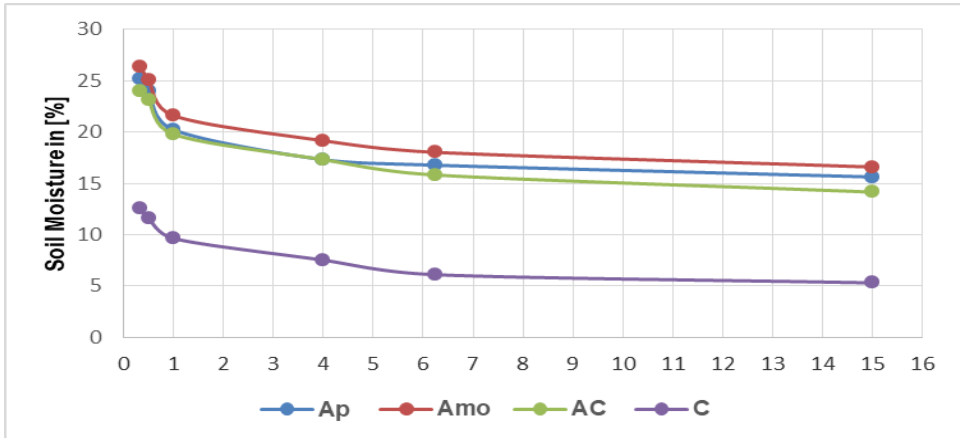Graphic 1. Soil moisture retention curves (profile 1)
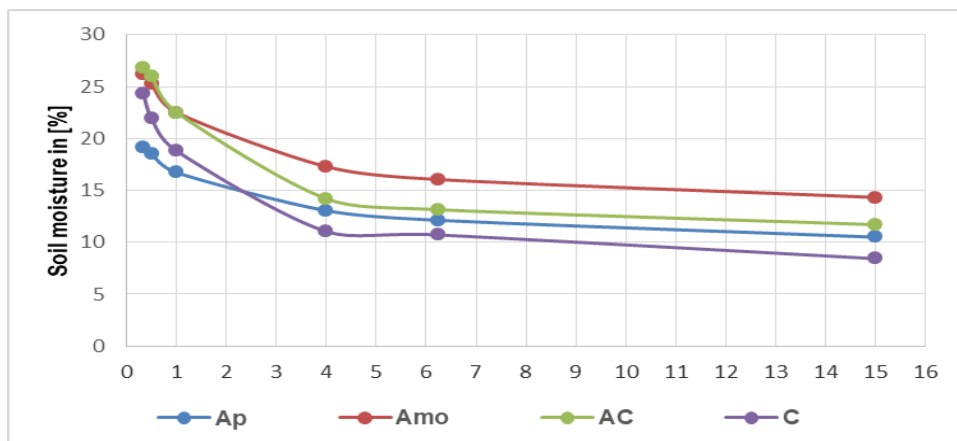
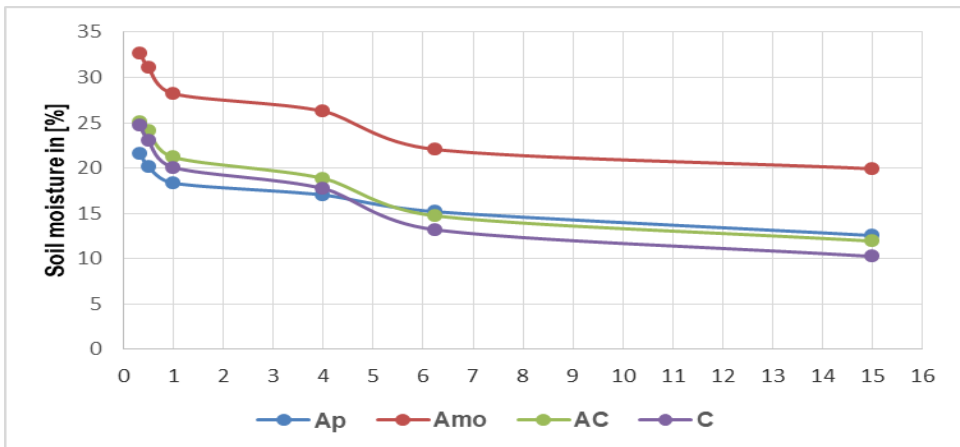Graphic 2. Soil moisture retention curves (profile 2)
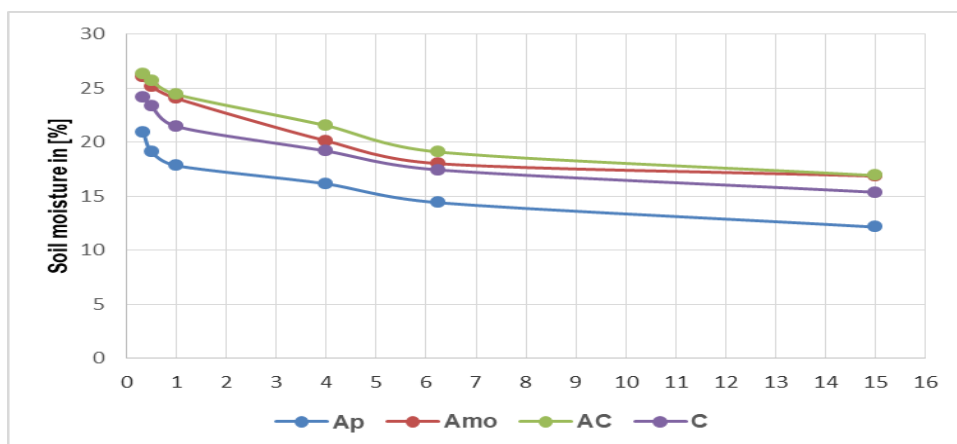
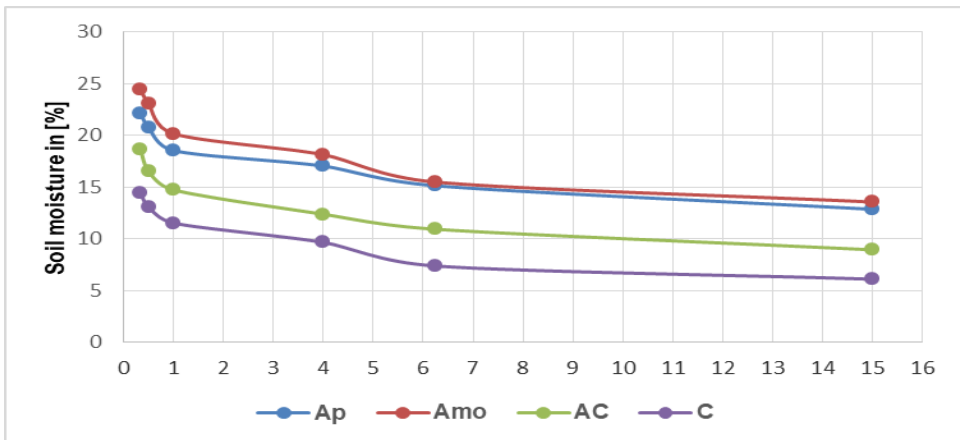Graphic 3. Soil moisture retention curves (profile 3)

Graphic 4. Soil moisture retention curves (profile 4)

Graphic 5. Soil moisture retention curves (profile 5)

Graphic 6. Soil moisture retention curves (profile 6)

Graphic 7. Soil moisture retention curves (profile 7)

The highest curve is the retention curve of the Amo_{ca} horizon due to the high content of humus and physical clay.

It can also be noted that the retention curves in all the horizons, ranging in tension from 2 to 15 tension bars, in almost all the cases are nearly horizontal and show a small decline since the content of clay and silt is not large. According to Filipovski (1996), the higher retention in Rendzinas can be explained by the higher content of Montmorillonite and Allophanes and higher content of $CaCO_3$ in the silt fraction. Filipovski et al (1980) give data on the retention curves of a profile of a Rendzina in the region of Kocani, where lower values of moisture at all applied pressures have been noted. The soil is characterized with lighter mechanical composition. The highest retention is present in the Amo horizon, as a result of the presence of organic matter and the influence of the mechanical composition (clay and silt). Similar values of retention curves for two horizons A and AC in rendzinas are presented by Wolińska, et al. (2010).

From the presented charts we can notice gradual changes in retention forces with the change of moisture without oscillations. It tells us that the distribution of soil moisture in various forms fails to find justification in the retention curve, as the reduction of the amount of water has no large oscillations at different tensions.

CONCLUSIONS

Based on the obtained results, the following conclusions can be drawn on the impact of mechanical composition of soil and humus content on the retention curves:

- The mechanical composition of the studied soils is characterized by domination of fractions of physical clay (clay + silt) and clay in soil separates, which strongly affect retention curves of soil moisture;

- In the humus accumulative Apca and Amoca horizon, the average content of humus is the largest (2.1% and 1.36%) where we have the highest retention of soil moisture;

- Moisture content that is retained at pressure of 0.33 bars is high in all horizons. The highest retention of Amoca 25.89% (presence of clay, physical clay and organic matter) is present in the Apca horizon, followed by the transitional ACca and the substrate Cca;

- Values obtained for the wilting point (pressure of 15 bars) are high in all horizons of rendzinas. This is due to the high content of physical clay and content of $CaCO_3$.

- Positive correlation has been established between the retention of moisture at 0.33 and 15 bars and the content of clay, silt, humus, and high negative correlation between retention of moisture at 0.33 and 15 bars.

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