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THE INFLUENCE OF THE PERLITE AS A SUBSTRATE FOR IMPROVING ON SOME WATER PROPERTIES ON THE FLUVIAL SOIL WITH AN APLICATION OF RETENTIONAL CURVES

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Abstract

This work is focused on the determination of potential of moisture retaining in perlite and fluvial soil. For assessing this parameter, the method of bar extractors and Porous plate extractors has been explored. The method is applied on 7 different regimes of pressure, (0.1; 0.33; 1; 3; 6.25; 11; 15 bars) in samples composed of perlite and fluvial soil present in different ratios of 20/80, 30/70, 50/50. The major goal of this study is to explore the experimental results of moisture content and to show the effectiveness of the water retention properties of perlite. Water retention curve is the relationship between the water content, and the soil and substrate water potential. This curve is characteristic for different types of soil and substrate, and is also called the soil moisture characteristic. The retention curve reflects the moisture content during different tension. The data determined in this work are useful to assess the effective zone of the root system. We show that perlite exhibits specific features in respect to the water retention in several types of soils. Because of the good physical properties and the high porosity, the expanded perlite has a significant role in maintaining and improving the water-air regime in the fluvial soils. In addition, it gives better accessibility of air and moisture for the plants, having a very positive influence on the soil features.

Key words: *Water retention, root system, physical properties.*

INTRODUCTION

Perlite is a glass volcanic rock of rhyolitic composition containing 2-5 % of combined water (Roulia et al. 2006). Technically, the term perlite is used for glassy volcanic rock which can be thermally expanded (Koukouzaset al.1994). The commercial product, commonly designated as expanded perlite, is produced by heating the material at 760–1100 °C, there by converting its indigenous water to vapour and causing the material to expand to 4 to 20 times its original volume while forming lightweight high-porosity aggregates, snow-white granules are composed of many tiny closed air cells or bubbles. They are very light in density, they have excellent thermal insulation properties, and they are fully inert and neutral (Dogan and Alkan, 2004; Harben, 1990).

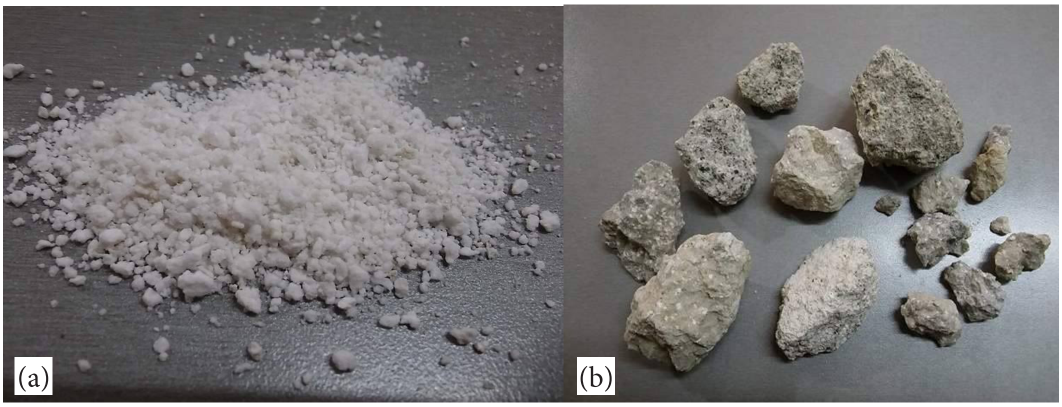

Figure 1. a) Expanded perlite b) Raw perlite
Photo: (Markoska, 2018)

Expanded perlite has several attractive physical properties for commercial applications including low bulk density, low thermal conductivity, high heat resistance, low sound transmission, high surface area, and chemical inertness Ennis (2011). Precisely, because of the expansion process and the series of positive features, the perlite is applied in many branches, (agriculture, construction, industry, technology, etc). As far as applications of perlite are concerned, it is mainly consumed as fillers, filter aids, in producing building construction materials (Morsy et al., 2008; Aglan et al., 2009), adsorptive materials, precursor for geo-polymer formation (Vance et al., 2009), removal of heavy metal ions and other pollutants from atmosphere (Mostaedi et al., 2010), in thermal insulation (Vaou et al., 2010), removal of dyes (Vijaykumar et al., 2009), Dogan and Alkan (2003) in horticulture sorption of oil etc. Perlite is a naturally occurring waste, estimated with about 700 million tons worldwide reserves. We use it in our research in expanded form as a substrate. The application of substrates to improve the properties of the soils requires knowledge of their physical and chemical properties that are responsible for providing adequate support and a reservoir for air, water and nutrients. The use of various organic and inorganic substrates such as perlite allows for better nutrient intake, sufficient growth and development due to optimization of water and oxygen (Verdonck and Demeyer, 2004). These media should guarantee better rooting conditions and provide anchorage for the root system, supply water and nutrients to plants and suitable aeration environment to roots (Gruda et al. 2013, 2006). One of the most important properties of substrates is by adding such improvers and substrates in the soil itself; they improve the soil regardless of what type of soil it is. The substrates are used to solve problematic soils such as sandy soils that do not retain enough water or too clayey soil which, on the contrary, retains too much moisture and less oxygen. But also, when soil conditions change, substrates serve as part of preventive care, even in the absence of the familiar problems. The reason why the substrates are to be added to the soil is to provide a better environment for the root system and plant growth. This includes improving the soil structure and water storage capacity, the availability of nutrients and living conditions for soil organisms that are important for plant growth and development.

MATERIAL AND METHODS

The experimental part served to determine the retention of moisture of perlite and fluvial soil at different pressures. The experimental part was divided into two parts: field part and laboratory part. The field part consisted of taking soil samples from Strumica and from the locality of the exploitation of the raw material perlite "Cera Poliana" in Mariovo, Gradesnica, Republic of Macedonia. The raw material perlite in this research will be used in its expanded form as a substrate. These soils are prevalent in all valleys of the area. Most of them are in Gevgelija and Strumica valleys. The hydrological maps of individual sheets on the area give a precise idea of their prevalence. During the pedological mapping of the valleys, it was established that the total area of alluvial soils is 8955 ha. Markoski (2015). The laboratory part consisted of preparation of the soil / substrate for analyses and conducting quantitative laboratory analysis. The soil and perlite were analysed in all three of their different ratios: 20/80, 30/70, 50/50 with the ultimate goal to determine the ability to retain water in the soil or substrate, and the role of perlite in improving the aquatic regime in examined soil. Soil samples were taken from the mentioned sites, perlite was used in expanded form as an expanded perlite or as a substrate, which further served us as a material for analysis. The soil samples from Strumica were taken at depth of 0-30cm. In laboratory conditions, soil samples were brought to an airy dry state. Then the soil was finely milled and sifted through a sieve with 2mm openings, and an average analytical sample was prepared in which further soil analysis was carried out. In laboratory conditions there was determined retention of perlite moisture and soil at higher pressures with application of a pressure limiter with Bar extractor for determination of moisture retention at 0.1 bar (pF - 2); 0.33 bar (pF - 2.54); 1 bar (pF - 3); To determine soil moisture retention in higher pressures, the Richard Porous plate extractor method was applied, 2.00 bar (pF - 3.3); 6.25 bar (pF - 3.90); 11 bar (pF - 4.04) and 15 bar (pF - 4.2), described by (Resulović, 1971; Belić et al., 2014). The obtained results for moisture retention in mass percent are presented in a tabular manner. Keeping water in the soil or perlite is marked as retention. The characteristics of moisture retention include the relations between the matrix potential and the moisture content and can be represented by a retention curve. It shows the moisture content at different tensions. Water retention is the result of two forces: adhesion (attraction of water molecules by the particles) and cohesion (attraction of water molecules to each other). Adhesion is much stronger than cohesion.

Figure 2. Preparing soil/substrate and placing samples on Bar extractor and Porous plate extractor

The force with which the water is retained in the soil, that is, the force it needs to squeeze out of the soil is denoted as capillary potential and is closely related to the water content. The free water in the soil has a capillary potential equal to zero, a condition in the soil when all pores, capillary and non-capillary, are filled with water. Markoski (2013) To obtain a clearer representation of the intensity of moisture retention, especially for soil and perlite, the fluvial soil along with perlite, the humidity values in mass percent tabular and graphic with pF values are displayed, the height of the water column in cm (1 bar = 1063 cm / cm^2).

RESULTS AND DISCUSSION

All examined samples of perlite and fluvial soil and their respective ratios were placed on 7 different pressure modes (0.33; 1; 3; 6.25; 11; 15 bar) using Bar extractor and Porous plate extractor, and the obtained results for moisture retention in mass percent's are presented in a tabular manner.

Table 1. Moisture retention in weight % at different tension in substrate perlite and fluvial soil na 0.1 bar; 0.33 bar; and 1bar

Substrate Perlit(P) Fluvial soil(Aa) and Corelations		0.1bar		0.33 bar		1bar	
	n	x	SD	x	SD	x	SD
Aa50/P50	3	27.52	0.02	24.53	0.03	20.51	0.01
Aa70/P30	3	25.05	0.17	23.14	0.15	19.07	0.12
Aa80/P20	3	22.15	0.12	20.72	0.22	15.08	0.23
P-perlite	3	67.88	1.88	58.35	1.59	47.70	1.57
Aa-soil	3	9.28	0.02	7.83	0.01	7.03	0.01

P- Perlite;Aa- Fluvialsoil; Corelations: P20/Aa80, P30/A70, P50/Aa50

Table 2. Moisture retention in weight % at different tension in substrate perlite and fluvial soil na 3 bar; 6.25 bar; 11bar and 15 bar

Substrate Perlite(P) Fluvial soil(Aa) and Corelations		3bar		6.25 bar		11bar		15bar	
	n	x	SD	x	SD	x	SD	x	SD
Aa50/P50	3	17.06	0.03	15.78	0.02	12.10	0.10	11.92	0.02
Aa70/P30	3	16.10	0.22	13.21	0.27	11.10	0.18	10.07	0.18
Aa80/P20	3	13.84	0.78	10.68	0.80	9.34	0.67	7.92	0.55
P-perlite	3	39.78	2.58	34.84	2.66	30.10	2.40	26.65	2.75
Aa-soil	3	5.24	0.01	4.39	0.01	3.99	0.01	3.02	0.01

P-Perlite ;Aa- Fluvial soil; Corelations: P20/Aa80, P30/A70, P50/Aa50

To understand more clearly the intensity of moisture retention in fluvial soil with perlite, the mean moisture values in mass percentage are shown. In the data given in Table 1 and 2 is noted that the P-perlite substrate has the largest retention capacity in all variants and at all points of pressure tension such as: At a pressure of 0.1 bar with an obtained result of an average value of 67.85% at pressure of 0.33 bar with an average value of 58.35%, at a pressure of 1 bar 47.70% of 3 bar 39.78% of 6.25 bar 34.84 at a pressure of 11 bar 30.10%, of 15 bar with average value of 26.65. The retention capacity of the fluvial soil is lower than the perlite in all pressures of different tension: from 0.1 bar = 9.28%, from 0.33 bar = 7.83%, from 1 bar = 7.03% , from 3 bars = 5.24%, from 6.25 bars = 3.99%, from 11 bars = 3.99%, from 15 bars = 3.02%.In other analysed ratios, where the perlite is represented by 20%, 30% and 50% in soil, the soil retention capacity is increased dramatically, for example in the ratio P20/80Aa at a pressure starting at 0.1 bar with an average value of 22.15%, at a pressure of 0.33 bar, the retention pressure equals an average value of 20.72%, at a pressure of 1 bar, the retention pressure equals the mean value of 15.08%, of 3 bar the retention pressure equals the mean value from 13.84%, from 6.25 bars with an average value of 10.68% at a pressure of 11 bars with an average value of 9.34%, a pressure of 15 bar retention pressure amounts to an average value of 7.92%. The retention pressure of other relations, such as P30/Aa70, and P50 /Aa50, is presented in table 1, with the addition of a larger percentage of perlite to soil, the retention pressure will increase. Figure 3 and 4 represent the retention curves of the substrate perlite and the fluvial soil. From the curves it can be noted that the percentage of moisture in the substrate perlite is higher, compared to the retention curve in the fluvial soil. The ability of the substrate to retain and maintain moisture is crucial for improving the efficiency of water use for growing crops in closed (greenhouses, greenhouses, etc.) and open conditions. According to the author Richards (1955) Retention curves have great practical and theoretical importance, because they show all data about the water in the soil and substrates. Retention curves or moisture retention curves (MRCs) were first described in Bunt (1961) and were obtained in a similar manner as in soils. The equivalent pores ratio can be estimated according to the retention curve. The tension occurring in the meniscus of water in one cylindrical pore depends on the pore diameter. Therefore, it can be concluded that the amount of water that soil releases in a certain dimension corresponds to this interval of tension. Moisture retention curves provide us data about soil and substrate capacity for available moisture, with the upper limit of field water capacity and the lower limit of the coefficient of the set. For estimating soil moisture, using capillary potential quantified Vućić (1987)pF values were determined, whereby the water force in the soil was expressed through the height of the water column in cm (1 bar = 1063 cm/cm2). pF values affect the change in the mechanical composition of the soil. The higher fraction of small fractions results in higher pF values, especially at a pressure of 0.33 bar. Markoski (2013) Apart from the mechanical composition of the soil, water - physical relations affect the mineral composition, the content of organic matter and others. This influence was studied Hillel (1980) and (Maclean and Yager, 1972) in many soils in America, Europe and Asia. In their research the soil moisture retention in West Midland mostly depends on organic matter, mechanical composition and mineral composition of soil. Filipovski (1996) also explains that retention of moisture in various tensions is closely related to the content of humus, clay, dust and mineral clay composition. According to the author Kutilek M. and Novak V., 1998 the hydrological characteristics of soils, such as water retention and the rate of water movement, depend on a large degree on the total porosity and pore-size distribution of the material while the moisture content in the perlite substrate depends on a higher percentage of the porous material. For our exploration of fluvial soil, the samples were taken at a depth of 0-30 cm. Fluvial soils are young roots of river that contain regulates and soil material from the obtained areas. These soils have good physical properties: they have good water resistance, and are well aerated. (Markoski et al., 2015) With the appearance of a sandy layer or gravel on the surface of the soil, the physiologically active layer of low humus content decreases. These types of soils are characterized by high water tolerance. Sometimes such negative examples of deterioration of the physical properties of the soil, using substrates or enhancers as perlite in our research can positively affect the improvement of these properties.

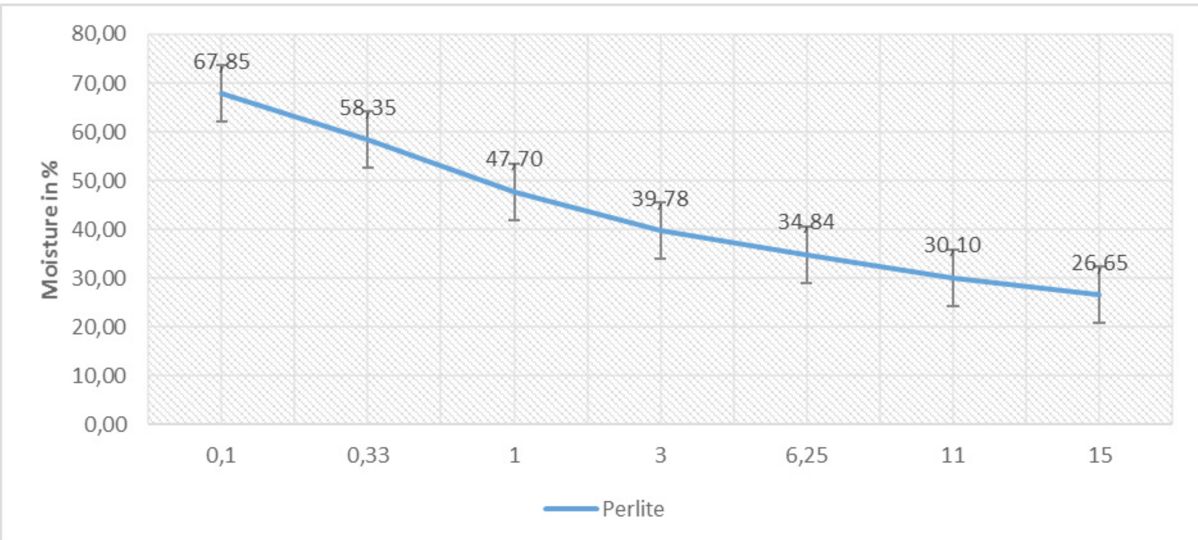

Figure 3. Moisture retention in substrate perlite

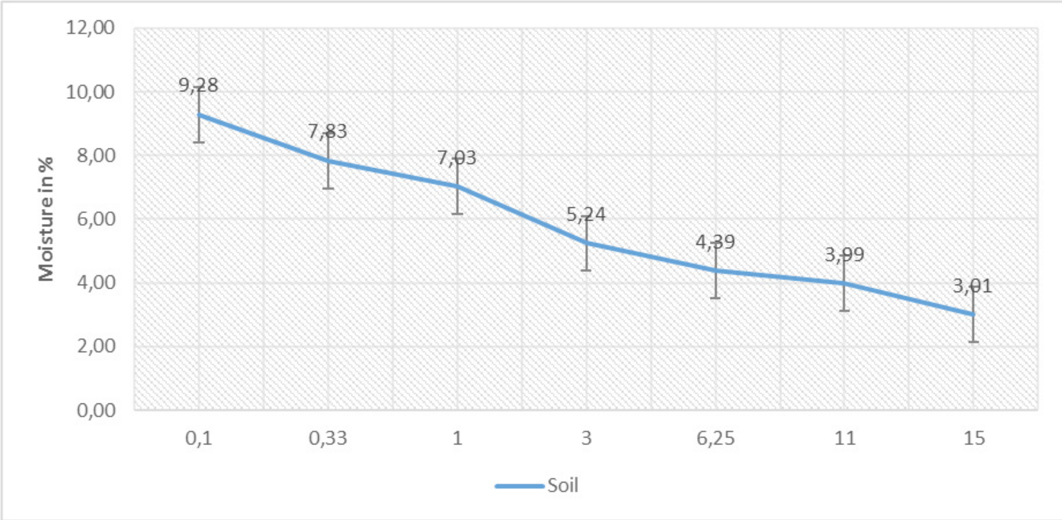

Figure 4. Moisture retention in fluvial soil type

Figure 5 shows the values of the retention curves of relations Aa80 / P20, also fluvial soil and pure perlite substrate. It can be noticed that the highest curve shows pure perlite, and the lowest shows fluvial soil. In the Aa80/P20 ratio, moisture retention increases by 10 to 22%, where retention curves increases in parallel. Because of the addition of 20% perlite to 80% of soil, where perlite with high porosity capacity can retain water with its particles, the percentage of moisture increases. Figure 6 shows the retention curves of three ratios, perlite as a pure substrate, fluvial soil and perlite ratio of 30/70 to fluvial soil. The largest retention ratio is the ratio of pure perlite substrate. It can also be noted on the curve that higher retention moisture occurs at 0.1 bar and 0.33 bar where all the pores are filled with water. The lowest retention occurs in the fluvial type of soil. In the ratio of Aa30/P70 where 30% of perlite and 70% of soil is fluid, the retention curve is growing from 10% to 28% of available moisture.

Figure 7 presents the retention curves of the relations between perlite and fluvial soil, and the ratio between perlite and fluvial soil is 50/50. Moisture retention in pure substrate perlite is represented by the highest retention curve due to its effective porous space to retain and maintain water in its pores, to create a relatively high content of available moisture. The retention curve of the soil shows lower retention of the perlite substrate; a significant difference between the soil type and the perlite substrate can be observed here. Whereas in the proportion of the mixture of 50% perlite and 50% fluvial soil, we have higher retention compared to the retention of pure fluvial soil, or a moderate increase in retention, the perlite as a substrate keeps the water in its pores, which can increase the retention of soil moisture

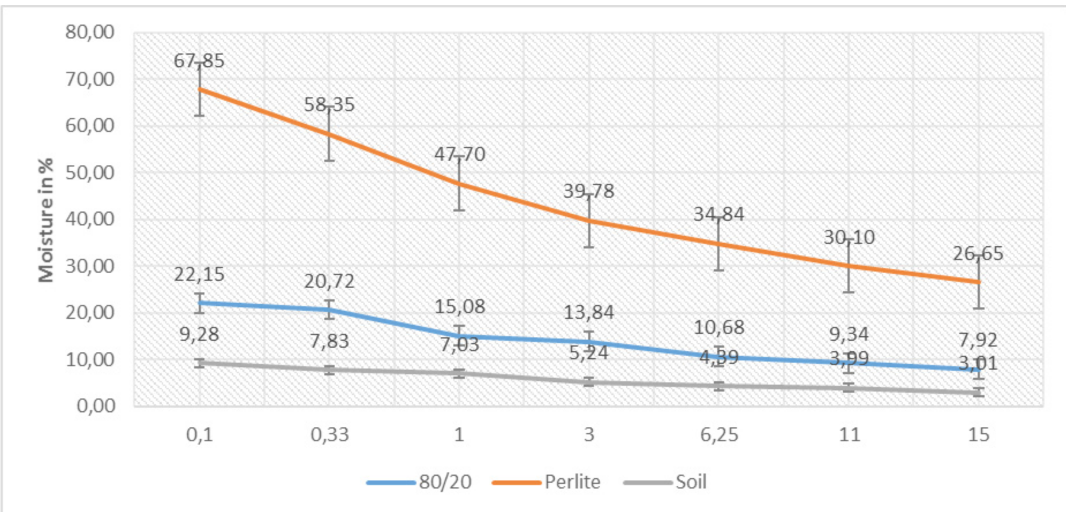

Figure 5. Moisture retention in perlite P20/80 Aa-fluvial

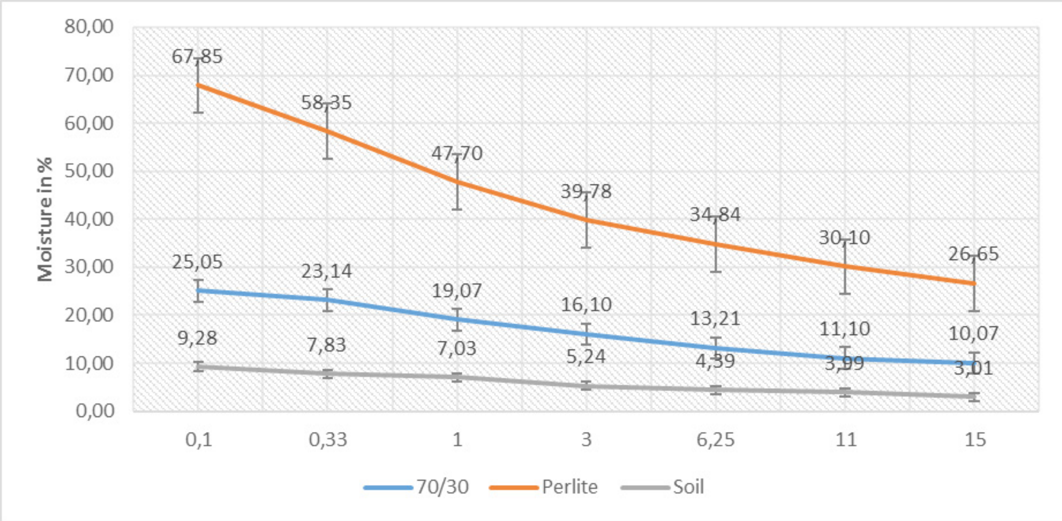

Figure 6. Moisture retention in perlite P30/70 Aa-fluvial

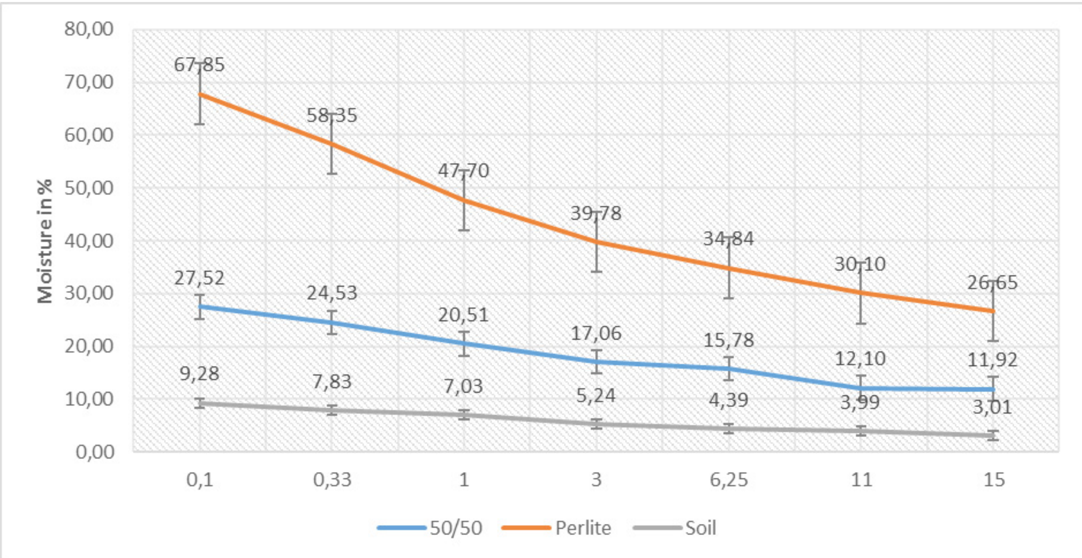

Figure 7. Moisture retention in perlite P50/50 Aa-fluvial

Table 3. Correlation coefficients between the tension points of 0.33; 1; 3; 6.25; 11; 15 bars

Correlation coefficients	0,1bar	0,33 bar	1bar	3bar	6.25bar	11bar	15bar
0,1 bar	1	0.998**	0.982**	0.972**	0.978**	0.958**	0.951**
0,33 bar		1	0.985**	0.977**	0.982**	0.962**	0.957**
1 bar			1	0.987**	0.991**	0.991**	0.979**
3 bar				1	.993**	0.978**	0.989**
6.25 bar					1	0.975**	0.991**
11 bar						1	0.972**
15 bar							1

In table 3 the coefficients of correlation of the researched properties in different ratios of the perlite substrate and the fluvial soil are given. On the basis of the correlation analysis, it can be noted that there is a high positive correlation between all points of tension within the mutual relations. The authors of the paper Jeb S, Fields, William C, Fonteno, and Brian E, Jackson, (2014), have examined the physical properties of the perlite and tested the moisture retention by methods from the manual (Fonteno and Harden, 2010), with Volumetric Pressure Plate Extractors with (-Kra), which yielded similar results with ours, the percentage of moisture in the perlite substrate was 66% per 0.1 bar, 43% per 1 bar and 31% of moisture per 10 bar.

CONCLUDING REMARKS

Based on the results obtained in the laboratory analysis of the perlite as a substrate and the fluvial soil, we can conclude the following: The analysis of moisture retention in the perlite shows high moisture retention at all points of tension (0.1; 0.33; 1; 3; 6.25; 11; 15 bar). The analysis of the retention capacity of the analysed fluvial soil shows a lower retention capacity compared to the perlite's retention capacity at all points of tension. In other proportions of Aa80/P20 or the addition of 20% perlite in river soil, the value increases several times, which again confirms that the addition of perlite in the fluvial soil samples causes an increase in retention capacity at all points of tension such as 0.1; 0.33; 1; 3; 6.25; 11; 15 bar, starting from 0.1 bar with an average value of 22.15% to 15 bar of retention soil, which amounts to 7.92% moisture. The Aa70/P30 ratio also shows a slight increase in retention capacity of fluvial soil at all points of tension such as 0.1; 0.33; 1; 3; 6.25; 11; 15 bar. With a further 50% perlite increase in soil at the Aa50/P50 ratio, retention capacity increases with an average value of 27.52%, starting from 0.1 bar to 15 bar with a moisture content of 11.92%.A high retention curve which reflects the characteristics of moisture retention in pure perlite substrate shows that this results in the fact that it's effective porous space keeps and maintains water in its pores. It is noted that the addition of substrate perlite in the soil also increases the values for retention capacity. Perlite due to its high porosity, which keeps water in its pores, influence the improvement of the water regime of the examined fluvial soil by retaining and maintaining moisture and providing adequate support and a water reservoir that is needed for proper growth of the plants and more healthier soil. Retention curves have great practical and theoretical significance, because through them almost all data about water in the soil and substrate can be obtained, these curves give the opportunity to determinate when and what content of water the plant's needs. In this way we can see the relations among the water, soil, and plants. The strength of water persistence in the soil or substrate can be determined for all content of water. Humidity retention curves provide us with data about the capacity of the humidity available within the soil and substrates, whose upper limit defines the water capacity of the ground and lower limit the coefficient of fading. These data, particularly for the effective area of the root system, become applicable when water is exploited in the soil.

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ВЛИЈАНИЕ НА ПЕРЛИТОТ КАКО СУПСТРАТ ЗА ПОДОБРУВАЊЕ НА НЕКОИ ВОДНИ СВОЈСТВА НА ФЛУВИЈАТИЛНА ПОЧВА СО ПРИМЕНА НА РЕТЕНЦИОНИ КРИВИ

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Резиме

Во овој труд ќе бидат прикажани податоците за потенцијалот на задржување на влагата кај перлитот и флувијатилната почва со методот на Barextractor и Porous plate extractor на 7 различни режими на притисок, при различна тензија од (0,1; 0,33; 1; 3; 6,25; 11; 15 бари), кај перлитот и флувијатилна почва со нивни различни соодноси од 20/80, 30/70, 50/50. Резултатите од кривите на ретенција ќе бидат прикажани графички. Исто така, прикажани ќе бидат и резултати од регресискиот мултиваријантен статистички модел за влијанието на различните варијанти, различниот соодноs во варијантите и нивната интеракција врз различни режими на притисок. Целта на оваа студија е да се презентираат и да се дискутираат експерименталните резултати на содржината на влага и својствата на ефективно задржување на вода кај почвата и супстратот перлит. Под карактеристики на ретенцијата на влага се подразбира односот помеѓу содржина на вода и потенцијалот на вода во почвата /супстратот и може да се претстави со ретенциона крива, таа ја покажува содржината на влага при различна тензија. Овие податоци се корисни особено за ефективната зона на кореновиот систем и наоѓа примена во употреба на вода во почвата или супстратите. Поради добрите физички својства и висок порозитет, експандираниот перлит има улога да го одржува и подобрува водно-воздушниот режим во флувијатилната почва, при што влагата и воздухот ги прави подостапни за растенијата и со тоа влијае позитивно врз почвата.

Клучни зборови: *ретенција на влага, коренов систем, физички карактеристики*