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A RESEARCH ON THE INFLUENCE OF POROSITY ON PERLITE SUBSTRATE AND ITS INTERACTION ON POROSITY OF TWO TYPES OF SOIL AND PEAT SUBSTRATE

SUMMARY

Perlite is a generic name for an amorphous volcanic rock that expands by a factor of 4–20 when rapidly heated to (760–1100°C). Water trapped in the structure of the material vaporises and escapes, and this causes the expansion of the material to 7–16 times its original volume. The expanded material is a brilliant white, due to the reflectivity of the trapped bubbles. 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.

The perlite supplies the ideal balance between air and water. Perlite is sterile, inert, non-toxic, non-decomposable and easy to handle with, enhanced water retention and aeration capacity. The application of substrates which improve the properties of the soils requires knowledge of their physical and chemical characteristics that are responsible for providing adequate support and a reservoir for air, water and nutrients.

Agricultural production is increasingly concerned about the study of the impact of improvers of properties, such as perlite, that affect the properties of soils as well as their impact on yield and plant quality. The goal of this paper is to observe the influence of porosity on the Perlite substrate and its interaction with the porosity of two types of soil and the peat substrate. The laboratory part comprised preparation of the substrate perlite, soils, and substrate peat for analyses and conducting quantitative laboratory analysis.

The substrate perlite, soils and substrate peat were analysed in all five of their different ratios: Perlite (Pe) 20%; 30%; 50%; 70%; 80% by volume) and 100% perlite. Fluvial soil (FS) 80%; 70%; 50%; 30%; 20% by volume) and 100% fluvial soil. Mollic Vertic Gleysol (GS) 80%; 70%; 50%; 30%; 20% by volume) and 100% mollic vertic gleysol. Peat (P) 80%; 70%; 50%; 30%; 20% by volume) and 100% Peat. In laboratory conditions the total porosity (in percentage form) was determined with the help of apparent and specific density (apparent density through applying the Koppecki method (specific density was determined

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through the Gracanin method. The pores' total content is determined indirectly on the basis of the specific mass and volume mass. The results will be displayed through statistical data processing.

Key words: perlite, soil, porosity.

INTRODUCTION

Perlite is a 100% natural siliceous volcanic glass mineral, which traps crystalline water into its mass. Perlite expands when rapidly heated in temperatures of 700°C–1100°C (Dogan and Alkan, 2004). The way of preparation of fine expanded perlite, was given by (Sodeyama et al., 1999). Causing entrapped water molecules in the rock to turn to steam and expand the particles like popcorn.

The abrupt, controlled rise of temperature forms a white mass of minuscule glass bubbles. Perlite melts and expands in an extremely porous surface and increasing its volume up to 4-20 times of its original volume (Ennis, 2011). It is very porous, has a strong capillary action and can hold 3–4 times its weight in water. (Bures et al. 1997a). This microstructure gives the material a set of favourable properties such as excellent insulation properties, low density and high porosity (Sengul et al., 2011; Kramar and Bindiganavile 2013; Polat et al., 2015). Here are a number of obvious advantages of perlite over other substrates like stability, great properties such as: ultra-lightweight, excellent water retention up to four times its weight, advances drainage and aeration, pH natural and asbestos free, chemically inert, sterile, free of weeds and permanent, serves as an insulator to reduce extreme soil temperature fluctuations, reduces concentrations of salt and also promotes the long term effect of fertilizers (Raviv, M., and Lieth, J ,H, 2008; Asher B.,T et al., 2008).

Moreover, it is commonly used in the food industry, filter product, growing of seed, regulating of the soil in agriculture, and in so many other industrial applications (Alihosseini et al., 2010). Perlite has very good physical characteristics. The physical properties of container-growing substrates, particularly air space, container capacity, and bulk density, have a significant impact on plant growth, and knowledge of these properties is essential in properly managing nursery irrigation and fertilization programs (Yeager et al., 2000). Peat is formed as a result of the partial decomposition of plants (Sphagnum, Carex) typical of poorly drained areas (peat bogs), with low nutrients and pH, under low temperatures and anaerobic conditions (Raviv et al., 2002). Other relevant properties are the high easily available water under conditions of container capacity, i.e. after the end of free drainage and the high oxygen diffusion rate. On the other hand, as negative aspect peat can be a conducive substrate for numerous soil-borne diseases and its sterilization does not solve the problem as it leaves a biological vacuum that can be easily filled by pathogenic fungi. (Abad et al., 2001).

Peat use in horticulture increased during the last decades, resulting in rising costs and generating doubts about availability of this material in the near future due to environmental constraints. In fact, peat mining has been recently questioned because it is harvested from peat lands, highly fragile wetlands ecosystems with a great ecological and archaeological value, included in the list of natural habitats with a potential degradation. (Barber et al., 1993). Peat also plays an important role in improving groundwater quality, and peat bogs also serve as a special habitat for wild plants and animals. Moreover, these ecosystems represent important carbon dioxide (CO_2) sinks (Maher et al., 2008). Peat is the most widely used growing media and substrate component in horticulture, currently accounting for 77–80 percent of the growing media used annually in Europe's horticultural industry (Gruda, 2012),

Seedlings and transplants are grown predominantly in organic substrates based on peat it is also used in horticulture as a raw material for substrates in which container plants are grown (Gruda, 2005). The term alluvial originates from the Latin word *alluvio* which means rubble. Lately, names that originate from the Latin word *fluvius* river are being used. The following such names can be frequently encountered: fluviogenic soil, fluvizem, fluvisol, fluvent etc. In our newest classification multiple terms are used: alluvial or fluviatile soils (fluvisol) which are classified as fluvisol according to WRB 2016. In regards to physical properties fluvial soils are quite heterogeneous in their mechanical composition. All varieties of soils can appear among fluvial soils from sandy to clayish soils. However, they are most often sandy loam or loamy sand. In most cases, fluvial soils have good porosity, an advantageous relation between capillary and non – capillary pores, they are well aerated, they permeate water quite well etc.

The following definition is ascribed for the soil type of Mollic Vertic Gleysol (Filipovski, 1996) hydromorphic soils which have a darkly colored mollic humus horizon with possible signs of hydromorphy. The humus horizon usually has a dark grey color to a distinctly black color, out of which the name is derived. These soils are rich in clay and the clay content is above 40% in hor. A. The physical properties (water-air regime) of these soils depend on the mechanical composition of the substrate and the mineralogical composition (especially the contents of montmorillonite), the humus contents, some processes that are significant for the physical properties (re-covering with new rubble, duality of the layers, alkalization and human influence).

Aeration as an important physical property is of great significance for non – capillary porosity which on average is around 5%. This speaks to the fact that the soil is not aerated enough when it is saturated in regard to its field capacity. The goal of this paper is to observe the influence of porosity on the perlite substrate and its interaction with the porosity of two types of soil and the peat substrate. The water and air regime of the soil/substrate depends on the porosity and its character which means supplying the plant with sufficient quantities of water and air. Knowing the total porosity, the relationship between the macropores and micropores, the stability of the porous system and the total internal surface of the pores has an immense practical significance for the soil as well as the substrates for plants growth.

MATERIAL AND METHODS

The experimental part served to determine on the influence of porosity on perlite substrate and its interaction on porosity of two types of soil and peat substrate. The experimental part was divided into two parts: field part and laboratory part. The used perlite originates from Cera Poliana, Mariovo Gradesnica, Republic of Macedonia, and was applied in expanded (commercial) form. The experimental part was divided into two parts: field part and laboratory part. The laboratory part comprised preparation of the substrate perlite, soils, and substrate peat for analyses and conducting quantitative laboratory analysis.

The substrate perlite, soils and substrate peat were analyzed in all five of their different ratios: Perlite (Pe) 20%; 30%; 50%; 70%; 80% by volume) and 100% perlite, Fluvial soil (FS) 80%; 70%; 50%; 30%; 20% by volume) and 100% fluvial soil. Mollic Vertic Gleysol (GS) 80%, 70%, 50%; 30; 20 by volume) and 100% mollic vertic gleysol. Peat (P) 80%; 70%, 50%; 30%; 20% by volume) and 100% peat. The soil samples 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 the total porosity (in percentage form) was determined with the help of apparent and specific density (apparent density through applying the Koppecki method (Mitrikeski and Mitkova, 2013) (specific density was determined through the Gracanin method (Resulovic, H. et al., 1971). The pores' total content is determined indirectly on the basis of the specific mass and volume mass.

The results will be displayed through statistical data processing. The first statistical analysis of the gathered data was made with the descriptive procedure for analysis of frequencies and data dispersion depending on the factors of influences. The obtained results are represented as an average with a ± standard deviation from the arithmetic mean value. With the help of the general linear model, the multivariate procedure, the influence of independent (factor) variables were tested and their interaction on the mean values of the different groupings from the physical and chemical properties of the examined variants. For those variables, for which the F-value has displayed statistical significance, a post – hoc test was implemented i.e the Bonferoni test. With it, the differences between the specific mean values of the pairs were assessed in a multiple comparison for the factors involved in the model. The interdependence of variables incorporated in statistical regression models was examined through Pearson's correlation coefficient. The obtained results will be presented through tables, sketches, etc.

RESULTS

In Table 1 the results are displayed with the mean values of: total porosity, water and air porosity of the analyzed samples: Perlite (Pe) 20%; 30%; 50%; 70%; 80% by volume) and 100% perlite. Fluvial soil (FS) 80%; 70%; 50%; 30%; 20% by volume) and 100% fluvial soil. Mollic Vertic Gleysol (GS) 80%; 70%, 50%; 30%; 20% by volume) and 100% Mollic Vertic Gleysol. Peat (P) 80%; 70%; 50%; 30%; 20% by volume) and 100% peat. The results of the multivariate regression statistical model will be presented for the influence of the different variants, the different correlation in variants and their interaction with total porosity, water and air porosity. Additionally, the results of the post hoc analysis for the testing of the differences in mean values of dependent variables are presented, depending on the sources of variation.

The analyzed sample of Perlite (Pe) has displayed the highest percentage of total porosity out of all analyzed samples from Table 1 with a mean value of 88.09%, out of which 60.2% in mean value is air porosity and 27.9% is water porosity. The contents of total porosity of fluvial soil (FS) is has a mean value of 77.73% out of which 39.68% with a mean value is water porosity and 38.05% is air porosity. All the other analysed samples in their various ratios are displayed in Table 1.

	Formulation	Designation
1.	100% Perlite (commercial substrate)	(Pe)
2.	100% Peat (commercial substrate)	(P)
3.	80% Perlite + 20%Peat	Pe80/P20
4.	70%Perlite + 30% Peat	Pe70/P30
5.	50%Perlite + 50% Peat	Pe50/P50
6.	30%Perlite + 70% Peat	Pe30/P70
7.	20%Perlite + 80% Peat	Pe20/P80

	Formulation	Designation
1.	100% Perlite (commercial substrate)	(Pe)
2.	100% Fluvial soil (soil)	(FS)
3.	80% Perlite + 20% Soil	Pe80/FS20
4.	70%Perlite + 30% Soil	Pe70/FS30
5.	50%Perlite + 50% Soil	Pe50/FS50
6.	30%Perlite + 70% Soil	Pe30/FS70
7.	20%Perlite + 80% Soil	Pe20/FS80

	Formulation	Designation
1.	100% Perlite (commercial substrate)	(Pe)
2.	100% Mollic Vertic Gleysol (Soil)	(GS)
3.	80% Perlite + 20% Soil	Pe80/GS20
4.	70%Perlite + 30% Soil	Pe70/GS30
5.	50%Perlite + 50% Soil	Pe50/GS50
6.	30%Perlite + 70% Soil	Pe30/GS70
7.	20%Perlite + 80% Soil	Pe20/GS80

Table 1. Physical properties of perlite substrate and fluvial soil

	n	Air porosity %		Water porosity %		Total porosity %	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Pe-Perlite	3	60.20	0.01	27.90	0.01	88.09	0.01
FS-Fluviol Soil	3	38.05	0.28	39.68	0.60	77.73	0.84
Pe80/FS20	3	55.77	0.01	29.61	0.01	85.38	0.01
Pe70/FS30	3	53.56	0.19	31.43	0.40	84.99	0.23
Pe50/FS50	3	49.13	0.03	33.79	0.03	82.92	0.02
Pe30/FS70	3	44.69	0.62	36.15	0.22	80.84	0.79
Pe20/FS80	3	42.48	1.06	37.16	0.89	79.64	1.95

An overview of the following results is displayed in Table 2 total porosity, water and air porosity of analyzed samples of Perlite (Pe), Mollic Vertic Gleysol (GS) and their mixtures in various ratios. The highest value of total porosity was recorded in the Perlite ratio with a mean value of 88.09% while the lowest value was recorded in the Mollic Vertic Gleysol with a mean value of 49.99%. The highest percentage of water porosity was noted in the mollic vertic gleysol with a mean value of 42.79% and the lowest in perlite with a mean value of 27.9%.

The highest air porosity was noted in perlite with a mean value of 60.2% while the lowest air porosity was recorded in mollic vertic gleysol with a mean value of 4.21%. All the other analyzed samples in their various ratios are displayed in Table 2

Table 2. Physical properties of perlite substrate and mollic vertic gleysol

	n	Air porosity %		Water porosity %		Total porosity %	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Pe-Perlite	3	60.20	0.01	27.90	0.01	88.09	0.01
GS- Mollic vertic gleysol	3	4.21	1.41	42.79	0.01	46.99	1.41
Pe80/GS20	3	49.00	2.74	30.23	1.06	79.23	0.86
Pe70/GS30	3	43.40	1.70	32.37	1.03	75.77	0.93
Pe50/GS50	3	32.20	1.03	35.34	1.17	67.54	1.65
Pe30/GS70	3	21.00	0.09	38.23	0.93	59.23	1.33
Pe20/GS80	3	15.40	0.92	39.65	1.22	55.05	1.13

The following results are displayed in Table 3 total porosity, water and air porosity and the total retention capacity of the analyzed samples of Perlite, Peat and their mixtures in various ratios. The highest total porosity was noted in Peat (P) with 90.8% out of which 10.7% belong to air porosity and 80.1% with a mean value belong to water porosity. A somewhat lower porosity was noted in Perlite (Pe) with a mean value of 88.09% out of which 27.9% belong to water porosity and 60.2% to air porosity. All the other analyzed samples in their various ratios are displayed in Table 3.

Table 3. Physical properties of Perlite substrate and peat

	n	Air porosity %		Water porosity %		Total porosity %	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Pe-Perlite	3	60.20	0.01	27.90	0,01	88.09	0.01
P-Peat	3	10.70	1.03	80.10	0.93	90.80	1.95
Pe80/P20	3	50.30	0.16	39.96	0.53	90.26	0.68
Pe70/P30	3	45.35	0.15	44.64	1.08	89.99	1.02
Pe50/P50	3	35.45	0.28	54.00	0.28	89.45	0.55
Pe30/P70	3	25.55	0.56	63.55	0.41	88.90	1.76
Pe20/P80	3	20.60	0.83	68.03	0.60	88.63	1.58

Table 4. Multivariate general linear model for the influence of variants, various ratios within the variants and their interaction on water porosity, air porosity, total porosity

Parameters	Source of variation									
	Model		Variants		Ratios		Variants x ratios		Error	
	df	F	df	F	df	F	df	F	df	Variance
[a]Air porosity %	21	5454.2***	2	1045.4***	6	1919.9***	12	1360.8***	42	0.9
[b]Water porosity %	21	7046.9***	2	6245.3***	6	836.6***	12	1163.3***	42	0.9
[c]Total porosity %	21	14120.7***	2	3608.3***	6	335.8***	12	138.3***	42	1.2

[a]R^2 = 0,919; [b]R^2 = 1; [c]R^2 = 0,1.

***statistically significant on level p<0.001;**statistically significant on level p<0.01;*statistically significant on level p<0.05

All statistical models about the influence of the variants and the different ratio of Perlite and fluvial soil, Perlite and Peat and Perlite with Mollic Vertic Gleysol soil in the respective variants, as well as the interaction of the variant and the ratio with water porosity, air porosity and total porosity have displayed a high statistical significance ($p<0.001$).

According to the results obtained out of the statistical model, displayed in Table 4 the variants displayed a significant statistically high influence of water porosity, air porosity and total porosity ($p<0.001$). The influence of the various ratios within the variants have also displayed a significant statistically high influence on water porosity, air porosity and total porosity ($p<0.001$). The interaction of the variants and the ratios have displayed a statistically high influence ($p<0.001$) on water porosity, air porosity and total porosity. The value of R^2 in all three statistical models was high. This means that a large part of the variant for water porosity, air porosity and total porosity can be explained through the variation sources involved in the model.

The testing of the differences between the mean values of air porosity depending on the variant are displayed in Table 5. A statistically significant difference between the mean values of air porosity was recorded among all variants. Throughout it, the largest statistically significant difference in the mean values of air porosity has been determined among the Perlite/Fluvial soil and Perlite/Peat variants with a value of 12.72%.

Table 5. Testing the differences of the mean values of air porosity between the variants

Air porosity %	Perlite/ Peat	Perlite/ Mollic Vertic Gleysol
Perlite/ Fluvial soil	12.72*	9.1*
Perlite/ Peat	1	-3.6*

*statistically significant on level p<0.05

Table 6. Testing the differences of the mean values of air porosity depending on the different ratio of Perlite, Fluvial soil, Peat and Mollic Vertic Gleysol in the respective variants

Air porosity %	FS,GS, P70/Pe30	FS,GS,P80/ Pe20	FS,GS, P30/Pe70	FS,GS, P20/Pe80	Perlite	FS, FG, P
FS,GS,P50/Pe50	6.49*	9.58*	-2.27*	-5.67*	-31.11*	-11.70*
FS,GS,P70/Pe30	1	3.10*	-8.75*	-12.15*	-37.60*	-18.19*
FS,GS,P80/Pe20		1	-11.85*	-15.25*	-40.70*	-21.28*
FS,GS,P30/Pe70			1	-3.40*	-28.85*	-9.43*
FS,GS,P20/Pe80				1	-25.45*	-6.03*
Perlite					1	19,41*

*statistically significant on level $p<0.05$

A statistically significant negative difference was noted in the mean values of air porosity between Perlite and the different ratios which points to the realization that the percentage of air porosity in Perlite is larger compared to the presence of air porosity in the different ratios of the variants in Table 6. The biggest statistically significant difference between the values of air porosity of the variants was determined between the ratio FS, GS, P80/Pe20 and FS, GS, P20/Pe80 with a value of 15.25%. Likewise, the difference in the mean values of air porosity of the soils and Peat that are used in the formation of various ratios and the ratios within the variants has displayed a statistically significant difference. However, the greatest difference in the mean values of air porosity i.e. 19.41% was noted between Perlite and the appropriate soils and Peat which in various ratios comprised the variants.

The testing of the differences between the mean values of water porosity depending on the variant is displayed in Table 7. A statistically significant difference between the mean values of water porosity was noted among all variants. Throughout it, the largest statistically significant difference in the mean values of water porosity was determined between the variants Perlite/Mollic Vertic Gleysol and Perlite/Peat with a value of 30.94%. A very noticeable fact was the statistically significant positive difference in the mean values of water porosity between Perlite and the ratio FS, GS, P80/Pe20. The largest statistically significant difference between the values of water porosity and the variants was determined between the ratio FS, GS, P80/Pe20 and FS, GS, P20/Pe80 with a value of 15.98%.

Table 7. Testing the differences of the mean values of water porosity between the variants

Water porosity %	Perlite/Peat	Perlite / Mollic Vertic Gleysol
Perlite/ fluvial soil	-20.08*	10.86*
Perlite/Peat	1	30.94*

*statistically significant on level $p<0.05$

Table 8. Testing the differences of the mean values of water porosity depending on the different Perlite ratio, Fluvial soil, Peat and Mollic Vertic Gleysol in the respective variants

Water porosity **%**	FS,GS ,P70/Pe30	FS,GS P80/Pe20	FS,GS P30/Pe70	FS,GS P20/Pe80	Perlite	FS,GS,P
FS,GS,P50/Pe50	-5.70*	-8.81*	5.85*	7.17*	14.82*	11.66*
FS,GS,P70/Pe30	1	-3.11*	11.55*	12.87*	20.52*	17.36*
FS,GS,P80/Pe20		1	14.66*	15.98*	23.63*	20.47*
FS,GS,P30/Pe70			1	1.32	8.97*	5.81*
FS,GS,P20/Pe80				1	7.65*	4.49*
Perlite					1	-3.16*

*statistically significant on level p<0.05

The difference in the mean values of water porosity of the soils and Peat used in the formation of the various ratios and the ratios within the variants has also indicated a statistically significant difference depicted in Table 8. However, the largest difference in the mean values of water porosity i.e. 20.47% has been noted between Perlite and the respective soils and Peat which in various ratios formed the variants. The testing of the differences between the mean values of total porosity depending on the variant is displayed in Table 9. A statistically significant difference between the mean values of total porosity was noted among all variants. Throughout it, the largest statistically significant difference in the mean values of total porosity was determined among the Perlite/ Mollic Vertic Gleysol and Perlite/Peat variants with a value of 27.63%.

Table 9. Testing the differences of the mean values of water porosity between variants

Total porosity %	Perlite/Peat	Perlite / Mollic Vertic Gleysol
Perlite/ fluvial soil	-7.63*	19.99*
Perlite/Peat	1	27.63*

*statistically significant on level p<0.05

Table 10. Testing the differences of the mean values of total porosity depending on the different ratio of Perlite, Fluvial soil, Peat and Mollic Vertic Gleysol in the respective variants

Total porosity %	FS,GS P70/Pe30	FS,GS P80/Pe20	FS,GS P30/Pe70	FS,GS P20/Pe80	Perlite	FS, GS, P
FS,GS,P50/Pe50	0.34	0.55	3.54*	1.50	-16.29*	-0.04
FS,GS,P70/Pe30	1	0.21	3.20*	1.17	-16.63*	-0.38
FS,GS,P80/Pe20		1	2.99*	0.95	-16.84*	-0.59
FS,GS,P30/Pe70			1	-2.04*	-19.83*	-3.58*
FS,GS,P20/Pe80				1	-17.79*	-1.5
Perlite					1	16.25*

*statistically significant on level p<0.05

A statistically significant negative difference was once more noticeable in the mean values of total porosity between Perlite and the different ratios which points to the realization that the total porosity in Perlite is larger compared to the total porosity in the various ratios of the variants. The largest statistically significant difference between the values of total porosity was determined between the ratio FS, GS, P30/Pe70 and FS, GS, P50/Pe50 with a value of 3.54% which is depicted in Table 10. The difference in the mean values of total porosity of the soils and Peat used in the formation of different ratios and the variants ratios has also displayed a statistically significant difference. Never the less, the largest difference in the mean values of total porosity i.e. 16.25% was noted among Perlite and the respective soils and Peat which comprised the variants in various ratios.

DISCUSSION

Porosity or void fraction is the total volume of the pores (cavities) expressed in voluminous percentages of the total soil/raw material in a natural (undistorted) state. The volume of all pores in a certain volume i.e. soil/raw material constitutes total porosity which is encompassed by water and air. In the macropores (non – capillary pores) there is air while in the micropores (capillary pores) there is water. Through irrigation the water gets into all pores but it is only retained in the capillary pores. A different ratio between capillary and non – capillary pores will induce a different water and air regime. Total porosity, capillary and non – capillary porosity differ among each other. In our research the values of total porosity, water porous capacity, air porous capacity of Perlite substrate with Fluvial soil, Mollic Vertic Gleysol and Peat substrate were analyzed. Out of the obtained results with their respective values from Table 1 and Table 2 for total porosity it can be noted that Perlite as a substrate has a very high porosity with a mean value of 88.09% out of which 60.2% belong to air porosity and 27.9% belong to water porosity with high capillary porosity. This is due to the high porosity level which facilitates the retention of oxygen and water in the pores.

The effortless availability of nutrients and water is of great significance for the healthy growth and development of plants. (De Boodt and Verdonck, 1972) and (Fonteno et al, 1981) through their research point to the fact that an ideal substrate should have a TPS or total porous space which exceeds 85%. The pores are filled with air or water depending on their dimension and the contents of the base. The substrates' total porous space is higher than the soils' porous space whose percentage amounts to a quantity which is approximately 50% of the volume. (Michiels et al., 1993) claims in his research that in principle, according to the shape and size of the particles, organic substrates should have a total porosity that amounts to around 85-95% of the volume (Michiels et al., 1993; Raviv at al., 2002) in his research points to the fact that the total porous space in the substrates for plant cultivation should amount to 60-90% in volume. A lot of studies and authors with (Eriksson, 1982) being one of them stressed the importance of the presence of air in the pores for healthy growth of plants and high yield.

The authors (Wesseling and Van Wijik, 1957; Paul and Lee, 1976) stress that there is a general consensus on the fact that the minimal volume of the air porous space for an appropriate air exchange for supporting plant growth should amount to around 10% of the volume. (Brückner U, 1997) underscores in his research that the relative balance of air and water in the pores of the soil space is of crucial significance for the growth of plants.

The analyzed soil sample of fluvial soil in Table 1 also has a high total porosity with a mean value of 77.73% which points to the fact that this type of soil falls in the category of soils which are high in porosity which is an indicator for excellently aeriated soils rich in sand and with less clay which influence high porosity. (Filipovski, 1997) has divided soil types depending on porosity in four categories: quite porous (pores that exceed 60%), porous (45-60%), slightly porous (30-45%) and quite moderately porous (pores whose percentage is below 30%).

Knowing the value of total porosity, the relation between macropores and micropores, the porous system's stability and the total internal surface of the pores has immense practical significance for the soil and the growth of plants. It is not beneficial for the plant when only non - capillary or only capillary pores are present in the soil. In the first case the soil doesn't retain water and in the second all the pores fill with water and enough air isn't available or there is weak aeration. The obtained values from the air porous space of the fluvial soil has a mean value of 38.05% while the water porous space has a mean value of 39.68% which can be explained with the fact that fluvial soil has an optimal water and air regime. (Gajic, 2006) points to the fact that optimal physical and water physical properties and their water – air regime can be obtained when the capillary and non – capillary porosity are in a mutual relation of 1:1 or 2:3. (Filipovski, 1996) claims that the most advantageous relation of porosity occurs when out of the total porosity 60% of the pores are capillary pores and 40% of the pores are non – capillary pores. All the other analyzed samples have displayed optimal water – air porosity.

Out of the analyzed properties of the Mollic Vertic Gleysol soil type and Perlite substrate with their mixtures in Table 2 we can draw the conclusion that the examined trials of total porosity of Mollic Vertic Gleysol have displayed a total porosity with a mean value of 46.99% which points to a soil which is porous. But, the Mollic Vertic Gleysol soil type falls in the category of clay soils with high porosity. Its characteristics are low presence of non – capillary pores with a presence which usually doesn't exceed 8% which makes the water – air regime of these soils disadvantageous. In our research the obtained values from the analyzed properties of water porosity had a mean value of 42.79% and a high capacity of the capillary pores while the analyzed samples of air porosity displayed quite low values with a result of 4.21%. This is due to the high percentage of clay present in that soil, the low presence of non – capillary pores, poor filtration and infiltration with the low diffusion of gasses which characterize poorly aerated soil. The authors (Steffens D, et al., 2005) point to the fact that soils which access to limited conditions for aeration in the inside of the soil's porous volume have an increase in CO_2concentration with a transient increase of pH around the root's absorption system. The author (Spirovski, 1965) achieved similarly low values of air porosity in his research with a value of 6.44%. Because of the higher content of clay, Mollic Vertic Gleysol is falls into the category of heavy soils in which non – capillary pores dominate while clay soils despite the greater content of capillary pores often have a low quantity of easily accessible water because of the high content of micropores (smaller than 3 microns). The water in these micropores isn't easily accessible for the plants. Out of the results in Table 3 it can be easily noted that out of the analyzed properties of Peat substrate the highest result for total porosity stands out with a mean value of 90.8% which defines a high total porous volume. This high percentage of porosity present in Peat is due to the high content of organic matter which can be found in Peat.

With the increase of organic matter the total porosity also increases. Never the less, the mutual water and air regime is disadvantageous because the capillary pores have a mean value of 80.1% which points to a very high content of water capacity while air capacity has a low capillarity or insufficient retention of air with a mean value of 10.7%. All the other analyzed samples in various ratios indicate a different balance between the water and air regime. With adding or mixing of Perlite and Peat, the percentage of air porosity increases. For example, the analyzed sample in a mixture with a ratio Pe20/P80 or 20% Perlite + 80% Peat displays a total porosity with a mean value of 88.63%, which points to high porosity and an advantageous water – air regime. Air capacity has a mean value of 20.6% and water porosity has a high mean value of 68.03%. All the other analyzed samples of mixtures in ratios of Pe50/P50 and Pe70/P30 display different values. By adding a mixture of 50% Perlite and 50% Peat total porosity reaches a mean value of 89.45%, air porosity reaches a mean value of 35.45% while water porosity displays a mean value of 54.0%. These states allow us to claim that the analyzed sample Pe50/P50 has a high total porosity and advantageous water – air capacity. By adding a mixture of 30% Perlite and 70% Peat the total volume of the pores (both capillary and non – capillary) reaches a value of 88.9%.

The water regime is high and filled with capillary pores with a mean value of 63.55%. Non – capillary pores have an advantageous air porosity with a mean value of 25.55%. Similar results to ours were also obtained by the authors (Jeb S, Fields et al., 2014) in their research on the hydrohpysical properties of Perlite and Peat. They reached the following results: total porosity of Peat with a value of 91.0%, air porosity with a value of 10.7%, water porosity of Perlite with a value of 66.4% and air porosity with a value of 12.2%.

CONCLUSIONS

Once more, the analyzed properties of total porosity of Perlite as a substrate have displayed a very high porosity with a mean value of 88.09% out of which 27.9% belong to water porosity which points to a presence of solid capillary porosity while the researched properties of air porosity in Perlite have displayed a very high air capacity with a mean value of 60.2%. That points to the fact that this is a substrate with a high level of superiority for appropriate retention of air whose application can act as a betterment for the increase of aeration of problematic heavy soils which will impact plants directly in their roots when the need for stable supply with oxygen exists. Through the application of Perlite in mixtures in various ratios an influence of the water and air porosity is displayed in the analyzed samples of fluvial soil, mollic vertic gleysol and Peat.

The fluvial soil type also has a high total porosity with a mean value of 77.73%. The obtained values from the air porous space of the fluvial soil type has a mean value of 38.05% while the water porous space has a mean value of 39.68%. This can be explained with the high water and air porosity because of the high quantity of sand and the lower quantity of clay. While it is a characteristic of mollic vertic gleysol soil type to have a low percentage of non – capillary pores with a value which doesn't exceed 8% which points to a low percentage of air porosity. Water porosity has an average value of 46.99% which points to an advantageous water porosity. This soil type has a disadvantageous ratio of water and air i.e. a weak exchange between the water regime and the aeration regime. Here the positive influence of Perlite substrate on air porosity is the most visible.

There is a drastic improvement of the air porosity in soil. It can be derived out of all of this that Perlite as a substrate improves the soil's aeration power of soil types with a poorer aeration capacity. It can be derived out of the analyzed properties of Peat substrate that this substrate stands out with the highest total porosity with a mean value of 90.8% that defines a high total porous volume. This high Porosity percentage in Peat is due to the high content of organic matter which can be found in Peat. With the increase of organic matter itself the total porosity increases. Nevertheless, the mutual water and air regime is disadvantageous because capillary pores have a mean value of 80% which points to a very high content of water capacity while air capacity has a low capillarity or insufficient air retention with a mean value of 10.7%. In all the other ratios a different balance between the water and air regime can be noted while with the mixing of Perlite and Peat, air porosity displays a higher percentage.

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