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INVESTIGATION OF THE SUBSTRATE WITH BIOCHAR ON THE DEVELOPMENT OF TOMATO SEEDLINGS

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Abstract

The purpose of the study was to determine the possibility of the application of Biochar as an additive substrate for seedlings growing. Three types of the substrate with woody Biochar were investigated. As a control, the peat and perlite (1:1) substrate was used. Some morphological signs (stem height, leaf number, leaf area, root volume, etc.) and physiological indicators of the seedling plants were determinate. The effect of biochar depends on both its quantity and the other components. The using of the substrate mixture with peat:perlite:biochar (1:1:1) provoke a positive effect on the development of the root system. The volume of the root system increased by 36.8% and the weight by 28.4% compared to the control. The physiological status of the plants has improved. The total chlorophyll content and the dry matter content in the plant organs increased.

***Key words**: biochar, seedling mixture, tomato seedlings, morphological behavior of the plants.*

INTRODUCTION

The most widely used product in seedling production is a peat. The growing uses of peat in horticulture poses a serious danger of its rapid depletion, as a non-renewable resource. In connection with this, a global movement has been created to achieve sustainable use of peat and intelligent operation of wetlands. Efforts are being made to find and use sustainable peat substitutes that meet the specific requirements of plants, are easily available in sufficient quantities and, of course, are cost-effective (Fascella, 2015). A number of studies have been conducted related to the use of biochar in agriculture as a soil improver and as an alternative substitute for peat in seedling production. It is considered a potential soil substitute worldwide (Glaser et al., 2002; Lehmann et al., 2003). Biochar is a highly porous black material produced by pyrolysis of biomass under oxygen deficient conditions (Brewer & Brown, 2012). Pyrolysis is the thermal decomposition of hydrocarbons in organic biomass at a temperature in the range (450-500^{0}C) in the absence of oxygen. It is carried out by indirect heating of the biomass in an airless environment, or by its partial combustion with limited supply of air or pure oxygen. The most traditional product of pyrolysis is bio-oil, syngas, and charcoal (Manolova, 2014; Benev, 2008; Laird, 2008). Pyrolysis can be subjected to biomass from agricultural crops, forestry waste, sawdust (Chan et al., 2007).

In addition to playing a role in the uptake of carbon into the soil, biochar serves as a soil improver. Increases the pH of acidic soils because it has an alkaline pH (Yamato et al., 2006; Chan et al., 2007), increases cation exchange capacity in organically poor soils (Silber et al., 2010), increases nutrient retention in light soils (Glaser et al., 2002), improves their uptake by plants and helps to increase beneficial soil microorganisms (Kolb et al., 2009; Kolton et al., 2011). Biochar added to the soil increase the concentration of nitrogen and phosphorus by adsorption, helping to prevent their loss, leading to mineralization of organic N and P by activating microbial activity and promoting of root growth (Gul & Whalen, 2016; Gul et al., 2015,). This in turn leads to the degradation of P by the production of organic acids by the roots and rhizosphere microorganisms.

Weeds are a serious competitor of agricultural crops in terms of certain vegetation factors (Yanev, 2020; Yanev, 2015). Weeds losses are higher than other factors including animal pest, fungal and bacterial pathogens and viruses which caused 16%, 18% and 20% yield loss, respectively (Oerke, 2006). Carbonaceous materials have affect sorption, degradation, and bioavailability of pesticides to plants (Hilton and Yuen, 1963). According to Laird (2008) application of charcoal to soils is reduce leaching of pesticides and nutrients to surface and ground water.

Opinions on the application of biochar in seedling production are contradictory. According to Frenkel (2017) biochar have mainly positive or neutral effects on plant growth compared to peat media when they are in concentrations higher than 25% of volume of mixture. According to other authors, the biochar used as a substitute for peat and used in high concentrations may pose a latent risk as it may weaken plant protection or lead to the predisposition of roots to pathogenic attack (Jaiswal et al., 2015).

MATERIALS AND METHODS

The experimental work was done during the 2018-2019 in Agricultural University - Plovdiv, Bulgaria. Biochar of oak (*Quercus robur)* was added to a commercial potting substrate of peat and perlite to obtain three type of seedling mixture: peat:perlite:biochar in ratio 1:1:1; peat:biochar - 1:1; perlite:biochar - 1:1. The peat is from the company Durpeta from Lithuania and is factory enriched with N-250 mg/l, P2O5 - 270 mg/l, K2O-270 mg/l and Fe, Cu, Mn, B, Mo, Zn - 1.2 mg/l. The salt concentration of peat, measured in ms/cm, is 1.2, and the pH is 5.5-6.5.The seed of 'Aleno sarce' tomato variety were sown into 40 cells trays containing one of the investigated mixtures. For the control was used peat:perlite mixture (1:1). The seedlings were grown for 45 days. During the period of growing seedlings, care was applied according to the physiological condition and the degree of growth of seedlings. In both years, repeated feeding of seedlings with water-soluble fertilizers was applied.

On the end of the seedling period was measured some biometric indicators - stem height and thickness (cm), leaf number, leaf area (cm^2) by Konyaev (1970), shoot fresh and dry weight, root fresh and dry weight and root volume. It was determinate dry matter content (g) (Manuelyan, 1966). The total chlorophyll content was determined by Chlorophyll Meter SPAD-502. The mathematical processing of the data was done by standard program BIOSTAT.

Figure 1. Tomato plants grown in substrate with biochar

RESULTS AND DISCUSSIONS

Seedling growth parameters of tomato grown in growing media with biochar are better or worse compared to control. Shoots parameters of the plants in all investigated variants are smaller compared to the control. The stem height (Table 1) of the plants grown in a substrate containing biochar is from 13.6 cm to 20.6 cm, while in the control is 26.4cm. Biochar has a negative effect on the size of the leaf area. Plants grown in a substrate containing biochar have a leaf area of 1,54 to 4.84 times lower compared to the control. The plants grown in biochar and perlite (variant 4) are most affected - 66.89 cm^2. Comparable to the variant with the same percentage of biochar (var. 3), the leaf area is twice lower, despite the same number of leaves. The leaf area is greatest in plants grown in a substrate containing peat: perlite and biochar. A summary indicator of the vegetative growth of the seedlings is the shoot fresh weight. The value of this indicator, depending on the investigated mixture is from 4.63 (4) to 8.80 (2) g., compared to control - 11.51 g. The volume and weight of the root system are essential for the quality and vitality of seedlings. Despite the reported advantage of control on shoot parameters, the reported values for volume and weight of the root system are inferior to some of the variants with biochar. In variants with peat:perlite:biochar and peat:biochar, the volume and weight of the root system exceed the control by 23.3% and

36.8%, for the first indicator, and for the second the excess is by 10.2% and 28.4%

The higher values refer to variant 2 (peat:perlite:biochar), and the differences are statistically proven. The plants grown in perlite:biochar are distinguished by the least developed root system.

Figure 2. Tomato plants grown in substrate with biochar

Although the participation of biochar in the tested mixture in variant var.4 does not differ from the mixture in variant 3 (50% of the mixture), the root system of the plants develops much less. The volume of the root system is twice smaller and the weight is reduced by over 40%. Obviously, the effect of biochar on plant growth depends not only on its percentage application, but also on the type of other components in the mixture. Overall, the studies reported that application rates of biochar into the substrates under 25% by volume generally resulted in similar or higher plant growth compared to the referential commercial substrate (Huang L, 2019). According to Dumroese et al. (2011) the high content of biochar (over 50% relative to peat) can lead to undesirable changes in the structure of the substrate, increases the density, reduces the water holding capacity of the substrate, and the C: N ratio is much higher compared to a mixture containing 75 % peat and 25% biochar. The reason for the obtained results may be due to changes of this nature. The effect of biochar is changes when used in combination with perlite. All indicators concerning the morphological development of seedlings have the lowest values when using this type of mixture.

Table 1. Biometric indicators of plant, average for the period 2018/2019

Indicatiors/Variant		Peat:perlite 1:1	Peat:perlite:biochar 1:1:1	Peat:biochar 1:1	Perlite:biochar 1:1	LSD 0,5
Stem height		26,4	20,6	17,7	13,6	2,58
Stem thickness (mm)		47,7	43,7	43,7	37,3	-
Leaf number		7,8	7,8	7,4	7,4	
Leaf area	cm^2	324,05	210,2	156,4	66,89	56,27
	%	100,0	64,9	48,3	20,6	-
Shoot fresh weight	g	11,51	8,80	7,30	4,63	1,63
	% to the control	100,0	76,5	63,5	40,2	-
Root volume	cm^3	2,81	3,85	3,47	1,69	1,02
	% to the control	100,0	136,8	123,3	60,1	-
Root fresh weight	g	2,75	3,53	3,03	1,78	0,54
	%	100,0	128,4	110,2	64,7	-
Shoot:root ratio		4,18	2,49	2,41	2,60	

The coefficient for all plants grown in a mixture containing biochar is lower than the control. The lower value of the coefficient indicates more harmonious combination in biological terms and is a prerequisite for better adaptation and recovery after planting in a permanent place. This means that the differences between the compared biometrics are smaller and the plants are more harmoniously developed. Changes in the morphological characteristics of seedlings are accompanied by changes in their physiological status (Table 2). The average results show that the shoots dry weight on the variants with biochar is from 0.515 to 1.255 g, in the case of the reported for the control plants - 1.475 g. The amount of shoot dry matter content is an important indicator that reflects the productive potential of young plants, and its higher content shows greater physiological potential of young plants and is a prerequisite for better adaptability to environmental factors in which they will fall after planting them in a permanent place.

Table 2. Dry weight and dry matter content of plants

Indicators / Variants	Period	Peat:perlite 1:1	Peat:perlite:biochar 1:1:1	Peat:biochar 1:1	Perlite:biochar 1:1
Shoot dry weight, g	2018	1,51	1,18	0,56	0,51
	2019	1,44	1,33	0,92	0,52
	average	1,475	1,255	0,74	0,515
Shoot dry matter content, %	(%)	12,81	14,26	10,14	11,12
	% to the control	100,0	111,3	79,1	86,8
Root dry weight, g	2018	0,21	0,31	0,23	0,15
	2019	0,31	0,55	0,41	0,21
	average	0,26	0,43	0,305	0,18
Root dry matter content, %	(%)	9,45	12,18	10,07	10,11
	% to the control	100,0	128,9	106,6	107

The higher shoot dry matter content can be used like a criterion for greater biological and physiological potential and a prerequisite for their faster recovery after planting (Shopova, 2014). The shoot dry matter is highest in variant 2 - 14.26%. The control plants also have an advantage in this respect. The root dry matter, in the variants containing biochar and peat (var. 2 and var. 3) as well as the amount of root dry matter content are higher than those reported in the control. The root dry matter content in variant 3 exceeded the control by 6.6%, and in variant 2 by 28.9%. In variant 4, a higher dry matter content was reported compared to the control by 7%, despite the significantly lower mass of the root system.

The results for the content of total chlorophyll in the leaves (Table 3) complement the characteristics of the seedlings. The data show that the total chlorophyll content for the experiment is between 33.8 to 42.7 SPAD units. The reported value in the control is 38,5 SPAD units. The content of total chlorophyll is highest in the plants of variant 2 , as the excess over the control is 10.9%. When using biochar in combination only with peat or only with perlite, the plants react differently in terms of chlorophyll content in the leaves. Despite the equal participation of biochar, in combination with peat the chlorophyll content increases, while in combination with perlite - decreases. In the second case, the decrease compared to the control is by 12.2%. Some authors (Akhtar et al., 2014) reported a significant reduction in chlorophyll content due to a reduction in nitrogen content in the leaves of plants grown in a substrate containing only biochar. In combination with peat, a favorable C: N ratio is observed in the substrate, which makes the available nitrogen readily available to plants (Scherer et al., 1996). Despite the presented results, other authors report that there is no difference in chlorophyll content in tomato plants when using a mixture containing pyrolysis residues in combination with compost and a mixture containing pure compost (Akhter et al., 2015).

Table 3. Content of total chlorophyll, average for the period 2018-2019

Variant	Content of total chlorophyll	
	SPAD	% to the control
peat:prelite 1:1		
1.	38,5	100,0
Peat:perlite:biochar 1:1:1		
2.	42,7	110,9
Peat:biochar 1:1		
3.	41,2	107,0
Perlite:biochar 1:1		
4.	33,8	87,8

CONCLUSIONS

Biochar, included in standard seedling mixture change the behaviour of the seedling plants. Its most effective when used as a component of a seedling mixture containing peat and perlite (1:1:1). The effect of biochar is most pronounced on the development of the root system. In combination with peat or with peat and perlite, the biochar leads to improvement of the physiological status of the plants. The content of total chlorophyll increases, as well as the amount of dry matter content in the plant organs. The use of biochar in combination with perlite has negative effect on the morphological and physiological development of tomato seedlings, growth is inhibited and the amount of chlorophyll is reduced.

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