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Original Article

Yield of the tomato farmed by organic principles in the greenhouse with the application of retort beach charcoal

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Abstract:
The experiment was established in the greenhouse designed by random block system with tomato genotype Optima, treated with cow manure and retort beech charcoal, while the control treatment comprised of cow manure only. The aim was to determine the influence of the applied material on the number of fruits per plant and the weight of the fruit directly affecting the yield in the organic growing system. In the treatment with retort beech charcoal, the Optima genotype had an average yield 23.88% higher than the control plants.

Key words:
fruit, organic cultivation, retort beach charcoal, tomato, yield

Apstract:
Prinos paradajza uzgajanog po organskim principima u stakleniku uz primenu retortnog bukovog uglja
Eksperimentalni ogled bio je postavljen po dizajnu slučajni blok sistem u plasteniku sa sortom paradajza Optima, tretmanom sa kravljim stajnjakom i retortnim bukovim ugljem i kontrolom sa kravljim stajnjakom bez retortnog bukovog uglja. Cilj je bio da se utvrdi uticaj retortnog bukovog uglja na broj ploda po biljci i masu ploda koji direktno utiču na prinos u organskom sistemu gajenja. U tretmanu, sorta Optima je u proseku imala 23,88% veći prinos u odnosu na biljke iz kontrole.

Ključne reči:
plod, organsko gajenje, retortni bukov ugalj, prinos

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is the most widely grown vegetable in the world, with a very wide range of distribution. It is grown on 4,725,416 ha with a yield of about 35 t ha^{-1} (FAO, 2013). The world's largest producers of tomatoes are China, India, the United States, Turkey, Egypt, Russia, Italy and Mexico. In 2018, 8,629 ha were sown under these vegetables in Serbia, with an average yield of 15.3 t ha^{-1} (webrzs.stat.gov.rs, 2018). Tomato accounts for 11.6% of total vegetable consumption in Serbia - 15.2 kg per capita per year (Vlahović & Puškarić, 2012). Tomato is one of the most used and widespread vegetable species used as a fresh vegetable, ripe fruit and in the form of wide-range products (De Sousa et al., 2008). Annually, over 40 million tons of tomatoes are processed worldwide to produce canned tomatoes, ketchup, tomato juice, sauce and many other products (WPTC, 2015). In particular, the consummation of tomato and its products has been shown to be associated with a reduced risk of prostate, lung, and gastric cancer (Hwang & Bowen, 2005; Palozza et al., 2011; Yang et al., 2013). Depending on the type of growth, tomato can be produced in different ways and used for different purposes. Seeds and planting material, especially in the vegetable industry, represent an important factor for high quality production (Popović et al., 2015).

Organic farming combines tradition, innovation and science in order to produce healthy product and keep the environment protected. The use of activated carbons in organic production is one of the possibilities to preserve and raise the soil quality and therefore the yield of the cultivated plants (Lehman et al., 2005; Biederman & Harpole, 2013).

Soil biochar amendment is based on two thousand years old experience, which in recent decades has been renewed because of proven multiple benefits (Chan et al., 2007). This importance is largely long-term, but also reveals the short-term effects (Mann, 2005).

Both biochar and activated carbon are pyrogenic carbonaceous materials (PCM). They are produced by thermochemical conversion of carbonaceous feedstock (pyrolysis or/and activation). Biochar is produced from sustainably sourced biomass and is used for non-oxidative applications in agriculture (e.g., in the soil) and is also discussed as a raw material for industrial processes. By definition, it is used for carbon sequestration. Hence, if "biochar" is used as a fuel, it is burned and the carbon is transformed (oxidized) into CO_2, it is actually classified as charcoal. Activated carbon is produced from any carbon source (fossil, waste or renewable) and engineered to be used as sorbent to remove contaminants from both gases and liquids. Both materials have their distinct history, widely separated scientific communities and separated bodies of literature. Unfortunately, a generally accepted terminology and definition is lacking (Hagemann et al., 2018).

However, as the proposed applications of biochar and activated carbon increasingly overlap, awareness of the "other" domain in each case can be beneficial. Nowadays both biochar and activated carbon are used for soil remediation, which before has been solely an application of activated carbon. When the activated carbon is not removed after the application and if this activated carbon was produced from renewable feedstock and is complying to further specifications, it can be considered as biochar (Laird 2008; Woolf et al., 2010; Hagemann et al., 2018; Yadav et al., 2018).

Many studies confirmed that soil incorporated with biochars can improve plant growing (Šeremešić et al., 2015; Tian et al., 2018; Yadav et al., 2018). According to Tian et al. (2018) biochar incorporation induces soil alkalization which can increase soil nitrification and nitrogen (N) levels. Increases in soil pH are likely to affect electrical conductivity (EC), cation exchange capacity (CEC) and increase alkaline metal (Mg^{2+}, Ca^{2+} and K^{+}) oxides. Likewise, it reduces soluble forms of aluminum, which is suggested as the most significant biochar factor affecting P solubility (De Luca et al., 2009; Tian et al., 2018; Yadav et al., 2018). Beneficial effects of biochar have been elaborated in studies word wide. However, there is a lack of experimental confirmation of the biochar application in our agricultural science. Researches of biochar use have been mainly conducted on soils under tropical and humid climatic conditions, which are more degraded and have a lack of soil organic carbon (Šeremešić et al., 2015; Tian et al., 2018; Yadav et al., 2018).

Therefore, the aim of this study is to research the charcoal application in vegetable farming under organic conditions. The parameter that is followed is tomato yield under temperate climatic conditions. For the organic production, it is very important to choose the right genotype to be grown according to ecological principles (Vasić, 2016). The total area under certification (taking into account the organic status of the plots and plots in the conversion period) in Serbia is 7,998 ha, plus meadows and pastures of 1,549 ha. In 2014, vegetables accounted for only 2% of the certified plant species.

Material and methods

The experiment was set up at Trmčare locality, Kruševac municipality in a greenhouse according to a random block system in 2 replicates, planting 23 plants treated with cow manure and retort beech charcoal and 23 plants treated only with cow manure as a control.

The row spacing was 70 cm, while the plant spacing in one row was 40 cm. The production of tomato Optima genotype seedlings has been started on 20 March, 2019 in the glasshouse, and the seedling has been done on 20 May, 2019 in the greenhouse. Before sowing, the soil was prepared by adding cow manure in the amount of 200 kg per 60 m^2 at the depth of the sowing layer. Seven days before planting, a mixture of cow manure in the amount of 200 g/plant and 200 g/plant of retort beech charcoal was introduced at the depth of the sowing layer. The control was not treated with retorted beech charcoal, but only with cow manure in the amount of 200 g/plant. The activated charcoal used for this purpose was produced from natural raw materials and obtained by carbonation of beech, selected according to strictly defined technical requirements by activation of steam in a static furnace.

Due to its organic origin and production method, charcoal has a certain degree of activity (iodine number of 233-750 mg/g), which allows it to retain water reserves and thus provide the moisture needed by the plant. The use of activated carbon in organic production is very useful because of the introduc-

Table 1. T-test for dependent samples marked differences are significant at $p<0.05$ for fruit yield and fruit size (in grams per plant)

T-test for Dependent samples marked differences are significant at $p<0,05000$								
Variable	Mean	Std. dv.	N	Diff.	Std. dv. diff.	t	df	*p*
Test	242,6221	38,4676						
Test	242,6221	38,4676	172	-0,0000	0,00000	0,00000	171	1,00000
Test	239,1909	36,8420						
Cont.	316,2818	123,1446	110	-77,0909	120,4985	-6,70993	109	0,00000
Cont.	316,2818	123,1446						
Test	239,1909	36,8420	110	77,0909	120,4985	6,70993	109	0,00000
Cont.	310,4830	118,5543						
Cont.	310,4830	118,5543	147	-0,0000	0,00000	0,00000	146	1,00000

* The statistically significant differences in treatment and control are indicated in red.

tion of N, P, K, trace elements (mg/kg: Ca-8590, Mg-1260, K-7400, P-380, S-350 Mn-32, Fe-230, Zn-20, Cu-23), organic substances, humic acids and amino acids that help the plant's level and improve their health. The granulometric range of the material ensures that the soil is loose because it does not dissolve in the soil. Activated carbon granulometry 0-2.5 mm was used in this experiment. The ashes of the material thus obtained have a high level of elements such as oxides of potassium, calcium and magnesium.

Also, activated charcoal contains a higher percentage of charcoal so it has phosphates in ash, which is an excellent source of this microelement for the plant. Due to the origin and content of alkali metals, the pH of this material is 9-11.

Tomatoes were grown by a support (pillar) on a single tree. The following parameters were monitored in the experiment: fruit yield per plant and number of fruits per plant. Analysis of variance (ANOVA) in Statistica 8 statistical program was used to examine differences in the measured characteristics between treated and untreated tomato plants and their interaction, using the Student's T-test of significance level 0.05. The results were presented in a graph and table.

Results

The yield of treated plants averaged 3,535.65 g per plant and in the control plants averaged 2,690.87 g (**Fig. 1**). Fruit mass is a genotype characteristic and is one of the factors that determine its purpose.

Analysis of variance (ANOVA) for fruit yield (grams per plant) indicated a statistically significant difference between plants treated with retorted beech charcoal and non-treated plants as well as their interactions. Specifically, it was found that the plants from the treatment had a statistically significantly higher fruit yield (in grams per plant) than the plants from the control.

It was also found that there was a statistically significant difference between the total fruit yield and the number of fruits on the tomato plants under treatment compared to the control plants (**Fig. 2** and **3**, **Tab. 1** and **2**).

Treatment and control varied, both in total fruit

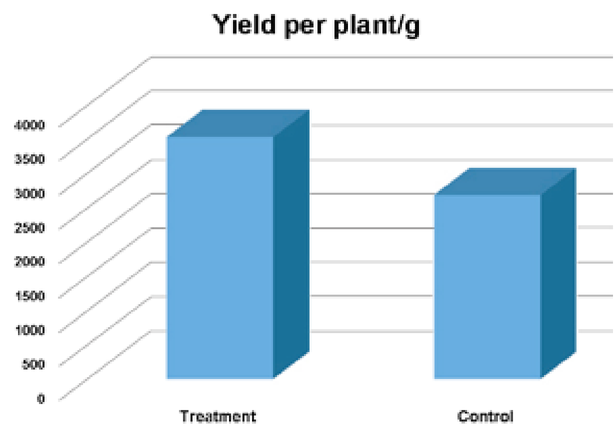

Fig. 1. Effect of treatment and control on yield of the friut (grams per plant)

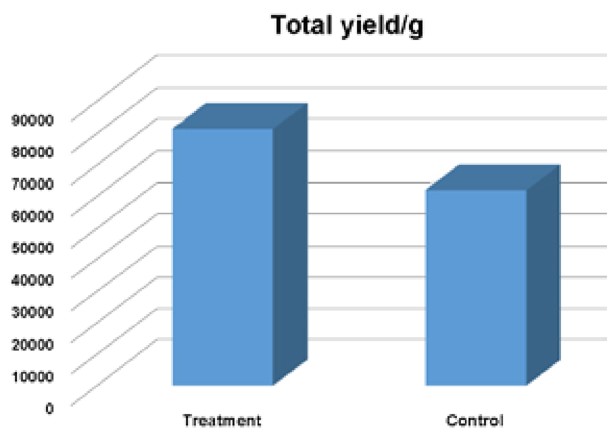

Fig. 2. Total fruit yield (grams) of treated and untreated tomato plants with retorted beech charcoal

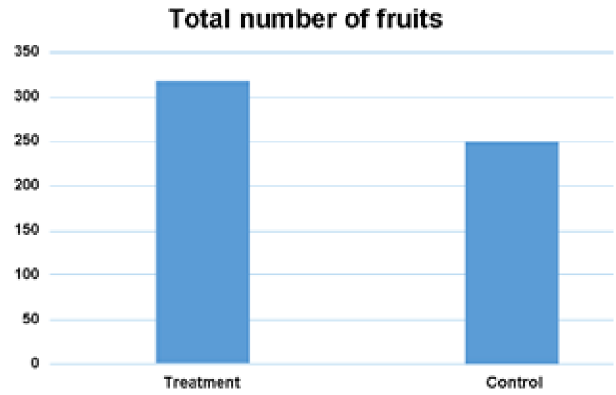

Fig. 3. Effect of treatment and control on total number of fruits

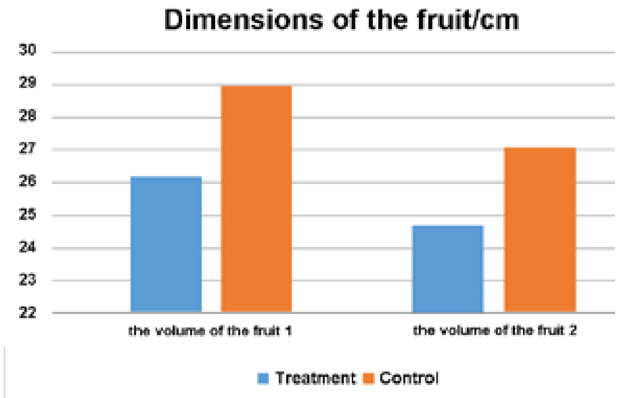

Fig. 4. Effect of treatment and control on the dimension of tomato fruit

yield per plant, harvest time and fruit yield over time. In plants treated with charcoal the first fruits were harvested on June 24, 2019 and the first harvest for plants in control was on July 7, 2019. It was also observed that the plants in the treatment had more even distribution of fruits for harvest than the plants in the control. Plants treated with activated charcoal began to bear fruits earlier than plants in control. It was also found that the plants under treatment had a larger number of smaller and uniform fruit sizes compared to control plants that had a smaller number of larger fruits, of unequal size (**Tab. 1**, **Fig. 3**).

The differences in yield between treatment and control within each individual harvest were statistically significant, with the smallest difference within the last harvest. On average, in treatment and control, the highest yield was recorded at the last harvest (**Tab. 1** and **2**).

The total fruit yield for the tomato plants under treatment was 81,320 g and for the control plants 61,890 g.

We also monitored the dimension of the fruits and after statistical data processing it was observed that the fruits from the treatment were smaller than the fruits from the control (**Tab. 1**, **Fig. 4**).

Discussion

Tomato yield is positively correlated with the number of fruits per plant and the weight of the fruit (Popović et al., 2015). The yield of the treated and control plants ranged from 3,535.62 g/plant and 2,690.87 g/plant, respectively (**Tab. 1**). Today, there are genotypes of large (120 g - 250 g), medium (80 g - 120 g), small fruits (60 g - 80 g), and more recently genotypes of cocktail type (30 g - 50 g) and mini (cherry) tomatoes (10 g - 30 g) (Đurovka et al., 2006). Optimal temperatures and brightness in the early stages of development determine the yield and quality of the fruit (Rylski et al., 1994).

In this study, it was found that plants treated with beech retort charcoal had a higher total fruit yield per plant as well as compared to control plants. Thus, for the plants from the treatment the first harvest was already on June 24, while for the plants from the control the first harvest was on July 7, 2019. Fruit yield is conditioned primarily by genetic polygenic factors, but is also dependent on the external environment (Zhuchenko, 1973). It is clear from this study that beech retort charcoal has a positive effect on tomato yield in the greenhouse. By growing tomatoes on five or six floors or growing on two trees, the yields would be higher by about 30-35%. There are no data in the literature on the effect of retorted beech charcoal on tomato yield.

Positive crop and biomass yield was found for biochar produced from wood, paper pulp, wood chips and poultry litter. Yadav et al. (2018) reviewed published data from 59 pot experiments and 57 field experiments from 21 countries and found crop productivity increased by 11% on average. Also, Yadav et al. (2018) found benefits at field application rates typically below 30 t ha^{-1} field application and

Table 2. Analysis of variance (ANOVA) for fruit yield (in grams per plant)

Effect	Degr. of freedom	Test	Test	Test	Test	Control	Control	Control	Control
Intercept	1	6293352	6293352	4636,567	0,00	11003761	11003761	725,6221	0,00
Error	109	147949	1357			1652940	15165		
Total	109	147949				1652940			

reported that increases in crop productivity varied with crop type with greater increases for legume crops (30%), vegetables (29%), and grasses (14%) compared to cereal crops corn (8%), wheat (11%), and rice (7%). These data are consistent with the results of this paper.

According to Yamato et al. (2006) maize production was significantly increased after the application of bark charcoal under a fertilized condition in an infertile soil environment. A positive effect of biochar addition on maize dry biomass could be ascribed to higher soil N-retention that was observed by Baronti et al. (2010).

These are only preliminary results. Further detailed investigations should be undertaken in order to find the most optimal amount and time of application of beech retort charcoal in crops under the climatic conditions of Serbia.

Conclusion

The highest fruit yield was achieved on activated carbon plants, while the yield on control plants was 23.88% lower. This study indicates the positive impact of retorted beech charcoal on the yield of tomato plants in the greenhouse.

References

Baronti, S., Alberti, G., Vedove, G.D., Gennaro, F.D., Fellet, G., Genesio, L, Miglietta, F., Peressotti, A., Vaccari, F.P. 2010: The biochar option to improve plant yields: first results from some field and pot experiments in Italy, *Italian Journal of Agronomy.* 5: 3–12.

Biederman, L.A., Harpole, W.S. 2013: Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis, *GCB bioenergy,* 5: 202–214.

Chan, K.Y., Van Zwieten, L., Meszaros, I, Downie, A., Joseph, S. 2007: Agronomic values of green- waste biochar as a soil amendment, *Australian Journal of Soil Research,* 45: 629–634.

De Luca, T.H., Mac Kenzie, M.D., Gundale, M.J. 2009: Biochar effects on soil nutrient transformation. In: J Lehmann, S Joseph (Ed.), *Biochar for environmental management science and technology*. Earthscan, London, pp 251–280.

De Sousa, A.S., Borges, S.V., Magalhaes, N.F., Ricardo, H.V., Azevedo, A. D. (2008): Spray-dried tomato powder: Reconstitution properties and colour. *Brazilian Archives of Biology and Technology*, 51(4): 807-814.

Đurovka, M., Lazić, B., Bajkin, A., Potkonjak, A., Marković, V., Ilin, Ž., Todorović, V. 2006: *Proizvodnja povrća i cveća u zaštićenom prostoru*. Univerzitet u Novom Sadu. Poljoprivredni fakultet, Novi Sad, 207.

Hagemann, N., Kurt Spokas, K.., Schmidt, H.P., Kägi, R., Böhler, M.A. and Thomas, D. Bucheli, T.D. 2018: Activated Carbon, Biochar and Charcoal: Linkages and Synergies across Pyrogenic Carbon's ABCs. *Water,* 10, 182.

http://webrzs.stat.gov.rs (pristupljeno novembra 2019.).

http://faostat.fao.org

http://www.wptc.to/releases-wptc.php

Hwang, E.S. and Bowen, P.E. 2005: Effects of tomato paste extracts on cell proliferation, cell-cycle arrest and apoptosis in LNCaP human prostate cancer cells. *BioFactors*, 23: 75-84.

Laird, D. 2008: The charcoal vision: A win-win-win scenario for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality. *Agronomy journal,* 100: 178–181.

Lehmann, J., Gaunt, J., Rondon, M. 2005: Biochar sequestration in terrestrial ecosystems–a review. *Mitigation and Adaptation Strategies for Global Change*, 11: 403–427.

Mann, C.C. 2005: *New revelations of the Americas before Columbus*. Vintage and Anchor Books, New York pp. 1–576.

Vlahović, B., Puškarić, A. 2012: Obeležja potrošnje povrća u Republici Srbiji. *XVII savetovanje o biotehnologiji. Zbornik radova*, 17. Univerzitet u Kragujevcu. Poljoprivredni fakultet, Čačak, 125-129.

Palozza, P., Simone, R.E., Catalano, A., Mele, M.C. 2011: Tomato lycopene and lung cancer prevention: From experimental to human studies. *Cancers*, 3: 2333-2357.

Popović, V., Takač, A., Glogovac, S., Medić Pap, S., Červenski, J. 2015: Prinos semena i ploda kod indeterminantnih genotipova paradajza gajenih na četiri etaže. *Selekcija i semenarstvo*, 21(1): 43-56.

Rylski, I., Aloni, B., Karni, L., Zaidman, Z. 1994: Flowering, fruit set, fruit development and fruit quality under different environmental conditions in tomato and pepper crops. *Acta horticulturae*, 366: 45-56.

Tian, X., Li, C., Zhang, M., Wan, Y., Xie, Z., Chen, B. 2018: Biochar derived from corn straw affected availability and distribution of soil nutrients and cotton yield. *PLoS ONE* 13(1): e0189924.

Vasić, M. 2016: Sorte pasulja u različitim sistemima gajenja. *50. Savetovanje agronoma i poljoprivrednika*, 24.01. – 30.01.2016., Zlatibor. Institut za ratarstvo i povrtarstvo, Novi sad.

Woolf, D., Amonette, J.E., Street-Perrott, F.A., Lehmann, J., Joseph, S. 2010: Sustainable biochar to mitigate global climate change. *Nature Communications,* 1: 56.

Yadav, N.K., Vijay, K., Sharma, K.R., Choudhary, R.S., Butter, T.S., Singh, G., Kumar, M., Kumar, R. 2018: Biochar and their impacts on soil properties and crop productivity: a review. *Journal of Pharmacognosy and Phytochemistry,* 7(4): 49-54.

Yamato, M., Okimori, Y., Wibowo, I.F., Anshori, S., Ogawa, M. 2006: Effects of the application of charred bark in *Acacia mangium* on the yield of maize, cowpea, peanut and soil chemical properties in south Sumatra, Indonesia. *Soil Science and Plant Nutrition,* 52: 489–495.

Yang, T., Yang, X., Wang, X., Wang, Y., Song, Z. 2013: The role of tomato products and lycopene in the prevention of gastric cancer: A meta-analysis of epidemiologic studies. *Medical Hypotheses*, 80: 383-388.

Žučenko, A.A. 1973: *Genetika tomatov*. Štiinca. Kišinev.

Šeremešić, S., Živanov, M., Milošev, D., Vasin, J., Ćirić, V., Vasiljević, M., Ujić, N. 2015: Effects of biochar application on morphological traits in maize and soybean. *Zbornik Matice srpske za prirodne nauke*, N 129: 17-25.