Voćarstvo, 57, 217–218 (2023), 125–130
Journal of Pomology, 57, 217–218 (2023), 125–130
https://doi.org/10.18485/pomology.2023.57.217_218.5

UDC: 634.713:631.95:622.33
Original scientific paper
Originalni naučni rad

Cultivating organic American highbush blueberries with retorted beech charcoal (RBC)

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Recivied: 27 October 2023; Accepted: 9. November 2023

Abstract. The research conducted in this study aimed to investigate the impact of retorted beech charcoal on the shoot number and length of the highbush blueberry cultivar 'Duke'. The experimental trial was established using randomized block system, consisting of three treatments and a control group. The control plants were potted in plastic containers filled with a mixture of sawdust and a substrate designed for commercial blueberry growing by Klasman. The plants in the treatment groups were potted similarly but with the addition of retorted beech charcoal in the root zone and around the root neck. Three different quantities of charcoal were used: 150 g (T_1), 100 g (T_2) and 50 g (T_3). The number and length of shoots were monitored over the two-year period. The results indicated a positive influence of retorted beech charcoal on the number and length of shoots. Specifically, the plants in the treatment groups exhibited longer and more numerous shoots compared to the control group. Furthermore, the results varied depending on the quantity of retorted beech charcoal applied. The treatment with 150 g of retorted beech charcoal recorded the highest average length and number of shoots. Additionally, in both the treatment and control groups, a greater number and length of shoots were observed in the second year of the study.

Keywords: organic plants growing, retort beech charcoal, highbush blueberry, vegetative growth

Introduction

In recent years, highbush blueberry (*Vaccinium corymbosum* L.) has taken an increasingly important place in the fruit production of many countries, particularly in highly developed ones. The economic significance of blueberries is on par with other types of berries and is determined by three key factors: i) the value of the fruit's utilization; ii) profitability; and iii) the high market demand for production (Leposavić & Jevremović, 2020). In the 1990s, there was a growing interest in establishing highbush blueberry plantations in Serbia. This increase in interest was response to declining demand for raspberries and a rising global demand for blueberries. During that period, blueberry plantations were established in various locations, including Lučani, Viča, Osečina, Pecka, and others (Leposavić, 2006).

The highbush blueberry has specific requirements regarding the land used for its production. Favorable conditions for blueberry cultivation include soils with sufficient depth (30.50 cm), fertility (humus content of 7–10%), acidity (pH 4.2–4.8), good drainage, and good aeration. In Serbia, ideal soil types for blueberry production include forest soils rich in decomposed biomass, as well as pastures, deluvial soils at the base of hills, and perennial natural meadows. Soils with high organic matter, such as humus, protect the sensitive blueberry roots by maintaining stable soil pH, moisture, and temperature. Regular monitoring of soil acidity is necesarry because any deviation from the optimum pH can quickly impact the plants, visibly affecting their growth. Blueberries are naturally found in well-drained, aerated, and light soils including sandy and sandy-loamy soils. Clay content in the soil should not exceed 20%, and the water table should be at least 50 cm below the soil surface. Soil moisture level should remain constantly moderate, avoiding both wetness and dry conditions. Excessive wet soil can be a significant problem in blueberry cultivation (Leposavić & Jevremović, 2020).

Organic farming combines tradition, innovation, and science to produce healthy products while preserving the environment. The use of activated carbons in organic production is one approach to improve soil quality and increase crop yealds (Lehmann et al., 2005; Biederman & Harpole, 2013). Soil biochar amendment draws upon two millennia of experience, which has seen renewed interest in recent decades due to its proven benefits (Chan et al., 2007). These benefits encompases both long-term and short-term effects (Mann, 2005).

Biochar and activated carbon are both pyrogenic carbonaceous materials produced through thermochemical conversion (pyrolysis or/and activation) of carbonaceous feedstock. Biochar is produced from sustainably sourced biomass for non-oxidative applications in agriculture, such as soil enhancement, and is also considered for use in industrial processes for carbon sequestration. However, if „biochar“ is used as a fuel, it is burned and the carbon is oxidized into CO_2, classifying it as charcoal. Activated carbon, on the other hand, is produced from verious carbon sources (fossil, waste, or renewable) and engineered as a sorbent to remove contaminants from gases and liquids. These materials have distinct histories, different scientific communities, and separated bodies of literature. Unfortunately, a generally accepted terminology and definitions are still lacking (Hagemann et al., 2018).

Nevertheless, as the applications of biochar and activated carbon increasingly overlap, awareness of each other's domain can be beneficial. Both biochar and activated carbon are now used for soil remediation, which was traditionaly the sole application of activated carbon. When activated carbon is not removed after application, and if it is produced from renewable feedstock and meets specific criteria, it can be considered as biochar (Laird, 2008; Woolf et al., 2010; Hagemann et al., 2018; Yadav et al., 2018).

Numerous studies have confirmed that soil enriched with biochar can enhence plant growth (Šeremešić et al., 2015; Tian et al., 2018; Yadav et al., 2018). According to Tian et al. (2018), biochar incorporation leads to soil alkalization, which can enhance soil nitrification and nitrogen level. An increase in soil pH can also affect electrical conductivity and cation exchange capacity while increasing alkaline metal oxides (Mg^{2+}, Ca^{2+} and K^{+}). It also reduces the soluble forms of aluminum, which is significant factor affecting phosphorus solubility (De Luca et al., 2009; Tian et al., 2018; Yadav et al., 2018). The beneficial effects of biochar have been extensively explored in studies wordwide. However, there is a lack of experimental confirmation of biochar application in our agricultural science. Most research on biochar use has been conducted on soils in tropical and humid climates that are more degraded and have lower levels of soil organic carbon (Šeremešić et al., 2015; Tian et al., 2018; Yadav et al., 2018).

In Serbia, organic fruit production covers 5,324 ha and is on the rise (Simić, 2020). According to the same source, the most commonly grown organic fruit species are raspberries and apples. Choosing the most suitable genotype for organic production and applying appropriate agrotechnical measures are crucial for successful organic fruit farming (Leposavić & Jevremović, 2020). Therefore, this study aims to investigate the impact of charcoal application on highbush blueberry cultivation under organic farming practises in temperate climatic conditions. The parameters under examination included the length and number of a new, young shoots of highbush blueberry.

Materials and Methods

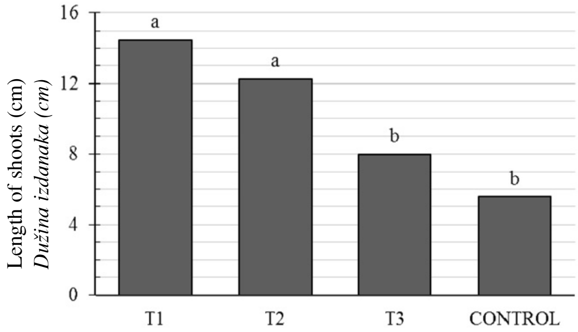
The experiment was performed in an open field at the Fruit Research Institute, Čačak employing a randomized block design with three treatments and control group. For the experiment, twelve highbush blueberry plants of the cultivar 'Duke' were selected, with one plant in each of the three replicates for both the treatments and the control group. These two-year-old blueberry plants of the mentioned cultivar were planted into plastic pots with a 60 cm diameter at the end of April 2021. Initially, the pots were filled with a mixture of sawdust and a commercial substrate produced by Klasman, designed for blueberry cultivation. Then, three pots, representing the control, were set aside, while the remaining pots had retorted beech charcoal added to the root zone and root neck of the blueberry plants. The retort beech charcoal was added in three different quantities: 150 g for the first treatment, 100 g for the second treatment, and 50 g for the third treatment. The parameters monitored included the number of shoot and shoot length (in centimeters), which were recorded during the planting year and the subsequent year.

The activated charcoal used for this purpose was produced from natural raw materials, obtained through carbonization of beech wood selected based on strictly defined technical requirements. The activation process involved steam activation in a static furnace. Because of its organic origin and production method, the charcoal possesses a degree of activity (iodine number of 233–750 mg g^{-1}), allowing to retain water reserves, thereby providing the necessary moisture to the plant. In this experiment, activated carbon with a granulometry range of 0–2.5 mm was used. The ash content of the material is notably rich in elements such as potassium, calcium and magnesium oxides. Additionally, activated charcoal contains a higher percentage of charcoal, resulting in phosphates in the ash, serving as an excellent source of this macroelement for the plants. Due to its alkali metals content, the material has the pH range of 9–11.

To analyze differences in the measured characteristics between treated and untreated highbush blueberry plants, an analysis of variance (ANOVA) was conducted using the Statistica 8 statistical program, along with Student's T-test at a significance level of 0.05.

Results and Discussion

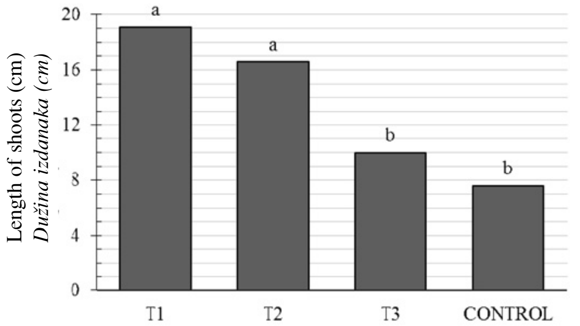
In the experiment, a positive effect of the applied retort beech charcoal was observed. Specifically, blueberry plants of the 'Duke' cultivar that received 150 g of retort beech charcoal in the first experimental year had an average shoot length of 14.50 cm, those treated with 100 g of retort beech charcoal had an average length of 12.25 cm, and plants treated with 50 g of retort beech charcoal exhibited an average shoot length of 8.00 cm (Graph 1). Control plants had the shortest average shoot length, measuring 5.58 cm. These results indicate a positive impact of the applied reort beech charcoal on shoot growth.



Graph 1. Impact of retort beech charcoal application on average shoot length of blueberry cultivar 'Duke' in the first experimental year
Grafikon 1. Uticaj primene retornog bukovog uglja na prosečnu dužinu izdanaka borovnice sorte Duke u prvoj godini proučavanja

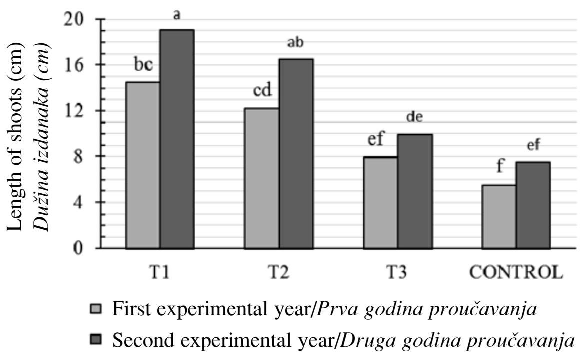
In the second year, the average shoot length of plants treated with retort beech charcoal ranged from 9.00 cm (T_3) to 19.08 cm (T_1). In contrast, plants in the control group during the second year exhibited an average shoot length of 7.58 cm (Graph 2).

Analysis of variance (ANOVA) indicated statistically significant differences in terms of average shoot length between plants treated with retorted beech charcoal and non-treated plants, as well as diffe-



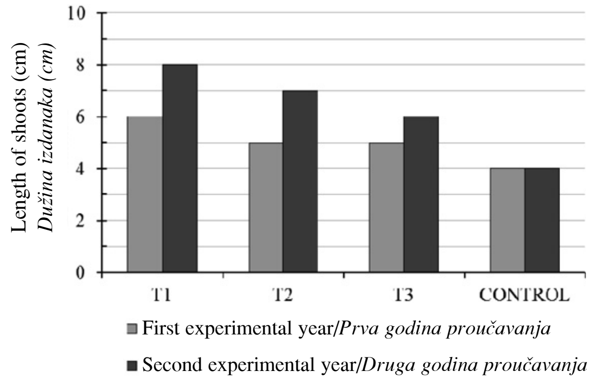
Graph 2. Impact of retort beech charcoal aplication on average shoot length of blueberry cultivar 'Duke' in the second experimental year
Grafikon 2. Uticaj primene retornog bukovog uglja na prosečnu dužinu izdanaka borovnice sorte Duke u drugoj godini proučavanja

rences between plants treated with different amounts of retorted beech charcoal. ANOVA also indicated that the shoot length of the investigated blueberry plants significantly differed between years, and the treatment-by-year interaction significantly influenced shoot length (Graph 3).



Graph 3. Impact of retort beech charcoal aplication and year of investigation on average shoot length of blueberry cultivar 'Duke'
Grafikon 3. Uticaj primene retornog bukovog uglja i godine proučavanja na prosečnu dužinu izdanaka borovnice sorte Duke

In addition to shoot length, the average number of shoots per plant was also higher under the conditions of retort beech charcoal application (Graph 4). In both experimental years, the highest number of shoots was recorded in the plants treated with 150 g of retort beech charcoal (6 shoots in the first and 8 shoots in the second experimental year, on average). Plants treated with 100 g and 50 g of retort beech charcoal had the same number of shoots in the first year (5), while in the second year the average number of shoots was 7 and 6, respectively. Blueberry plants grown without retort beech charcoal application had the smallest and the same average number of shoots in both years (4).



Graph 4. Impact of retort beech charcoal aplication and year of investigation on average shoot number of blueberry cultivar 'Duke'
Grafikon 4. Uticaj primene retornog bukovog uglja i godine proučavanja na prosečan broj izdanaka borovnice sorte Duke

There is no literature data on the effect of retorted beech charcoal on the growth and number of blueberry shoots. The results of previous studies indicate a positive impact of biochar on the yield of crops and biomass of tomato cultivar 'Optima' and pepper cultivar 'Amanda' grown in organic production in a green house (Živković et al., 2020a; 2020b). Yadav et al. (2018) reviewed published data from 59 pot experiments and 57 field experiments in 21 countries and found that application of retorted beech charcoal resulted in an average 11% increase in crops productivity. The same authors pointed out that field application of retorted beech charcoal at rates below 30 t ha^{-1} increased crop productivity to varying degrees, depending on the crop type. The greatest increase was found in legume crops (30%), followed by vegetables (29%), grasses (14%), and cereal crops, i.e., corn (8%), wheat (11%), and rice (7%). According to Yamato et al. (2006), the production of maize dry biomass significantly increased after the application of bark charcoal in infertile soil environment. A positive effect of biochar on maize dry biomass could be attributed to higher soil nitrogen retention, as observed by Baronti et al. (2010). These findings align with the results obtained in this paper. The positive effect of applying retorted beech charcoal on the number and length of blueberry shoots observed in this experiment can be attributed to its ability to maintain the balance of parameters required for plant growth. It is assumed that retorted beech charcoal has the capacity to regulate the pH value and maintain adequate substrate humidity by absorbing excess water, which, in turn, enhances soilaeration. The results obtained are also significant in addressing the issue of charcoal waste, a byoproduct in charcoal production.

These are preliminary results. Further research is required to determine the optimal amount and timing of retorted beech charcoal application in blueberry plantations under the climatic conditions of Serbia. Additionally, it is necessary to investigate its impact on other parameters, including yield and fruit quality.

Conclusion

This study suggests a positive impact of retorted beech charcoal application on the number and length of highbush blueberry shoots. This conclusion should be further supported by additional research activities, including testing a wider range of cultivars and parameters, as well as different soil types.

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ORGANSKA PROIZVODNJA AMERIČKE VISOKOŽBUNASTE BOROVNICE KORIŠĆENJEM RETORTNOG BUKOVOG UGLJA

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Rezime

Istraživanja obuhvaćena ovim radom sprovedena su u cilju proučavanja uticaja primene retortnog bukovog uglja na broj i dužinu jednogodišnjih prirasta kod biljaka visokožbunaste borovnice sorte Duke. Eksperimentalni ogled bio je postavljen po dizajnu slučajnog blok sistema i uključivao je tri tretmana i kontrolu. Biljke koje su poslužile kao kontola zasađene su u plastične saksije napunjene mešavinom strugotine i komercijalnog supstrata za gajenje borovnice čiji proizvođač Klasman. Biljke iz tretmana su posađene na isti način ali uz dodatak retortnog bukovog uglja u zoni korena i korenovog vrata biljaka u količini od 150 g (T_1), 100 g (T_2) i 50 g (T_3). Broj i dužina jednogodišnjih prirasta praćeni su tokom dve godine. Dobijeni rezultati su pokazali da retortni bukov ugalj pozitivno utiče na broj i dužinu jednogodišnjih prirasta. Naime, biljke u tretmanu su imale veću dužinu i broj jednogodišnjih prirasta u odnosu na kontrolne biljake. Utvrđene su i razlike u dobijenim rezultatima u zavisnosti od primenjene količine retortnog bukovog uglja. Najveća prosečna dužina i broj jednogodišnjih prirasta zabeleženi su u tretmanu sa 150 g retortnog bukovog uglja. Veći broj i veća dužina jednogodišnjih prirasta u svim tretmanima i kontroli zabeleženi su u drugoj godini proučavanja.

Ključne reči: organsko gajenje, retortni bukov ugalj, američka visokožbunasta borovnica, prirast lastara