*Natural Built Social Environment Health* **2**(1) 2026: 27-37 DOI: 10.63095/NBSEH.26.773234

**Natural Built Social Environment Health**

ISSN 3085-461X

www.nbseh.org

# The Effect of Applying Different Doses of Biochar on Amaranth and Sorghum Seedlings Grown in Black Soil

Mykola Kharytonov [1a*], Nadia Martynova [2b], Alla Samarska [3c]

[1]*Centre of Nature Agriculture, Dnipro State Agrarian and Economic University (ROR: https://ror.org/01s5n0596), 49009, Dnipro, Ukraine*

[2]*Laboratory of Natural Flora, Botany Garden, Dnipro National University (https://ror.org/00qk1f078), 49010, Dnipro, Ukraine*

[3]*Biology / Ecology Working Group, Institute of Biosciences, Technische Universität Bergakademie Freiberg, Freiberg (https://ror.org/031vc2293), Germany*

[a] ***ORCID:*** 0000-0002-9886-678X; ***Email:*** kharytonov.m.m@dsau.dp.ua

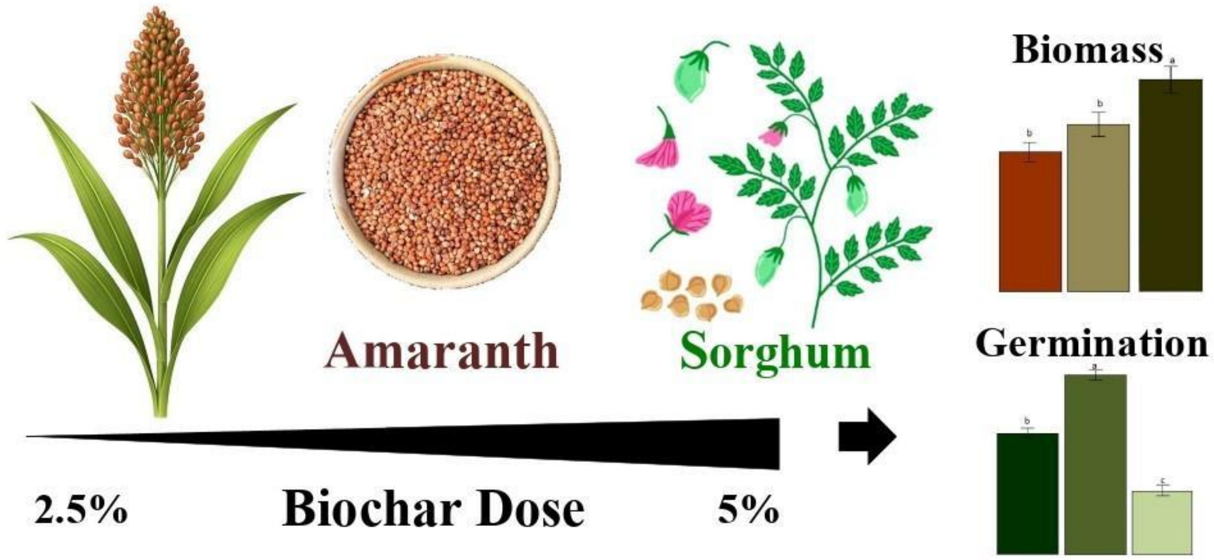
[b] ***ORCID:*** 0000-0002-1523-1886; ***Email:*** nadiamart.bg@gmail.com

[c] ***ORCID:*** 0000-0002-0828-9457; ***Email***: samarskaya.av@gmail.com

***Corresponding author:*** Mykola Kharytonov; ***Email***: kharytonov.m.m@dsau.dp.ua

## Graphical Abstract

This study examines the effect of two biochar application rates (2.5% and 5%) on the germination and biomass growth of amaranth and sorghum seedlings cultivated in black soil. Biochar application delayed germination in amaranth, yet both doses significantly increased seedling biomass compared to the control. In sorghum, a positive growth response occurred only at the lower dose (2.5%), but both doses reduced germination rates. These results indicate that the optimum biochar dose is crop-specific, with lower doses favouring sorghum growth and both doses enhancing amaranth biomass despite initial germination delays.




DOI: 10.63095/NBSEH.26.773234

Available online 06 February 2026

**Citation:** Kharytonov, M., Martynova, N., & Samarska, A., 2026, Effect of applying different doses of biochar on amaranth and sorghum seedlings grown in black soil. *Natural Built Social Environment Health* **2**(1), 27-37. DOI: 10.63095/NBSEH.26.773234

**Abstract:** Biochar shows broad potential for use as a soil amendment. The success of its application relies on the optimal dose and the type of plant grown. The use of biochar delayed the germination of amaranth seeds. Subsequent seedling development was significantly better than the control values in both experimental treatments (biochar application doses of 2.5% and 5%). In the experiment with sorghum, plants had a positive response only under a relatively small dose of the amendment (2.5%). In addition, both doses of biochar slowed down and reduced germination of sorghum seeds.

***Keywords:*** *Amaranth, Sorghum, Biochar, Black soil, Germination, Biomass growth.*

## Introduction

Archaeological research and anthropological analysis have shown that biochar enrichment of soils has contributed to high agricultural productivity in regions of South America [1]. Biochar is now applied for a wide range of purposes, from heat and electricity generation to flue gas cleaning, metallurgy, agriculture and livestock farming, and building materials production [2, 3]. Biochar has recently been employed as a replacement for fossil carbon carriers in an attempt to reduce greenhouse gas emissions [4]. Biochar is produced from crop residues from agriculture, forestry, sewage sludge, food waste, and animal manure [5]. The composition of biochar is an important indicator for determining its application [6-8]. Differences in the characteristics of biochar have consequences for its use as a soil amendment [9-10]. The effect of biochar on plants can have a dual impact: suppressing growth and development in some crops and increasing it in others [11-13]. The rates of biochar application are also significant [14-16]. Healthy soil is the basis of crop productivity. Yet, there is a large portion of degraded soils resulting from acidity, alkalinity, salinity, nutrient deficiency, and anthropogenic pollution. Various management strategies have been proposed and developed to improve degraded soils with biochar addition [17-20]. Biochar application shows great promise. Still, there are many questions and gaps in knowledge regarding its use as a soil amendment. Therefore, the main objective of this case study was to determine the effect of different doses of biochar introduced into black soil during the cultivation of amaranth and sorghum seedlings.

## Materials and Methods

Two model pot experiments were conducted to determine the effect of biochar on seed germination and the early phases of plant development. Two types of annual crops were selected for the study: amaranth (*Amaranthus caudatus*) and sorghum (*Sorghum bicolor*). Common black soil was used for seed germination. The substrate pH was 6.8. The experiment was conducted in three treatments: 1) soil without biochar (control); 2) soil 97.5% + biochar 2.5%; 3) soil 95% + biochar 5%. Biochar was obtained by pyrolysis of walnut shells at a temperature of 400 °C. Twenty-five amaranth seeds and five sorghum seeds were planted in each 0.4 l vessel. The same numbers of plants (ten amaranth plants and three sorghum plants) were left after germination in each vessel by thinning. All pots were watered daily to 75% of the field capacity by weight. Seed germination, seedling height, seedling root length, and seedling weight were investigated at the age of one month. All statistical data processing was performed in R version 4.3.2 [21]. ANOVA was used to analyse variance for two factors.

## Results and Discussion

### *Growing amaranth with the addition of biochar*

The germination of amaranth seeds in the control and experimental treatments was assessed 17 days after sowing. It was found that a dose of biochar of 2.5% led to an increase in seed germination energy by 25% (Figure 1). In contrast, the number of germinated seeds in the treatment with a dose of 5% did not differ from the control.

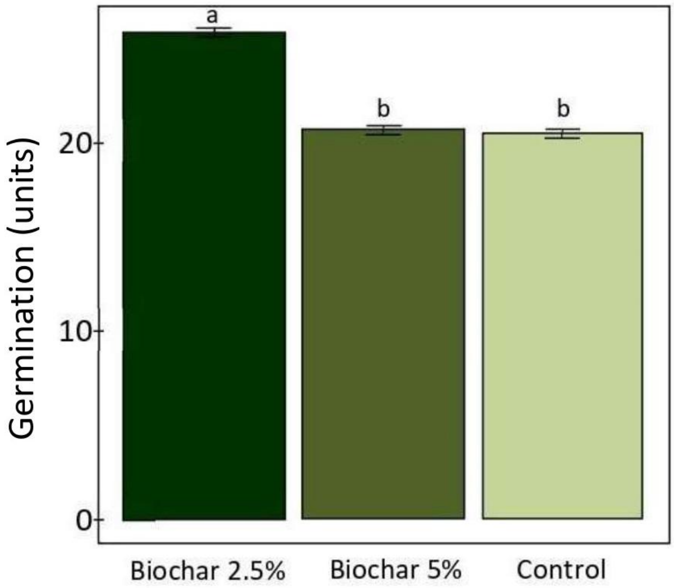



**Figure 1.** Germination of amaranth plants depending on the dose of biochar application

A clear inverse relationship between vertical growth and the dose of biochar applied to the soil was observed. Seedling height decreased with an increasing biochar content in the substrate (Figure 2).

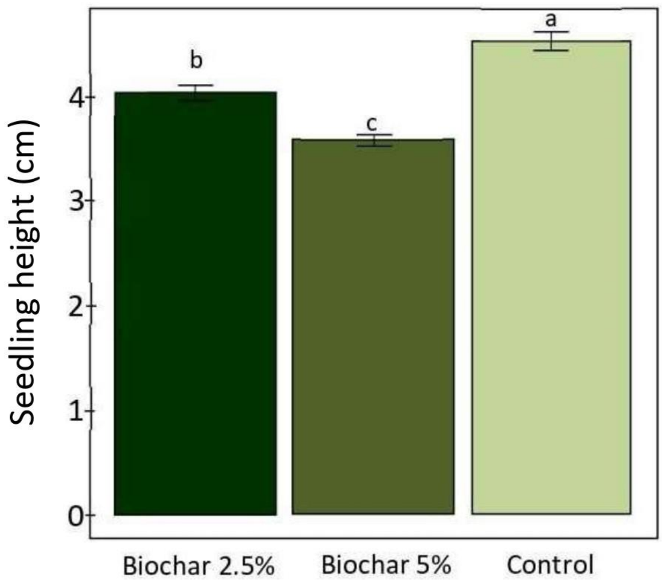



**Figure 2.** Height of amaranth seedlings depending on the dose of biochar application

A direct relationship between the amount of biochar in the substrate and the length of the roots was observed by measuring the root system length of amaranth seedlings (Figure 3).

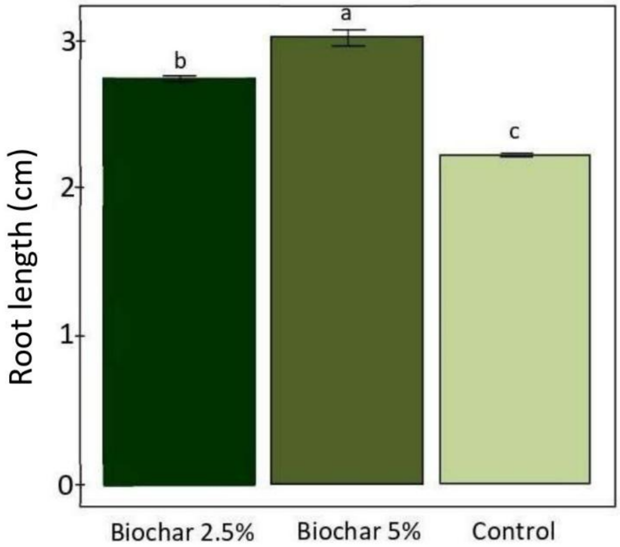



**Figure 3.** Root length of amaranth seedlings depending on the dose of biochar

The length of the root system increased relative to the control by 21.5% in the 2.5% biochar treatment and by 34.1% in the 5% biochar treatment (Figure 3). Notably, in the 5% biochar treatment, the root system was not only the longest but also the most developed. The addition of biochar led to an increase in the biomass production of amaranth seedlings (Figure 4).

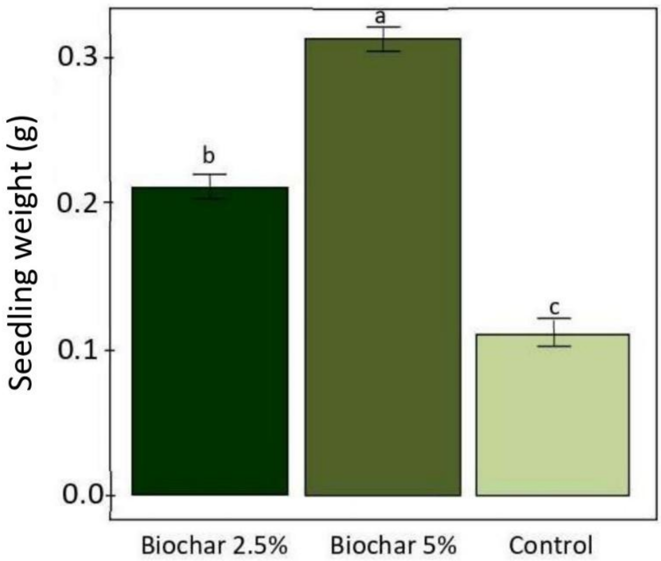



**Figure 4.** Weight of amaranth plants at the age of 1 month in different variants of the experiment, mg

The weight of plants in treatments with biochar exceeded the control values by 10–18%. In contrast, the height of plants in treatments with biochar was lower than in the control, as a result of the growth of the root system and stem thickening.

***Growing sorghum with the addition of biochar***

In the pot experiment with sorghum, the appearance of the first shoots was noted on the tenth day after sowing. In treatments with biochar, germination was delayed by 3–5 days compared to the control. Seed germination with biochar at a dose of 2.5% was slightly higher than with 5% biochar (Figure 5).

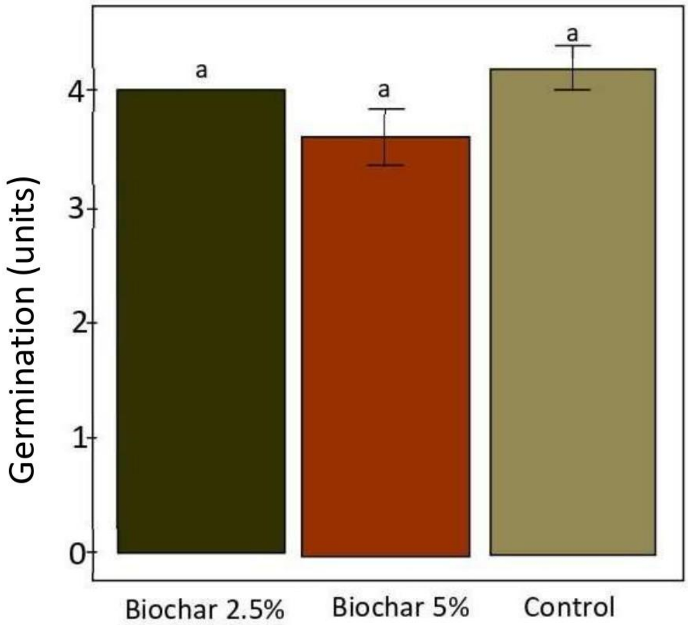



**Figure 5.** Germination of sorghum plants depending on the dose of biochar application.

Plant height in the treatment with the amendment was slightly lower than in the control (Figure 6).

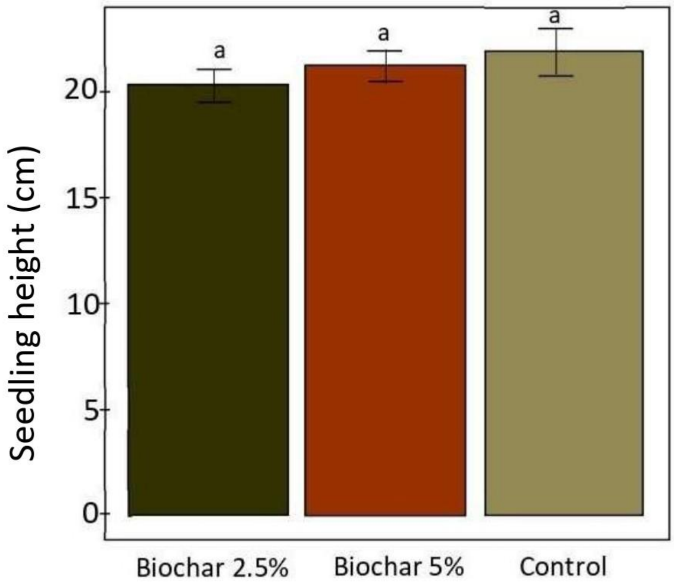



**Figure 6.** Height of sorghum seedlings in different options of the experiment, cm

Plants in the treatment with 2.5% biochar were stronger, with thicker stems and brighter leaves. The root system of sorghum was more sensitive to biochar than the aerial part of the plant. Different application rates of this soil amendment had contrasting effects. Adding biochar at a dose of 2.5% stimulated root system growth and development, whereas a rate of 5% suppressed it (Figure 7).

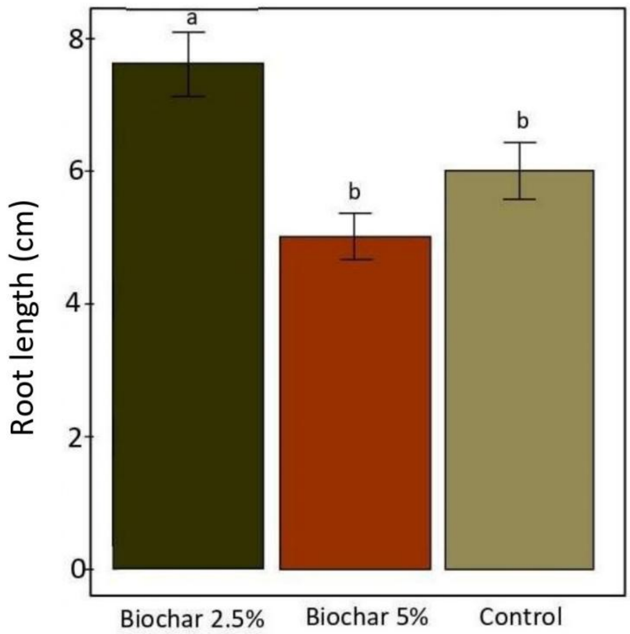



**Figure 7.** Root length of sorghum plants depending on the dose of biochar, cm

The root length in the 2.5% biochar treatment increased by 28% compared to the control, whereas in the 5% biochar option it decreased by 18%. A small dose of biochar promoted the formation of a larger number of lateral shoots than in other treatments of the experiment. Adding biochar to the substrate at 2.5% by weight had a positive effect on the growth and development of sorghum seedlings. At one month of age, they had a well-developed root system and healthy aerial biomass. As a result, the weight of the seedlings increased by 21.1% compared to the control (Figure 8).

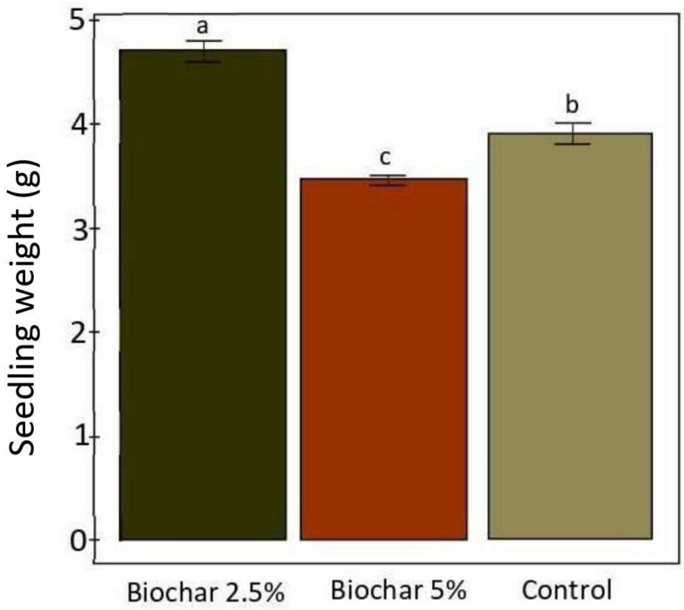



**Figure 8.** Weight of sorghum plants in different treatments, g

A double dose of biochar at 5% by weight had a negative effect on the growth and development of sorghum seedlings. In addition to the inhibition of seed germination, the plants were stunted in growth, and the root system developed slowly and was weaker than in control plants. As a result, the weight of the plants was 11% lower compared to the plants in the treatment without biochar addition.

This study confirmed that the type of crop determines the response of the plant to the introduction of biochar. In our case, the plants were grown on black soil. It is logical to assume that the type of soil also plays a role in the effect that biochar has on plants. This assumption is supported by the results of other studies in this area. In the experiment conducted by Videgain-Marco *et al.* [22], application of biochar at a dose of 3% significantly increased sorghum root dry weight in the sandy-loam growing substrate by up to 50% compared to the control. The sorghum dry matter yield grown in sandy desert soil was also significantly improved by 18% and 22% as application rates increased from 1.5% to 4.5% [23]. In a field experiment with *Amaranthus caudatus* grown in sandy soil, a biochar dose of 10 t/ha gave a greater increase than an application at a rate of 7 t/ha [24]. In contrast, results from another field experiment in clayey soil showed that the dose of 5% biochar gave the highest yield of red amaranth among the other treatments — 2.5% and 10% [25]. Thus, the reaction of plants to the addition of biochar can vary depending on the type of plant and the physical and chemical properties of the soil.

## Conclusion

The reaction to the addition of biochar varies with the type of plant. The reaction of amaranth seedlings was positive at both doses of biochar application. Even though the height of the experimental plants was slightly lower than in the control, root system development and the general condition of the seedlings were better in both variants with biochar. Sorghum showed a positive response only with a relatively small dose of the amendment. In addition, both doses of biochar slowed and reduced the germination of sorghum seeds. Thus, when growing this crop, an increase in the amount of biochar in black soil can cause undesirable consequences such as sparse shoots, uneven growth, weak root system development, and so on.

**Acknowledgement:** The research was supported by the Ministry of Education and Sciences of Ukraine and DAAD program “DAAD – Ostpartnershaften”2025 (Germany).

**Ethics Approvals:** This study was conducted in full accordance with ethical principles.

**Data Availability:** Verification required

**Code availability:** Verification required

**Conflict of interest:** Verification required

**References**

[1] Groot, H., Fernholz, K., Frank, M., Howe, J., Bowyer, J., & Bratkovich, S., 2016, *Biochar 101: An introduction to an ancient product offering modern opportunities* (Minneapolis, MN: Dovetail Partners, Inc.). https://www.dovetailinc.org/report_pdfs/2016/dovetailbiochar0316.pdf

[2] Ahmad, M., Rajapaksha, A., Lim, J., Zhang, M., Bolan, N., Mohan, D., Vithanage, M., Lee, S., & Ok, Y., 2014, Biochar as a sorbent for contaminant management in soil and water: A review. *Chemosphere* **99**, 19-33. https://doi.org/10.1016/j.chemosphere.2013.10.071

[3] Weber, K., & Quicker, P., 2018, Properties of biochar. *Fuel* **217**, 240-261, https://doi.org/10.1016/j.fuel.2017.12.054

[4] Bamdad, H., Hawboldt, K., & MacQuarrie, S., 2018, A review on common adsorbents for acid gases removal: Focus on biochar. *Renewable and Sustainable Energy Reviews* **81** (2). 1705–1720. https://doi.org/10.1016/j.rser.2017.05.261

[5] Cha, J., Park, S., Jung, S., Ryu, C., Jeon, J., Shin, M., & Park, Y., 2016, Production and utilization of biochar: A review. *Journal of Industrial and Engineering Chemistry* **40**, 1–15. https://doi.org/ 10.1016/j.jiec.2016.06.002

[6] Al-Wabel, M., Al-Omran, A., El-Naggar, A., Nadeem, M., & Usman, A., 2013, Pyrolysis temperature induced changes in characteristics and chemical composition of biochar produced from conocarpus wastes. *Bioresource Technology* **131**, 374-379. https://doi.org/10.1016/j.biortech.2012.12.165

[7] Gul, S., Whalen, J.K., Thomas, B. W., Sachdeva, V., & Deng, H., 2015, Physico-chemical properties and microbial responses in biochar-amended soils: mechanisms and future directions.Agriculture, *Ecosystems & Environment* **206**, 46-59. https://doi.org/10.1016/j.agee.2015.03.015

[8] Zhang, H., Voroney, R.P., & Price, G.W., 2015, Effects of temperature and processing conditions on biochar chemical properties and their influence on soil C and N transformations. *Soil Biology and Biochemistry* **83**, 19-28. https://doi.org/10.1016/j.soilbio.2015.01.006

[9] Chintala, R., Mollinedo, J., Schumacher, T.E., Malo, D.D., & Julson, J.L., 2014, Effect of biochar on chemical properties of acidic soil. *Archives of Agronomy and Soil Science* **60**(3). 393-404. https://doi.org/10.1080/03650340.2013.789870

[10] Singh, H., Northup, B.K., Rice, C.W., & Prasad, P.V., 2022, Biochar applications influence soil physical and chemical properties, microbial diversity, and crop productivity: a meta-analysis *Biochar* **4**(1), 8. https://doi.org/10.1007/s42773-022-00138-1

[11] Solaiman, Z.M., Murphy, D.V., & Abbott, L.K., 2012, Biochars influence seed germination and early growth of seedlings. *Plant and soil* **353**, 273-287. https://doi.org/10.1007/s11104-011-1031-4

[12] Visioli, G., Conti, F.D., Menta, C., Bandiera, M., Malcevschi, A., Jones, D.L., & Vamerali, T., 2013, Assessing biochar ecotoxicology for soil amendment by root phytotoxicity bioassays. *Environ Monit Assess* **188**, 166. https://doi.org/10.1007/s10661-016-5173-y

[13] Zhang, K., Wang, Y., Mao, J., & Chen, B., 2020, Effects of biochar nanoparticles on seed germination and seedling growth. *Environmental pollution* **256**, 113409. https://doi.org/10.1016/j.envpol.2019.113409

[14] Li, Y., Shen, F., Guo, H., Wang, Z., Yang, G., Wang, L., Zhang, Y., Zeng, Y, & Deng, S., 2015, Phytotoxicity assessment on corn stover biochar, derived from fast pyrolysis, based on seed germination, early growth, and potential plant cell damage. *Environmental Science and Pollution Research* **22**, 9534-9543. https://doi.org/10.1007/s11356-015-4115-5

[15] Das, S.K., Ghosh, G.K., & Avasthe, R., 2020, Ecotoxicological responses of weed biochar on seed germination and seedling growth in acidic soil. *Environmental Technology & Innovation* **20**, 101074. https://doi.org/10.1016/j.eti.2020.101074

[16] Chrysargyris, A., Prasad, M., Kavanagh, A., & Tzortzakis, N., 2020, Biochar type, ratio, and nutrient levels in growing media affects seedling production and plant performance. *Agronomy* **10**(9), 1421. https://doi.org/10.3390/agronomy10091421

[17] Fang, J., Zhan, L., Ok, Y., & Gao, B., 2018, Minireview of potential applications of hydrochar derived from hydrothermal carbonization of biomass. *Journal of Industrial and Engineering Chemistry* **57**, 15-21. https://doi.org/10.1016/j.jiec.2017.08.026

[18] Persaud, T., Homenauth, O., Fredericks, D., & Hamer, S., 2018, Effect of rice husk biochar as an amendment on a marginal soil in Guyana. *World Environment* **8**(1), 20-25. https://doi.org/10.5923/j.env.20180801.03

[19] Yu, H., Zou, W., Chen, J., Chen, H., Yu, Z., Huang, J., & Gao, B., 2019, Biochar amendment improves crop production in problem soils: A review. *Journal of environmental management* **232**, 8-21. https://doi.org/10.1016/j.jenvman.2018.10.117

[20] Wang, Y., Lin, Q., Liu, Z., Liu, K., Wang, X., & Shang, J., 2023, Salt-affected marginal lands: a solution for biochar production. *Biochar* **5**(1), 21. https://doi.org/10.1007/s42773-023-00219-9

[21] R Core Team, 2023, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

[22] Videgain-Marco, M., Marco-Montori, P., Martí-Dalmau, C., Jaizme-Vega, M.d.C., Manyà-Cervelló, J.J., & García-Ramos, F.J., 2020, Effects of Biochar Application in a Sorghum Crop under Greenhouse Conditions: Growth Parameters and Physicochemical Fertility. *Agronomy* **10**, 104. https://doi.org/10.3390/agronomy10010104

[23] Laghari, M., Mirjat, M.S., Hu, Z., Fazal, S., Xiao, B., Hu, M., Chen, Z., & Guo, D., 2015, Effects of biochar application rate on sandy desert soil properties and sorghum growth. *Catena* **135**, 313-320. https://doi.org/10.1016/j.catena.2015.08.013

[24] Islam, Md.M., Jalal, Md.S., Islam, Md.S., Hossain, Md.M., Işik, M., & Iqbal, Md.T., 2020, Akha biochar enhances soil fertility and productivity of red amaranth plant. *Net Journal of Agricultural Science* **8**(1), 1-7. https://www.netjournals.org/pdf/NJAS/2020/1/20-011.pdf