 https://doi.org/10.1051/bioconf/20248501061

Evaluation of the effect of different doses of biochar application on the yield of soybean cultivar sculptor in the conditions of agroecological station of K.A. Timiryazev

Maria Tikhonova[1], *Yaroslava* Zhigaleva [1], *Elena* Iliushkova [1], and Evgeny Taller[1]

[1]Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, Moscow, Russia

Abstract. In the conditions of the academic fields of the Timiryazev Academy (Moscow, Russia), an experiment was conducted to evaluate the impact of biochar on soybean cultivar Sculptor. Plots of 0.25 ha were laid on arable sod-podzolic soils, the doses of biochar application were 3 kg/m^2, 1 kg/ m^2 and reference variant without application. The plots were established in triplicate. The results of the studies showed an improvement in a number of soil properties at 1 kg per m^2, with more plant biomass, more stem pods per plant. With application of 3 kg per m^2 - development of soybean variety Sculptor did not have the necessary effect, at the first stages soybean developed rapidly, but later only slow development of weed plants was noted. On the reference plots plants had a smaller biomass compared to the variant with the application of 1 kg per m^2. Application of biochar to soybean crops shows a positive effect on yield and biomass of plants at the application dose of 1 kg per m^2.

1 Introduction

One of the most urgent challenges currently facing the entire global community is combating climate change and preserving and increasing the fertile land that can provide food for an ever-increasing global population. Biochar is a way of recycling carbon, which is rapidly increasing in the air, back into soils from which it is also rapidly disappearing. Modern agricultural practices, including tillage and the heavy use of chemical fertilizers, pesticides and herbicides, cause much of the organic soil carbon to release as CO_2 [1]. Thus, up to one-third of the excess carbon dioxide in the atmosphere comes from soils.

Each year, plants absorb and store about 60 gigatonnes of carbon [2]. If we prevent some of this biomass from decomposing by converting it into biochar and use it to improve soil fertility, we can address climate change and food security.

Biochar is a multi-purpose soil additive to address two key global challenges - soil degradation and climate change. The unique properties of biochar lie in its carbon structure, which is more stable than that of organic matter. When properly manufactured and applied, biochar can persist in the soil for hundreds of years.

This characteristic gives biochar a comparative advantage over alternative methods of soil carbon sequestration, both in terms of storage duration and compatibility with conventional tillage operations.

In parallel with the carbon sequestration effect, the application of biochar helps to improve soil quality and crop productivity.

The idea that coal could be used to improve soil fertility came from the discovery and study of Terra preta soils in the Amazon basin. Terra preta coal particles are very small, most are between 10 and 20 micrometers, and those in the upper soil horizon are aggregated with clay particles and a rich variety of minerals and mobile organic matter. Terra preta is both remarkably fertile and remarkably resilient, especially given its location in a tropical environment [3].

Thus, it can be concluded that such soils, those rich in clay fraction and infertile soils, have great prospects for the application of biochar. Their fractional composition can ensure the accumulation of carbon in the soil for many years and reduce the effects of global climate change, and improving the fertility of these lands contributes to the food and economic sustainability of the region, which is relevant for both developing countries and developed countries.

Now biochar is understood as condensed coal residue with a sufficiently high carbon content, which is formed as a result of thermal decomposition of biomass in the absence of oxidizing environment in the temperature range from 450°C to 900°C. As a raw material for biochar production various organic-containing raw materials can be used, which are wastes of agro-industrial and forestry complexes, such as low-commodity wood, manure, leaves, straw, buckwheat husks, etc.

In addition to soil carbon storage, the application of biochar to agricultural land can lead to:

- Improvement of soil structure and porosity;
- increase soil water-holding capacity;
- reduction of acidity;
- reduction of nitrous oxide emissions;
- regulation of nitrogen leaching;
- improved electrical conductivity;
- reduction of heavy metal toxicity;

- increasing microbial activity and the ability of soil to suppress pathogens [4-6].

The structure of biochar is largely amorphous but contains some local crystalline structure of strongly conjugated aromatic compounds. There are also voids in the structure of biochar formed in the form of pores, cracks and cellular morphology of the biomass. The carbon atoms are strongly bonded together, and this is what makes it resistant to microorganisms and decomposition. With a surface area of 200-500 m2 per gram and high porosity, biochar can absorb water and the nutrients it contains up to five times its own weight [7].

Analysis of the studies showed that on average, the addition of biochar to the soil increased pH, yield, carbon, nitrogen, and phosphorus content, as well as the concentration of potassium in plant tissues. Yield increase was more pronounced in highly degraded soils that received almost no fertilizer.

More important than the nutrient content of biochar is its ability to capture nutrients when mixed with other nutrient sources.

However, despite the long history of biochar use in modern agriculture, this material has only recently been introduced and its application still requires further research. In order to achieve the same effect as in the Amazon region, biochar must first be "activated", i.e. it must be enriched with nutrients and soil organisms, e.g. by composting. If pure biochar is applied to the soil, it takes water and dissolved substances from the environment and thus has the exact opposite effect. Solutions to this problem can be found in the way biochar is used as a supplement to animal feed or bedding, or applied to compost heaps, in the latter case it also contributes to reducing greenhouse gas emissions and increasing the microbiological activity required for the composting process.

Also, some researchers reported that the application of biochar had no effect on crop health or even negative one [8].

As a disadvantage, biochar can be a source of pollution, bringing polyaromatic hydrocarbons (PAHs), dioxins, VOCs and heavy metals depending on its feedstock and production conditions. However, biochar can immobilize heavy metals through sorption, precipitation and pH reduction/oxidation reactions and has been shown to consistently reduce heavy metal concentrations in plants.

Biochar can act as a source of PAHs in soils, but observed concentrations remain below the maximum permissible limit. Biochar can adsorb pesticides, potentially leading to their accumulation in soils, although they become less available and can also be degraded by biochar.

Contradicting data are also available on the stability of biochar and its ability to retain carbon [9]. All this suggests that as much research as possible is needed on the use of biochar in different climatic zones and types of management, so that we can get the most complete picture of its impact on soils, crops, animals, and humans, as well as on its ability to counteract global climate change.

2 Material and method

In 2022 at the Agroecological Station of the Field Station of the K.A. Timiryazev Russian State Agrarian University-MSA named after K.A. Timiryazev an experiment on modeling the conditions of approaching carbon neutrality was laid. The essence of the experiment is to grow leguminous crops on urbanized sod-podzolic soils with the use of biochar and assess its impact on the parametric features of the crop and soil.

The scheme of the experiment, laid at the Field Station of the Agroecological Station of the K.A. Timiryazev Russian State Agrarian University-MSHA, includes three plots of 2*10 m, one of which biochar was applied in the amount of 3 kg/m2, the second - in the amount of 1 kg/m2, and the third is a reference without biochar application (hereinafter referred to as variants 3, 1 and 0, respectively) (Fig. 1).

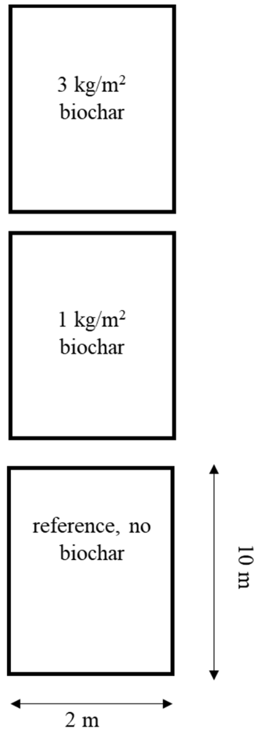

Fig. 1. Experiment scheme.

Glycine max soybean cultivar Sculptor was selected as a seed crop.

3 Results and discussion

As a result, we obtained the following data on biomass and yield of the crop under study.

The mean stem length was maximum in the reference variant and was 53.55 cm, with 48.5 cm in variant 1 and 38.84 cm in variant 3.

Also, the variant without biochar application showed the maximum stem length of 84 cm (77 cm and 60 cm in variants 1 and 3, respectively) (Fig. 2).

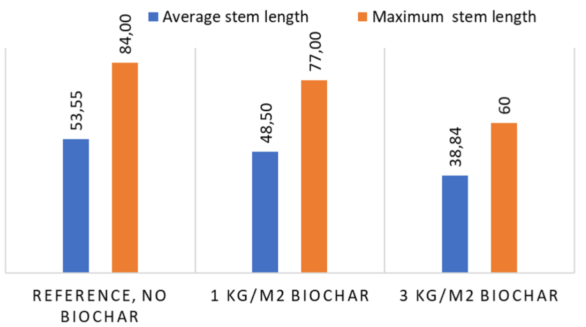

Fig. 2. Average and maximum stem length per plot.

However, the total number of plants from the plot was higher in variant 3 and amounted to 728 plants with 474 plants in variant 1 and 406 plants in variant 0 (Fig. 4). The total number of plants in the plots without biochar and with the application of 3 kg/m2 biochar differed almost 2 times, which can be explained by the moisture-holding capacity of biochar, which creates favorable conditions for seed germination.

The total number of beans from the plot is 8815 in variant 1, 6481 in variant 3 and 6314 in variant 0. Thus, due to the greater number of plants in the plot with the application of 3 kg/m2 of biochar, the total number of beans in variants 0 and 3 was almost equal, but the gap with the indicator of variant 1 is quite significant (Fig. 3).

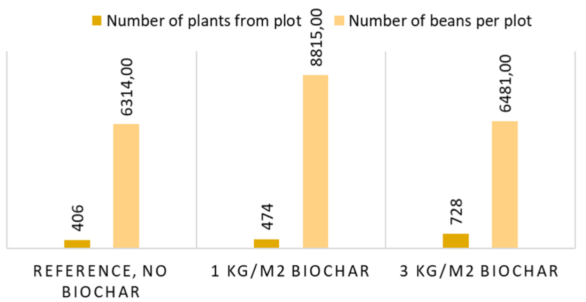

Fig. 3. Total number of plants and beans per plot.

The average number of beans per plant was maximum in variant 1 and amounted to 18.6 pieces. In variant 0 this indicator was equal to 15.55 pieces, and in variant 3 - 8.9 pieces. In this case, the difference between the variants is also almost twofold, but now the plot with maximum biochar application showed the worst result.

The maximum number of beans per plant was also recorded in variant 1 - 98 pieces, with 80 pieces and 37 pieces in variants 0 and 3, respectively (Fig. 4).

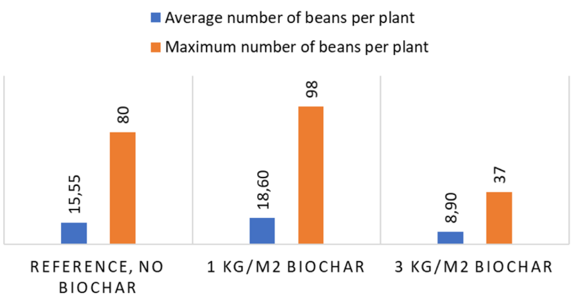

Fig. 4. Average and maximum number of beans per plant.

Total plant biomass (excluding roots) is 12.8 kg per plot in variant 0, 14.2 kg per plot in variant 1 and 8.65 kg per plot in variant 3. Bean weight per plot was 5.9 kg per plot in variant 0, 8.8 kg per plot in variant 1 and 4.7 kg per plot in variant 3 (Fig. 5).

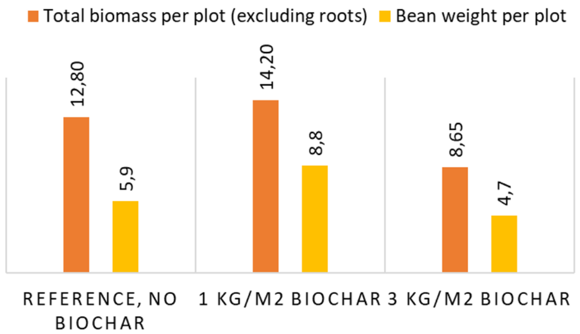

Fig. 5. Total plant biomass (excluding roots) and bean weight per plot.

Thus, the yield was 2.95 t/ha in variant 0, 4.4 t/ha in variant 1 and 2.35 t/ha in variant 3.

Accordingly, the best result in terms of yield and biomass growth was shown by the experiment variant with the application of biochar in the amount of 1 kg/m^2.

4 Conclusion

The study showed that the application dose of biochar 1 kg/m2 has a positive effect on the biomass growth of soybean cultivar. While the application of biochar at a dose of 3 kg/m^2 had a depressing effect on the studied crop (except for the indicator of the number of plants). Thus, the gain in yield in the variant 1 kg/m^2 was 49.1%, and the loss in the variant 3 kg/m^2 was 20.3% relative to the reference.

Funding

The research was financed by the Ministry of Science and Higher Education of Russian Federation, Agreement No. 075-15-2021-1030.

References

1. J. Meshalkina, et al., Agronomy 12, 7, 1606 (2022)
2. R.K.K. Dixon, A. Solomon, S. Brown, R. Houghton, M. Trexier, J. Wisniewski, Carbon Pools and Flux of Global Forest Ecosystems // Science (New York, N.Y.). 263. 185-90. 10.1126/science.263.5144.185 (1994)
3. B. Glaser, J. Lehmann, W. Zech, Biol Fertil Soils P. 219–230 (2002)
4. F.M. Santos, A.L. Gonçalves, J.C.M. Pires, Bioenergy with Carbon Capture and Storage. Using Natural Resources for Sustainable Development, 1–13 (2019)

5. J.H. Park, D. Lamb, P. Paneerselvam, G. Choppala, N. Bolan, J.W. Chung. Journal of Hazardous Materials, (2011)
6. D. Woolf, J.E. Amonette, F.A. Street-Perrott, J. Lehmann, S. Joseph, Nature Communications, P. 1–9 (2010)
7. A. Downie, A. Crosky, P. Munroe, Earthscan, London., P 13–32 (2009)
8. A. Zhang, R. Bian, G. Pan, L. Cui, Q. Hussain, L. Li, et al., Field Crops Research (2012)
9. S. Butnan, J. Deenik, B. Toomsan, M.J. Antal, P. Vityakon, Geoderma (2015)