



Effect of the soil treated with biochar on the rye-grass in laboratory experiment

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Abstract: The application of biochars to improve soils and to mitigate global climate change is a popular research area all over the world, although it is not a new topic. In our study, wood chips char (BC) and animal bone char (ABC) were applied. The pot experiments were conducted under laboratory conditions. 2 grams of rye-grass (*Lolium perenne*) were seeded into each pot. The following various soil parameters were measured: pH (KCl), AL-P₂O₅, AL-K₂O, total water soluble salt content and organic matter content. The measured parameters from the plant samples were: total-P, total-K and micronutrients. Results show that the negative or positive effect of pyrolysis solids cannot be determined clearly, further experiments are needed.

Keywords: wood chips char, animal bone char, soil properties, nutrient uptake

1. Introduction

The application of different biochars to improve soils is a notable research area nowadays. Most of the biochar-application-related research has taken place in tropical environments [1]; so, the experiments on different climatic regions and different soil types are especially necessary.

Biochar as a material is defined as: “Biochar is a carbon-rich product of the pyrolysis process, intended to be used as a soil amendment to improve the physical and chemical characteristics of soils and to mitigate climate change by sequestering carbon. When applied to soil, biochar provides plant nutrients, increases surface

area, CEC and water-holding capacity, and improves the soil as a microbial habitat” [4, 5].

The conditions of pyrolysis and feedstock types have a notable influence on the physical and chemical composition of the biochar. All these various properties determine its function, transport and fate in the environment, and, at last, the suitability for a given application. This heterogeneity renders the identification of the underlying mechanisms behind reported effects more difficult, but it also provides possibilities to engineer biochar with controlled properties [8].

The pH of biochars is usually neutral to basic; so, the biochar application has a liming effect on soils, which plays an important role in increasing plant productivity [8]. Biochar may also produce phytotoxic effects also due to the excessive soluble salts and the high pH [6]. Soluble salts are often present in the ash fraction of biochars, depending mostly on the mineral content of the feedstock [8].

Many studies have confirmed that biochar is a very efficient absorbent for nutrients [2, 3, 5]. The absorbance and slow release of plant nutrients of biochar provides a good feasibility to reduce the amount of fertilizers in agriculture.

Quilliam et al. found that biochar application benefits, e.g. improved soil nutrient levels or crop performance, seemed to be short-lived. The reapplication of biochar intensifies the short-term benefits rather than any lasting differences [7].

The goal of our experiment was to evaluate the effects of two types of pyrolysis solids as a potential soil amendment.

2. Materials and methods

The used soil samples were collected from the Ap horizon (0-30 cm) of an Arenosol from a research field plot of the Szent István University Crop Production and Biomass Utilization Centre, Gödöllő, Hungary. The air-dried samples were homogenized and were passed through a 2-mm sieve to the analysis. The basic properties of the soil are given in Tab. 1.

Tab. 1. The basic physical and chemical properties of the soil used in the study

Genetic horizon	Depth	OC	CaCO ₃	pH	pH	CEC	Total salt	AL-P ₂ O ₅	AL-K ₂ O	hy	WHC
	(cm)	%	%	H ₂ O	KCl	cmol kg ⁻¹	%	mg kg ⁻¹	mg kg ⁻¹		%
Ap	0-30	0.49	-	5.54	4.24	12.19	0.028	111.12	119.86	0.08	21.5

Wood chips char (BC) and animal bone char (ABC) were produced in different Hungarian pyrolysis plants. Biochar properties are summarized in Tab. 2.

Tab. 2. Characteristics of the two applied biochars
(BC: wood chips char, ABC: animal bone char)

Parameters	BC	ABC
Bulk density g cm ⁻³	0.36	0.31
Dry matter %	93.87	99.95
Ignition residue (ash) of dry matter %	11.61	100
Total carbon %	79.8	9.9
Total nitrogen %	0.7	1.8
C/N ratio %	99.4	5.1
pH	8.32	7.58
CEC cmol kg ⁻¹	14.7	n.d.
Calcium mg kg ⁻¹	30 200	300 000
Chromium mg kg ⁻¹	4	4
Copper mg kg ⁻¹	9	5
Iron mg kg ⁻¹	2 280	63
Potassium mg kg ⁻¹	4 450	2 000
Magnesium mg kg ⁻¹	1 200	6 000
Manganese mg kg ⁻¹	1140	1
Sodium mg kg ⁻¹	170	7000
Phosphorus mg kg ⁻¹	780	133 000
Zinc mg kg ⁻¹	41	152
Sum of PAH mg kg ⁻¹	4.82	0.37
Sum of PCB	-	-
Nitrite (KCl) mg kg ⁻¹	0.4	0.6
Nitrate (KCl) mg kg ⁻¹	< 10	<10
Potassium (AL) mg kg ⁻¹	1 450	1 500
Phosphorus (AL) mg kg ⁻¹	214	24 600

In the pot experiment, two types of biochar were used. Predetermined amounts of biochars were added to the soil depending on the volume ratio contained (Tab. 3.). The four biochar application levels fitted to 1% (10 g), 2.5% (25 g), 5% (50 g) and 10% (100 g). The 1,000-g mixture was watered with 150 cm³ kg deionized water equivalent to 60% of the soil's plasticity. These mixtures were divided into four plastic containers; each container was filled with 200 g of biochar-amended soils. 2 grams of rye-grass (*Lolium perenne*) were seeded in each pot. The pots were later watered to weight.

After the 4 weeks of the experiment, various soil parameters were measured: pH (KCl), AL-P₂O₅, AL-K₂O, total water soluble salt content and organic matter content according to Tyurin. The measured parameters for the plant samples were: total-P, total-K and micronutrients (Ca, Mg, Cu, Fe, Mn, Zn, Cr).

Tab. 3. Parameters of treatments

Treatments	Soil	Added pyrolysis solids
BC10	990g	10g wood chips char
BC25	975g	25g wood chips char
BC50	950g	50g wood chips char
BC100	900g	100g wood chips char
ABC10	990g	10g animal bone char
ABC25	975g	25g animal bone char
ABC50	950g	50g animal bone char
ABC100	900g	100g animal bone char
Control (C)	1000g	-

Differences in soil and plant properties between the treatments were statistically analysed using variance tests (Microsoft Excel. $P < 0.05$), while significant differences between individual treatments were determined by comparing the least significant difference (LSD) with the mean.

3. Results and discussions

The analysis of the soil after the reaping shows that both types of biochar (BC and ABC) had an effect and even the two types have had some differences. The pH_(KCl) show that the treatments had an effect; the pH lift proportionately with the added products. This was expected from the related literature results, as biochar researches had shown a similar effect on soils as liming (Fig. 1).

As for the soluble salt concentration, it also got higher, especially in the case of the treatment noted as ABC (Fig. 2). The differences between the measurements are most possibly caused by the different raw material of the biochars.

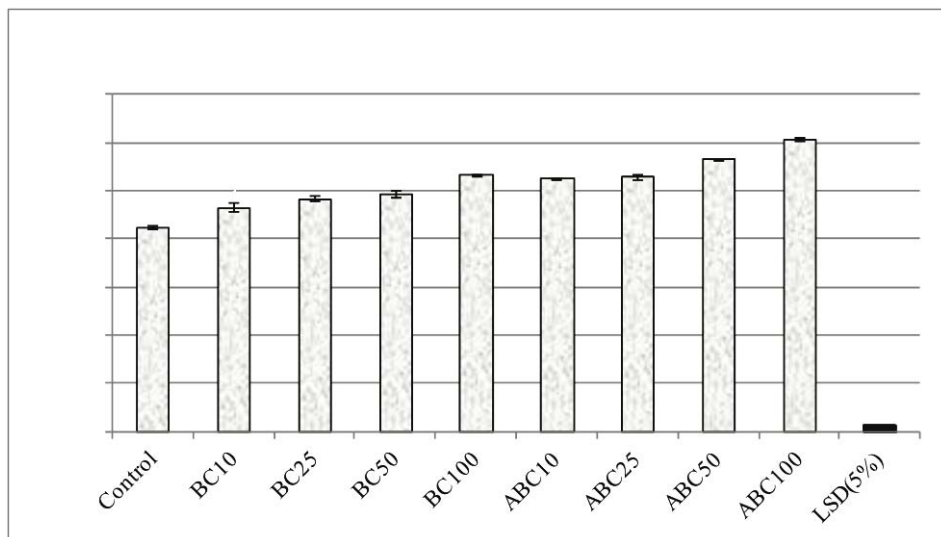


Fig. 1. Effect of different biochar treatments on the $\text{pH}_{(\text{KCL})}$ of soils

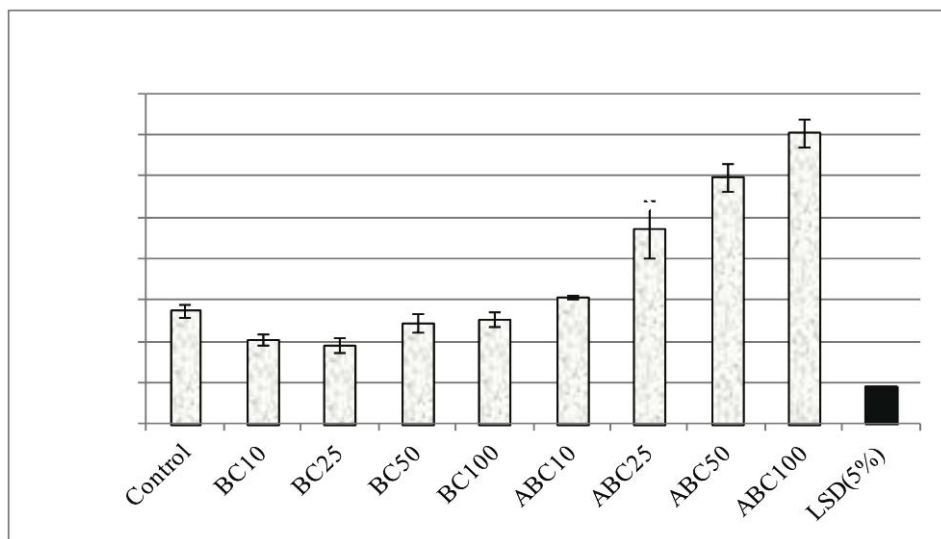


Fig. 2. Effect of different biochar treatments on the water soluble salt content of soils

As Fig. 3 shows, the bone char had great impact, proportionately with the added quantity. The differences between the measurements are expected and caused by the different raw materials of the biochars; the ones noted as ABC were

made from animal bone, and so the material contained a much higher concentration of phosphorus.

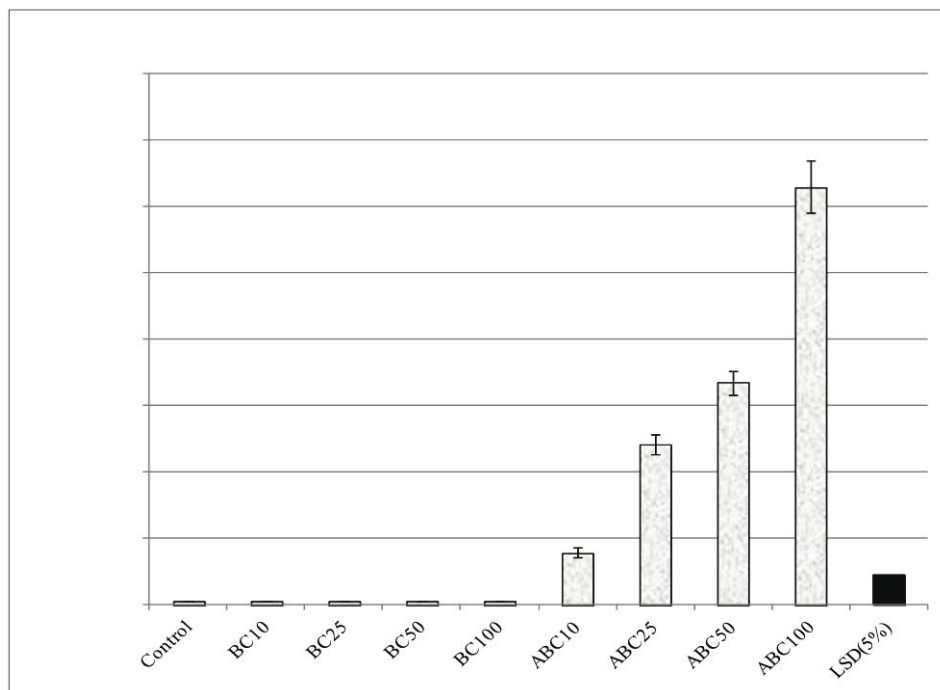


Fig. 3. Effect of different biochar treatments on the AL-P₂O₅ content of soils

The plant analysis shows that the biochar (wood chips char, animal bone char) application increased the air-dried mass of rye-grass in almost all cases, but this increase was not significant (Fig. 4).

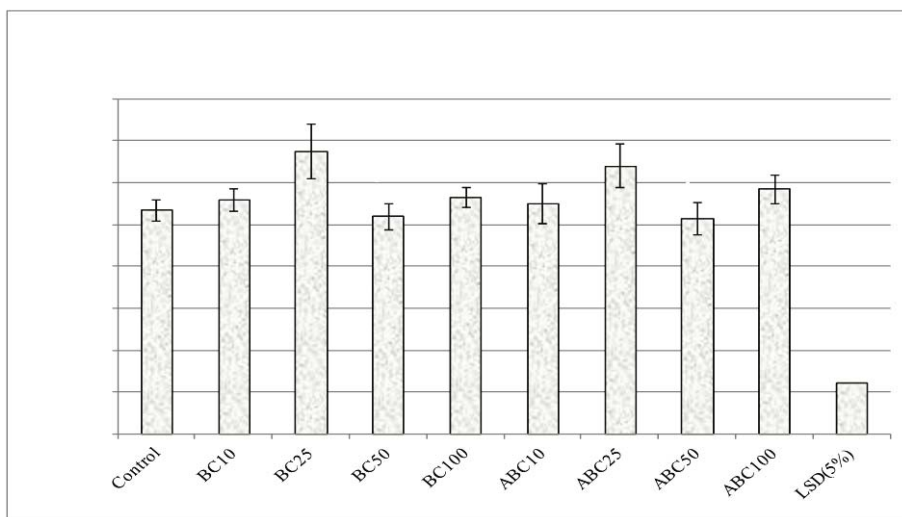
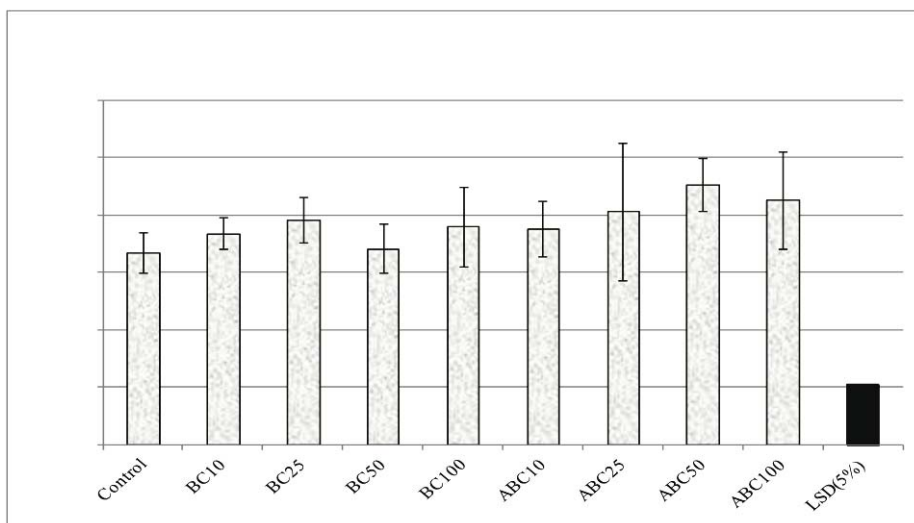
Fig. 4. Yield of test plants (*Lolium perenne*)

Fig. 5. Phosphorus uptake of test plants

Fig. 5 shows that the two types of biochar application increased the P-uptake (to one pot calculated); however, this increase did not show significant effect. The detected high P_2O_5 concentration in the soil due to the treatment, especially the bone char, had great amounts of phosphorus, but the test plants could not take up.

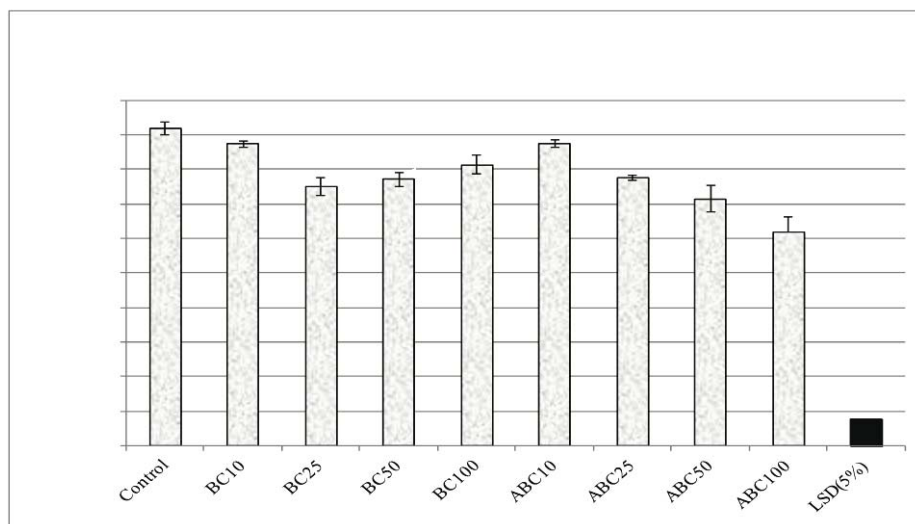


Fig. 6. Calcium concentration of test plants

The micronutrient analysis shows that the Ca concentration of test plants significantly decreased with the application rates of biochars (*Fig. 6*). This effect is very similar to the phosphorous content of rye-grass. Although the wood chips char and animal bone char have outstanding calcium content, this high amount is mainly unusable for plants.

4. Conclusion

We found the applied animal bone char (ABC) to be a good source of available phosphorous as it increased the easily soluble P_2O_5 content of the treated soil, but the plants could not take up such high amount in our short-term experiment.

The pH and water soluble salt content of the tread soil was increased significantly in the ABC treatments, while in the case of BC treatments the increase of pH was observed at all application rates and no effect on water soluble salt content was detected. The increase in pH and salt content did not cause very high alkalinity and/or salinity in neither treatment.

The application of pyrolysis products did not cause phytotoxic effects on test plants.

In our study, the high phosphorus content of ABC increased the easily soluble phosphorus content of soils. We suppose that the high Ca content of the applied biochars resulted in hardly soluble calcium phosphate forms and it prevented the uptake of the phosphate by the plants.

Decreasing Ca uptake was observed on test plants, possibly due to the high carbonate content of the applied biochars, which may form insoluble calcium carbonates under alkaline pH conditions.

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