INFLUENCE OF TYPE AND RATE OF BIOCHAR ON PRODUCTIVITY OF WINTER WHEAT

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Abstract. In recent years, one of the leading research areas in Europe is biochar and its production. Biochar is primarily used for purposes other than energy (in environmental protection and agriculture). It is a solid renewable fuel obtained from various types of biomass in the process of pyrolysis. The feedstock, from which biochar is produced, is highly diversified (energy crops, forest waste, and biomass of rapeseed, sunflower or corn cob, also sewage sludge, organic waste or chicken manure). It can be used as a natural fertiliser with the addition of liquid manure or as a component to composts. There are number of studies demonstrating the beneficial effects of biochars on growth and development of plants. A one-year pot experiment was carried out in the growing season 2017/2018 at the Vegetation Experiment Greenhouse belonging to the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy, Poland. The experimental plant was a winter wheat cultivar "Hondia". The first-order factor was the type of biochar: 0) control treatment (without biochar), 1) wheat husk biochar (WHB), 2) medical plant biomass after extraction biochar (MPB), 3) wood chip biochar from the Polish company "Fluid" (WCB), 4) sawdust biochar (SB), 5) rye straw biochar (RSB), 6) meat and bone meal biochar (MBMB). The second-order factor was the biochar dose: 1) 1 $t \cdot ha^{-1}$, 2) 3 $t \cdot ha^{-1}$. The study showed a statistically significant effect of the biochar type on the yielding of winter wheat. The highest grain yields of spring wheat were found where biochar from wood chips and sawdust biochar were used. There was no significant effect of the biochar type on the ear number per pot, the productive tillering and 1000 grain weight. The biochar rate did not have a significant effect on the values of the yield and the studied yield components of winter wheat.

Keywords: biochar, winter wheat, yielding.

Introduction

The world is now observing population growth, which directly translates into the growing demand for food, and it is estimated that by 2050 grain production must increase by 50-70 % [1]. These forecasts are becoming realistic by breeding more efficient and higher-yielding cultivars, also thanks to agrotechnical progress, more effective use of nutrients [1-2], and introduction into the environment of products and substances improving soil fertility

On the other hand, by determining the physical, chemical and microbiological properties of the soil, we observe the impact of agricultural and non-agricultural activities on the soil environment. Analysis of the condition of soils in Poland shows that this influence is not always good. Soil humus is of indisputable importance in many biochemical processes, and its deficit is constantly deepening through incompetent management of the soil environment. This leads to the search for alternative sources of substrates that can form humus. The addition of an external source of organic matter may cause significant changes in the quality and quantity of humus compounds.

One of the leading research areas in Europe in recent years is bio-carbon and its production. The area of improvement of biochar production facilities, modification of biochar and production of products based on it is developing dynamically. The definition of the International Biochar Initiative states that biocharate is a fine-grained carbonate with high organic carbon content and low susceptibility to degradation, obtained through the pyrolysis of biomass and biodegradable waste.

Biochar is used primarily for non-energy purposes (in environmental protection and agriculture). It is a solid renewable fuel obtained from different types of biomass through pyrolysis, which produces liquid and gaseous fuels [3]. The material from which biochar is produced is very diverse (energy crops, forest waste, biomass of rapeseed, sunflower, maize cobs, also sewage sludge, organic waste, or chicken manure) [4-7].

Materials and methods

In the growing season 2017/2018 in the Vegetation Experimentation Hall, belonging to the Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB) in Puławy (Poland), a two-factor pot experiment was carried out, in six replications. The first-order factor was

DOI: 10.22616/ERDev2019.18.N275

the type of biochar: 0) control treatment (without biochar), 1) wheat husk biochar (WHB), 2) medical plant biomass after extraction biochar (MPB), 3) wood chip biochar from the Polish company "Fluid" (WCB), 4) sawdust biochar (SB), 5) rye straw biochar (RSB), 6) meat and bone meal biochar (MBMB). The second-order factor was the biochar dose: 1) 1 $t \cdot ha^{-1}$, 2) 3 $t \cdot ha^{-1}$. The experiment was carried out in a completely randomized system, in Micherlich pots, which were filled with 7 kg of soil from crop rotation, where cereals accounted for 100 % of the sowing structure. Soil for the study was collected form the upper layer (0-30cm) of Haplic Luvisol developed from loam. The content of selected elements in the soil were: total carbon – 0.90 %, organic carbon – 0.78 %, total N – 0.10 %, P_2O_5 – 27.7 mg per 100g, K_2O – 28.2 mg/100g, pH – 6.08. The experimental plant was winter wheat form, cultivar Hondia (10 plants per each pot). Before filling the pots with soil, an appropriate type of biochar was added, together with appropriate fertilizers, and then mixed with the soil. Nitrogen was applied in the form of NH_4NO_3 using ½ rate at the start of the growing season (spring) and ½ rate at the stage of stem formation. Fertilization of the remaining components per 1 kg of soil was as follows: P – 156.96 $mg \cdot kg^{-1}$ in the form of KH_2PO_4, K – 241.89 $mg \cdot kg^{-1}$ in the form of K_2SO_4, Mg – 71.43 $mg \cdot kg^{-1}$ in the form of $MgSO_4$. In addition, iron (7.14 $mg \cdot kg^{-1}$), boron (0.71 $mg \cdot kg^{-1}$), manganese (0.43 $mg \cdot kg^{-1}$) and copper (0.43 $mg \cdot kg^{-1}$) were also added to the substrate. Moisture content of the substrate was maintained throughout the vegetation period at the level of 60 % of water holding capacity. The characteristic of types of biochar is in Table 1.

Table 1

Content of selected elements in types of biochar

Type of biochar	Total carbon, %	N, %	S, %	P, %	pH	Burning temperature, °C	Time of burning, min
WHB	70.8	3.9	0.074	0.320	8.50	550	n.d.
MPB	63.5	1.8	0.890	0.095	10.00	600	n.d.
WCB	67.6	2.4	< 0.100	0.330	6.79	500	4-7
SB	42.6	3.6	0.224	4.420	6.78	550	240
RSB	70.5	1.2	0.146	0.260	9.65	550	180
MBMB	75.6	1.9	0.136	0.120	8.32	550	240

n.d. – no data (the producer did not provide in the certificate)

After reaching full maturity, the plants were harvested. After harvest the following was determined: number of ears per pot, grain yield per pot, production bushiness, and weight of 1000 grains (according to PN-68/R-74017).

The aim of the study was to determine the effect of the type and rate of biochar on winter wheat productivity. The results were statistically analyzed using a one-way ANOVA, using the Statgraphics Centurion XVI computer program. Significance of differences between means were evaluated using the Tukey test at the level of significance p = 0.05.

Results and discussion

A significant effect (for $p = 0.05$) of the biochar type on winter wheat grain yield was found (Fig. 1). The best grain yields were found using wood chip biochar from the Polish company "Fluid" and sawdust biochar. The lowest wheat yield was recorded in treatments where medical plant biomass was applied after extraction of biochar. On the other hand, the amount of the biochar rate had no significant effect on the winter wheat yields (Table 2). In the literature there are no studies comparing the influence of different types of biochar on the yield and productivity of grain plants. There are many studies confirming the beneficial effect of biochar on plant growth and development. Research by Gebremedhin et al. [8] indicates a beneficial effect of biochar on wheat yield and characteristics of the wheat yield structure. The application of biochar in the amount of 4 $t \cdot ha^{-1}$ resulted in an increase in the grain and straw yield in relation to the control treatment. In a pot experiment [9], the addition of biochar from sewage sludge (10 $t \cdot ha^{-1}$) increased tomato yields by 64 % compared to the control. The authors explain this by a synergistic effect of increased availability of nutrients for plants and also by improving the soil properties. Uzoma [10] claims that the use of 15 and 20 $t \cdot ha^{-1}$ biochar increased the grain yield by 150 and 98 %, respectively. Graber [11] found a higher number of buds and fruits on tomatoes on treatments with biochar. A 4-year experiment [12] carried out on maize proves that in the second, third and fourth year of the research, after the application of 20 t·ha^{-1} of biochar, the maize yield increases by 28, 30 and 140 %, respectively, compared to the control. Jonest et al. [13] report that after the use of 25 and 50 t·ha^{-1} biochar, the height and total biomass of grass improved. The authors explain this by improvement of the absorption of macro and microelements.

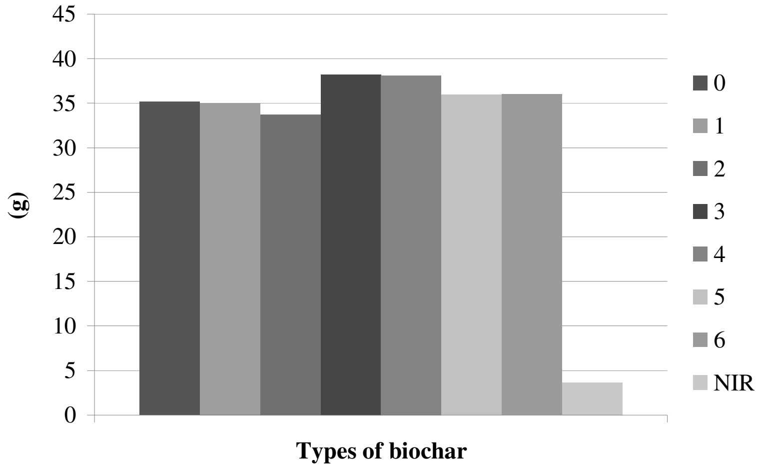

Fig. 1. **Winter wheat grain yield (g/pot) depending on type of biochar:**
0 – Control; 1 – WHB; 2 – MPB; 3 – WCB; 4 – SB; 5 – RSB; 6 – MBMB

Table 2

Winter wheat grain yield depending on biochar rate (g per pot)

Factors	**Rate of biochar**	
Type of biochar	**1 t·ha^{-1}**	**3 t·ha^{-1}**
Control	35.156	35.156
WHB	35.252	34.825
MPB	33.666	33.850
WCB	37.303	39.151
SB	36.299	39.978
RSB	38.431	33.503
MBMB	34.804	37.275
Mean	35.844	36.249
LSD $_{0.05\ for}$ Rate of biochar = n.s.		

n.s. – not significant

The number of ears and production tillering of winter wheat did not depend significantly (p = 0.05) on the experimental factors (Fig. 2, Fig. 3, Table 3, Table 4).

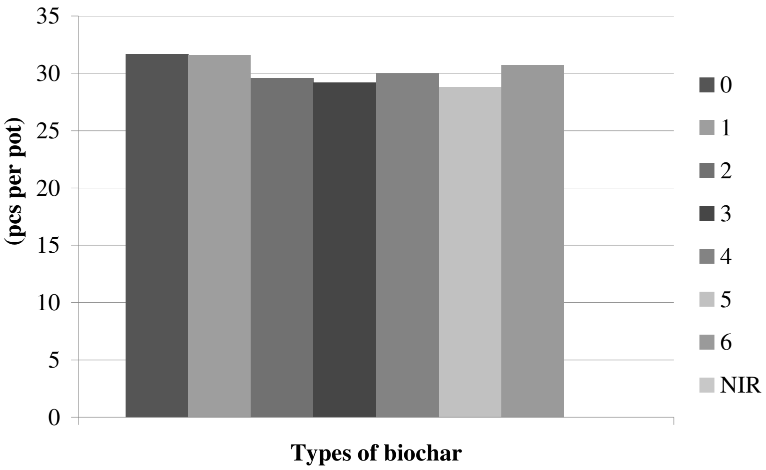

Fig. 2. **Number of winter wheat ears (pcs./pot) depending on type of biochar:**
0 – Control; 1 – WHB; 2 – MPB; 3 – WCB; 4 – SB; 5 – RSB; 6 – MBMB

Table 3

Number of winter wheat ears depending on biochar rate (pcs per pot)

Factors	**Rate of biochar**	
Type of biochar	**1 t·ha^{-1}**	**3 t·ha^{-1}**
Control	32.0	32.0
WHB	32.0	31.0
MPB	30.0	30.0
WCB	29.0	30.0
SB	29.0	31.0
RSB	29.0	29.0
MBMB	31.0	31.0
Mean	30.3	30.6
LSD $_{0.05}$ for Rate of biochar = n.s.		

n.s. – not significant (p = 0.05)

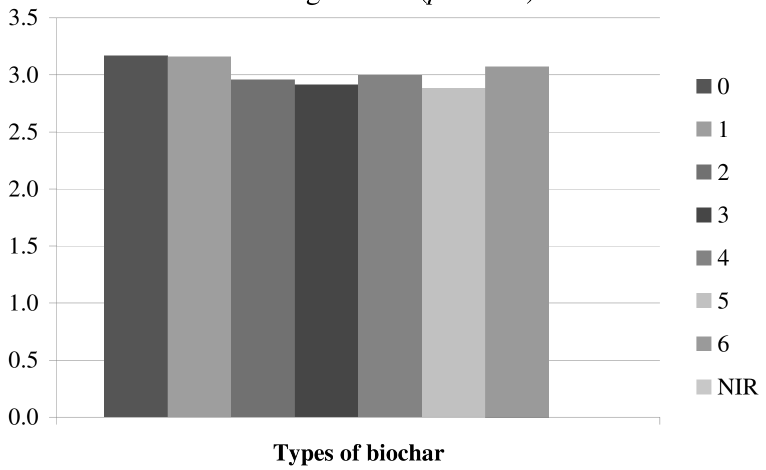

Fig. 3. **Winter wheat production tillering depending on biochar type:**
0 – Control; 1 – WHB; 2 – MPB; 3 – WCB; 4 – SB; 5 – RSB; 6 – MBMB

Table 4

Winter wheat production tillering depending on biochar rate

Factors	**Rate of biochar**	
Type of biochar	**1 t·ha^{-1}**	**3 t·ha^{-1}**
Control	3.167	3.167
WHB	3.200	3.117
MPB	2.950	2.967
WCB	2.883	2.950
SB	2.917	3.083
RSB	2.867	2.900
MBMB	3.067	3.083
Mean	3.007	3.038
LSD $_{0.05}$ for Rate of biochar = n.s.		

n.s. – not significant (p = 0.05)

There were no statistically significant differences (p = 0.05) in the value of 1000 grain weight depending on the type of biochar or the rate used (Fig. 4, Table 5). However, there was a tendency to increase the weight of 1000 grains, when wood chip biochar from the Polish company “Fluid”, sawdust biochar, and rye straw biochar were used. In the case of the first two, the higher value of this trait translated into a significantly higher grain yield obtained from the pots. No differences in the values of the tested traits depending on the applied biochar rate can be explained by the fact that the differences between the rates may have been too small.

Many scientists point to the positive effect of biochar on the growth and yield of plants [14-18]. Lehmann et al. [15] and Asai et al. [18] indicate on an increase in the plant productivity after application of biochar. This effect is explained by the increase in the content of nutrients in the soil.

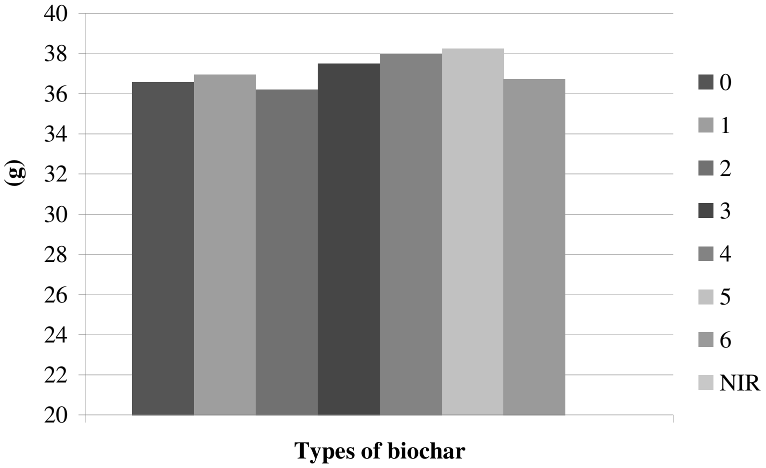

Fig. 4. **Weight of 1000 grains (g) of winter wheat depending on type of biochar:**
0 – Control; 1 – WHB; 2 – MPB; 3 – WCB; 4 – SB; 5 – RSB; 6 – MBMB

Table 5

Weight of 1000 grains of winter wheat depending on rate of biochar (g)

Factors	Rate of biochar	
Type of biochar	**1 t·ha^{-1}**	**3 t·ha^{-1}**
Control	36.583	36.583
WHB	36.725	37.193
MPB	36.600	35.838
WCB	36.527	38.478
SB	36.503	39.472
RSB	39.575	36.942
MBMB	36.232	37.218
Mean	36.964	37.389
LSD $_{0.05}$ for Rate of biochar = n.s.		

n.s. – not significant (p = 0.05)

The use of biochar derived from various feedstocks for agronomic purposes may be a potential opportunity to use various types of waste in agriculture. This work is the result of one-year research, which will be continued in the following years.

Conclusions

1. A significant influence of the type of biochar on the yield of winter wheat grain was found.
2. The highest yields of wheat grain were found in pots where wood chip biochar from the Polish company "Fluid" and sawdust biochar were used.
3. The biochar dose had no significant effect on the values of the examined traits.

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