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*Srđan I. ŠEREMEŠIĆ**, *Milorad S. ŽIVANOV*[2], *Dragiša S. MILOŠEV*[1], *Jovica R. VASIN*[2], *Vladimir I. ĆIRIĆ*[1], *Marjana B. VASILJEVIĆ*[3], *Nataša J. VUJIĆ*[1]

[1] University of Novi Sad, Faculty of Agriculture,
Trg D. Obradovića 8, 21000 Novi Sad, Serbia
[2] Institute of Field and Vegetable crops,
Maksima Gorkog 30, 21000 Novi Sad, Serbia
[3] "Dunav soja", Vase Stajića 8/19, 21000 Novi Sad, Serbia

EFFECTS OF BIOCHAR APPLICATION ON MORPHOLOGICAL TRAITS IN MAIZE AND SOYBEAN

ABSTRACT: This paper analyses the effects of the biochar application morphological traits in maize and soybean under semi-controlled conditions. During the study, the increasing doses of biochar (0%, 0.5%, 1, 3, and 5%) were incorporated in three soil types: Alluvium, Humogley and Chernozem to determine plant height and shoot weight. The experiment was set up as fully randomized design with three repetitions. The plants were grown in pots of 5 l with controlled watering and N fertilization. The research results have shown that there are differences in terms of biochar effects on soils. The greatest effect on plant height and shoot weight was obtained when the biochar was applied to Humogley soil and lower effects were found on the Alluvium soil. The increase in aboveground mass of maize and soybeans was significantly conditioned by adding different doses of biochar. Based on these results, it can be concluded that adding biochar can significantly affect the growth of plants. This is a consequence of the changes it causes in soil, which requires further tests to complement the current findings.
KEYWORDS: biochar, soil, maize, soybean, plant height, shoot biomass

INTRODUCTION

Arable soils are among the largest and most important natural resources of all mankind [Wall and Six 2015]. To protect the arable soil from degradation preventive measures are the most important, such as identification of hazards and detection of appropriate solutions to overcome risks of agricultural intensification. Today, a great effort is made to improve and utilize less productive soils and restore their initial fertility. One of the possible solutions

* Corresponding author e-mail: srdjan.seremesic@polj.uns.ac.rs

for the amending of degraded soils is biochar application [Biederman and Harpole 2013; Lehman *et al*., 2005]. Biochar is a solid material obtained in the process of carbonization, pyrolysis of biomass, usually of plant origin. The manufacturing process is similar to the process of obtaining charcoal with a difference in the used raw materials. Soil biochar amendment is based on two thousand years old experience, which in recent decades has been renewed because of proven multiple benefits [Chan *et al*., 2007]. This importance is largely long-term, but also reveals the short-term effects [Mann 2005].

Traditional charcoal production uses carbon dioxide sequestered into woody biomass tissue via the process in which tissue of biological origin is burnt (or charred) in the absence of, or at low levels of oxygen to produce 'biochar' [Preston and Schmidt 2006]. After pyrolysis, approximately 50% of the carbon contained in the original source of biomass can be retained within the biochar. However, recovery rates are highly dependent of the pyrolysis process. Among the many elaborated effects, the most beneficial result of the biochar application could be sequestration of the atmospheric carbon with the consequence to global climate [Laird 2008; Woolf *et al*., 2010]. Many studies confirmed that soil incorporated with biochars can improve plant growing [Yamato *et al*., 2006; Steiner *et al*., 2007]. According to Lehmann *et al.* [2003] biochar incorporation induces soil alkalization which can increase soil nitrification and N levels. Increases in soil pH are likely to affect electrical conductivity (EC), cation exchange capacity (CEC) and increase alkaline metal (Mg^{2+}, Ca^{2+} and K^{+}) oxides. Likewise, it reduces soluble forms of aluminium, which is suggested as the most significant biochar factor affecting P solubility [DeLuca *et al*., 2009]. The presence of biochar in the soil can provide a physical niche for growing hyphae and bacteria [Warnock *et al*., 2007]. Beneficial effects of biochar have been elaborated in studies word wide. However, there is a lack of experimental confirmation of the biochar application in our agricultural science. Researches of biochar use have been mainly conducted on soils under tropical and humid climatic conditions, which are more degraded and have a lack of soil organic carbon [Šeremešić *et al*., 2014]. Therefore, the aim of this study is to investigate the possibility of biochar application and doses on the contrasting soil types under temperate climatic conditions.

MATERIALS AND METHODS

In order to evaluate the dose-response pattern of biochar application, a pot experiment was set up under semi-controlled conditions of the vegetation shed at the Faculty of Agriculture, University of Novi Sad. The study included maize and soybean growing in three soil types Chernozem (C), Alluvium (A) and Humogley (H) and five application rates of biochar 0, 0.5%, 1%, 3, and 5% in a fully randomized experimental design with three replicates. The biochar doses were equivalent to application rates of 0.0, 12.5, 25, 75, 125 t biochar ha^{-1} assuming a soil bulk density of 1.25 g cm^{-3} up to a depth of 20 cm. Chemical analyses of biochar used in this study are presented in Table 1. Total carbon content of

74.5% was measured in 30 mg soil sub-samples on an elemental analyzer (CHNS). The obtained values corresponded with those described by Jindo *et al.* [2014].

Chemical soil properties are presented in Table 1. Preparation of the substrate preceded plant growing. Soil was first mixed with the biochar, and then the pots were filled with the substrate in order to ensure similar bulk density of substrate in pots (5 l – 20 cm of diameter; 20 cm of height). Pots were filled 2 weeks before sowing and watered to maintain soil water regimen and establish the stabilization of physical and chemical soil properties.

Table 1. *Chemical soil properties of the investigated soil types*

Soil type	Depth (cm)	pH		$CaCO_3$ %	*Total C* Humus %	Total N %	AL-P_2O_5	AL-K_2O
		KCl	H_2O				mg/100g soil	
Biochar	-	7.54	8.24	1.6	*74.51*	0.54	53.8	291.0
Chernozem (C)	0–30	7.21	8.13	1.04	2.75	0.159	23.96	29.08
Alluvium (A)	0–30	7.38	8.26	3.80	1.72	0.148	102.5	14.1
Humogley (H)	0–30	6.98	5.99	0.33	3.66	0.183	29.98	49.71

Soybean Favorit (NS Seme) as short vegetation variety (maturity group 000) and maize line with short vegetation (<1m in height) was used in this experiment. The nitrogen (in the form of NH_4NO_3) fertilization was applied in post-emergence stage to ensure undisturbed plant growth. The moisture of soil substrate was maintained by watering at an optimal level, between 70–80% of the water retention capacity of soil in pot to prevent water stress. Plants were harvested by cutting aboveground biomass for determination of yield and morphological properties. The plant material was dried in an oven at 105 °C for 48 h, after which the absolute dry mass was determined by using the technical scale. The soil substrates were also analyzed in order to determine their chemical properties. The data reported was assessed by analyses of variance (ANOVA). Analysis of variance was used to separate the treatment means when there was a significant difference at the $p < 0.01$ and $p < 0.05$ level. The analyses were conducted using the statistical software package Statistica 12.6. (StatSoft Inc., USA).

RESULTS AND DISSCUSION

In the combined analysis of variance, the effects of soil ($P<0,0004$) and interaction of soil type and biochar doses ($P<0.0261$) showed significant F-test for maize plant height (Table 2). The soil accounted for 27.6% of total height variation, whereas the interaction is responsible for 26.89% of total variation and 37.97% variation derives from residual influences. Biochar application has not significantly affected maize height in our study. Contrary to our study, the application of 50 t/ha biochar to acid soil increased height and the fresh weights of the maize aerial part [Rodríguez and Preston 2009]. Study of saline soil (pH 8.52) in the pot experiment and the application of biochar recorded 17.7 to 25.8% increase in the maize shoot length with the maximum of 78 cm plant^{-1} 30 days after sowing (Saranya *at al*., 2011).

Table 2. *Analysis of variance for maize plant height*

Sources of variation	d.f.	s.s.	SS %	m.s.	F	P
Soil (A)	2	2210.0125	27.59	1105.0062	10.171**	0.0004
Biochar (B)	4	342.9792	4.28	85.7448	0.789	0.5407
Interaction (A x B)	8	2153.8208	26.89	269.2276	2.478*	0.0261
Blocks	2	261.8792	3.27	130.9396	1.205	0.3096
Error	28	3042.1208	37.97	108.6472		
Sum	44	8010.8125	100			

d.f. – degrees of freedom, s.s. – total sum of squares, s.s.% – sum of squares relative to total sum, m.s. – mean squares

The analyses of variance for maize shoot biomass reveal that the soil very significantly influenced maize dry biomass (P<0,0000**), while doses of biochar (P<0,0114*) and interaction of soil type and biochar doses (P<0.0159*) showed significant F-test for dry maize biomass (Table 3). The soil accounted for 80.60% of total shoot biomass variation, whereas the residual influences accounted for only 8.39%. It appears that in maize growing different soil types showed higher effect regardless of biochar doses. Some researchers reported no changes in the maize production in the first year after biochar amendment, but a significant increase was observed in the following years Major *et al.* [2010]. According to Yamato *et al.* [2006] maize production was significantly increased after the application of bark charcoal under a fertilized condition in an infertile soil environment. A positive effect of biochar addition on maize dry biomass could be ascribed to higher soil N-retention also observed in Baronti *et al.* [2010]. Although some positive effects were observed, we assume that in our study biochar addition could manifest more beneficial effects to maize growing if added earlier (in the autumn).

Table 3. *Analysis of variance for maize shoot biomass*

Sources of variation	*d.f.*	s.s.	SS %	m.s.	F	P
Soil (A)	2	1563.3114	80.60	781.6557	134.473**	0.0000
Biochar (B)	4	85.9029	4.43	21.4757	3.695*	0.0114
Interaction (A x B)	8	126.6447	6.53	15.8306	2.723*	0.0159
Blocks	2	0.8770	0.04	0.4385	0.075	0.9274
Error	28	162.7571	8.39	5.8128		
Sum	44	1939.4932	100			

d.f. – degrees of freedom, s.s. – total sum of squares, s.s.% – sum of squares relative to total sum, m.s. – mean squares

Higher maize plant height was observed on Humogley soil, while application of biochar resulted in significantly lower plant height on Alluvium soil. Maize shoot biomass was significantly higher on Humogley soil compared with Chenozem and Alluvium. Obtained results indicate that the ameliorative effect of biochar is largely related with pH increase and N availability to plants. Our results with maize are in accordance with those presented by Zhang *et al.* [2011] who suggested that positive effects of biochar application in field crop production could be also observed in the calcareous soils.

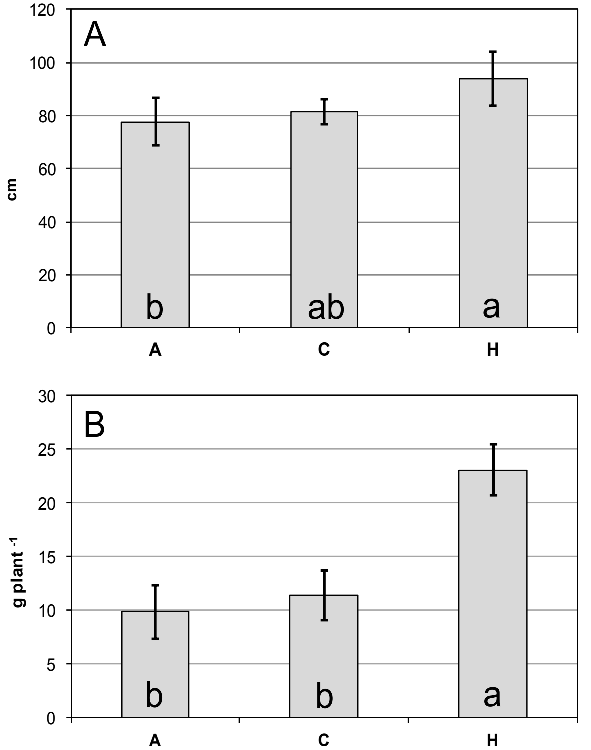

Figure 1. *Maize plant height (A) and shoot biomass (B) after biochar addition on Alluvium (A), Chernozem (C) and Humogley (H)* ([abc]Column marked with the different letters within treatments differ significantly at P≤0.05; Error bars indicate standard deviation)

The analyses of variance for soybean plant height indicate very significant effects of soil type and biochar doses on the plant height (P<0.0015**) and (P<0.0001**), respectively (Table 4). The biochar doses accounted for 40.27% and soil types for 17.66% of total height variation, whereas the interaction (A x B) is responsible for 26.89% of total variation and 37.97% variation derives from residual influences. Soybean height appears to be significantly influences by biochar doses compared to maize.

Table 4. *Analysis of variance for soybean plant height*

Sources of variation	d.f.	s.s.	SS %	m.s.	F	P
Soil (A)	2	461.5661	17.66	230.7831	7.900**	0.0015
Biochar (B)	4	1052.6328	40.27	263.1582	9.009**	0.0001 9.d
Interaction (A x B)	8	254.4651	9.73	31.8081	1.089	0.3892
Blocks	2	27.2328	1.04	13.6164	0.466	0.6362
Error	28	817.9235	31.29	29.2116		
Sum	44	2613.8203	100			

Soybean shoot biomass was significantly affected by soil type and biochar level (P<0.000**). Biochar doses showed considerable fraction in total variation (42.99%) indicating positive response of soybean to increased amount of biochar application. The error accounted for 25.06% of total shoot biomass variation. It clearly showed positive and higher reaction of soybean to biochar application compared to maize. Also, soil types had less effect to morphological trait manifestation in soybean compared to maize. Sun *et al.* [2012] suggested that biochar incorporation to brown soil might bring potential benefit to soybean production from N retention in soil and enhanced microbial turnover that resulted with P and K feedback. Our results correspond with Yin *et al.* [2012] study on acid black soil where soybean yield increased by 35.97% compared with the control.

Table 4. *Analyses of variance for soybean shoot biomass*

Sources of variation	d.f.	s.s.	SS %	m.s.	F	P
Soil (A)	2	9.1981	27.02	4.5991	15.098**	0.0001
Biochar (B)	4	14.6356	42.99	3.6589	12.012**	0.0000
Interaction (A x B)	8	1.6324	4.79	0.2041	0.670	0.7162
Blocks	2	0.0440	0.13	0.0220	0.072	0.9302
Error	28	8.5291	25.06	0.3046		
Sum	44	34.0393	100			

Significant effects of biochar application on the soybean shoot was obsereved on Humogley soil compared with soybean height that was obsered on Chernozem (Figure 2). Regarding shoot biomas, Humogley significantly influenced its formation compared with Alluvial soil. Obtained result could be explained with better water holding capacity of Humogley.

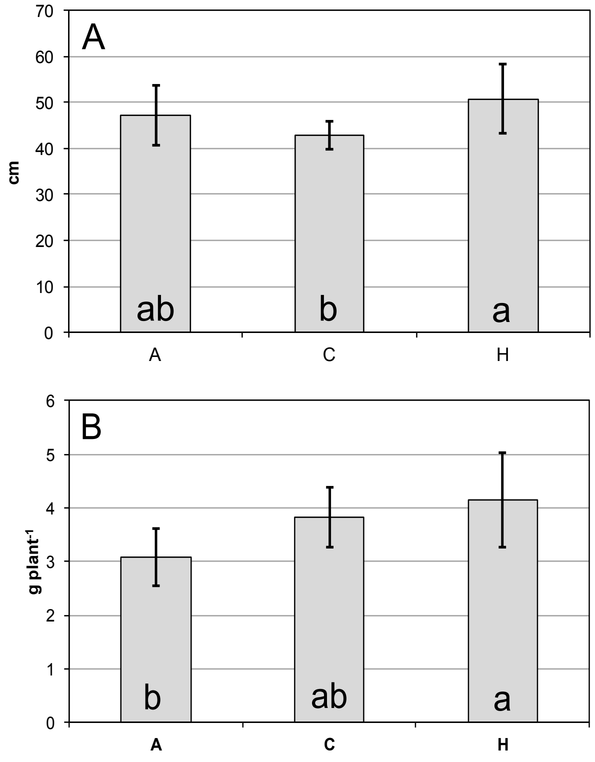

Figure 2. *Soybean plant height (A) and shoot biomass (B) after biochar addition on Alluvium (A), Chernozem (C) and Humogley (H)* ([ABC]Column marked with the different letters within treatments differ significantly at $P \leq 0.05$; Error bars indicate standard deviation)

CONCLUSION

Humogley soil showed higher response of the observed traits compared to Chernozem and Alluvium regardless of biochar doses. In maize experiment, different soil types exerted higher influence on the plant height and shoot biomass, while in the soybean experiment biochar application showed significant effects. Our study indicates better response of soybean to biochar application than maize. Based on the obtained results, biochar addition could contribute to crop growing, while additional examinations must be performed to identify doses of biochar corresponding to different soil types.

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ЕФЕКАТ БИОУГЉА НА МОРФОЛОШКА СВОЈСТВА КУКУРУЗА И СОЈЕ

Срђан И. ШЕРЕМЕШИЋ[1], Милорад С. ЖИВАНОВ[2], Драгиша С. МИЛОШЕВ[1], Јовица Р. ВАСИН[2], Владимир И. ЋИРИЋ[1], Марјана Б. ВАСИЉЕВИЋ[3], Наташа Ј. ВУЈИЋ[1]

[1] Универзитет у Новом Саду, Пољопривредни факултет Нови Сад, Трг Доситеја Обрадовића 8, 21000 Нови Сад, Србија

[2] Институт за ратарство и повртарство, Максима Горког 30, 21000 Нови Сад, Србија

[3] „Дунав соја", Васе Стајића 8/19, 21000 Нови Сад, Србија

САЖЕТАК: У раду је испитиван утицај примене биоугља на морфолошка својства кукуруза и соје у полуконтролисаним условима. Примењене су растуће дозе биоугља на три типа земљишта: алувијум, чернозем и хумоглеј и праћена је висина биљака и маса надземног дела. Оглед је постављен по рандомизираном распореду са три понављања у судове запремине 5 литара, а сетва је извршена у месецу мају. Резултати истраживања су показали да постоје разлике у погледу испитиваних земљишта и примењених доза биоугља. Најбољи ефекат је добијен када је биоугаљ примењен на земљиште хумоглеј а најмањи утицај примене биоугља је утврђен на алувијалном земљишту. Пораст надземне масе кукуруза и соје био је у значајној мери условљен додавањем различитих доза биоугља. На основу добијених резултата може се закључити да додавање биоугља може значајно утицати на пораст биљака који је последица промене које он изазива у својствима земљишта, али да је неопходно наставити даља испитивања како би се употпунила досадашња сазнања. Утврђено је да су испитивана својства код соје испољила већу реакцију на примену биоугља у односу на кукуруз.

КЉУЧНЕ РЕЧИ: биоугаљ, земљиште, кукуруз, соја, висина биљака, маса надземног дела