BIOCHAR AND ORGANIC-WASTE COMPOST AS SOIL AMENDMENTS TO ARABLE SOIL: POTENTIAL INFLUENCE ON SOIL REACTION, SALINITY AND PHYTOTOXICITY

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Abstract: Biochar may become a key element in our agriculture in the future, particularly in terms of soil fertility maintenance and negative impacts of soil erosion processes avoiding. From a global perspective biochar can be used in isolation of atmospheric CO_2. Present work deals with different properties of biochar from woody biomass, arable soil and compost. Conductivity, pH and total amount of dissolved solids (salinity) in the water extract has been determined for each of the samples. The measured results show a clear difference between biochar, arable soil and compost. Furthermore based on these results we conclude the potential effect of biochar addition on soil health and quality.

Key Words: soil health, compost, biochar, soil phytotoxicity, soil salinity, soil reaction

INTRODUCTION

In the recent years, considerable financial resources were used to remediate landscapes, which have been damaged by human activities. The key human activity affecting the landscape is the agriculture. Current agriculture must deal with the problems that have been self-caused: water and wind erosion, leaching of nutrients from the soil resulting in the reduction of soil fertility, soil degradation, loss of soil organic matter (SOM). Moreover, soil cannot be healthy without soil microorganisms and their varied activities that have important links to many of soil processes.

These problems could be solved through sustainable agricultural practice, based on the healthy soil. Soil health term is widely used within discussions on sustainable agriculture to describe the general condition or quality of the soil resource (Kibblewhite et al. 2008). There are several possibilities to improve content of SOM in soil and thus reduce the risk of natural soil properties loss (soil fertility – soil health and quality). Fischer, Glaser (2012) argue that one of the most efficient ways to increase the SOM level is compost application, produced especially from biomass wastes, as compost has a stimulation effect on both the microbial community in the compost substrate as well as the soil-born microbiota of soils. It is known that compost creates a favourable environment for plant and root growth by promoting a porous soil structure, decreasing soil erodibility, enhancing water storage capacity and improving percolation in soil (Diaz et al. 2007). In relation to the application of compost and its benefits, researchers (Graber et al. 2010, Zhang et al. 2012 and others) confirm that biochar, which is a solid material obtained from the carbonization of biomass, can be also an important tool to improve soil state in areas with depleted soils, scarce organic resources, and inadequate water and chemical fertilizer supplies.

But still, some facts remain not sufficiently explained, for example how exactly biochar amendment affects soil biota or how it influences such properties as pH, EC, phytotoxicity, etc. At the same time exactly these biochar properties may directly affect soil fertility (Oleszcuk et al. 2012, Lehman et al. 2012). Barrow (2012) draws attention to the fact that modern production of biochar in many ways reflects charcoal production, which has been known since ancient times. A more precise definition of biochar created Laird (2008), that biochar is a material based on charcoal, which is generated by thermo-chemical pyrolysis of plant biomass.

The aim of our study was to determine whether the addition of biochar, compost and their mixture can positively or negatively affect soil properties (pH, EC) and whether it has phytotoxic effect.

MATERIAL AND METHODS

Experiment structure

The present work deals with the possible differences between biochar, arable soil and compost in chemical and physical properties that may have a direct effect on soil fertility. Five variants of experiment with three repetitions were prepared (see Table 1).

Table 1 Overview of laboratory experiment

Variant	Repetitions	Characteristics	Composition of mixture
V1	3	Control	S
V2	3	Only compost	C_p
V3	3	Only biochar	B_{ch}
V4	3	Mixed of arable soil and biochar	w_S:w_{Bch} (10:1)
V5	3	Mixed of arable soil and compost	w_S:w_{Cp} (50:3)
V6	3	Mixed of biochar and compost	w_{Bch}:w_{Cp} (1:1)

Comment for Table 1: C_p is compost; B_{ch} is biochar; S is arable soil and w represents the weight fraction.

Arable soil from area of our interest: Březová nad Svitavou has been used for the experiment, along with compost from a Central composting in Brno and biochar provided by ECOGRILL company Ltd. Biochar has been made of beech biomass.

Material preparation

Biochar has been passed through a sieve of 2 mm meshed and homogenized according Graber et al. (2010). On the basis of the manufacture recommendations biochar was stored at 25°C in a closed paper bag and protected from light. Soil sampling was done on the 28th of September 2014 in accordance with CSN ISO 10 381-6 (Czech/International Technical Standard "Soil quality and Sampling"). Compost samples were taken from the Central Composting Plant in Brno on the 30^{th} of November 2014 according to CSN EN 46 5735 (Czech/European Technical Standard "Industrial compost"). Taken samples of soil and compost were homogenized after the transportation and have been passed through a sieve of 2 mm mesh. Sieved and homogenized samples have been placed in a thermostat (4°C). Before performing of each measurement samples of soil and compost were preincubated for 2 days at laboratory temperature (18.5°C).

Phytotoxicity test

Aqueous infusions of individual variants of experiment were prepared (w: wH_2O, 1: 10) and have been subsequently used for phytotoxicity tests establishing according to Oleszcuk et al. (2012). These particular test variants have been prepared: control (distilled water), biochar, soil, compost and their combinations (B_{ch} + soil, C_p + soil etc.).

pH determination

Active and potential pH value (current) has been determined using the device HACH LANGE sensION+ equipped with combined gel-filled electrode. Active pH was measured in aqueous extracts from soil, biochar, compost and mixed of theses samples and potential pH was determined in calcium chloride extracts form the above matters. Both type of pH was performed according to CSN ISO 10 390 (Czech/International Technical Standard "Soil quality – Determination of pH").

EC determination

EC was determined using the device HACH LANGE sensION+. EC measurements of aqueous infusions of biochar, soil and compost were performed according to CSN ISO 11 265. The same procedure (unified approach) for the determination of EC and pH for all variants of experiment was used due to the fact, that particular results could be comparable with each other. Both CSN are primarily intended for soil, in a case with pH this working procedure is identical for compost. These methods have been already used in the past for the determination of pH and EC in water infusion from biochar (Graber et al. 2010, Ding et al. 2010, Brewer et al. 2011) using a similar principle as ISO 10 390 and ISO 11 265, therefore these standards were used in this experiment.

Statistical analysis

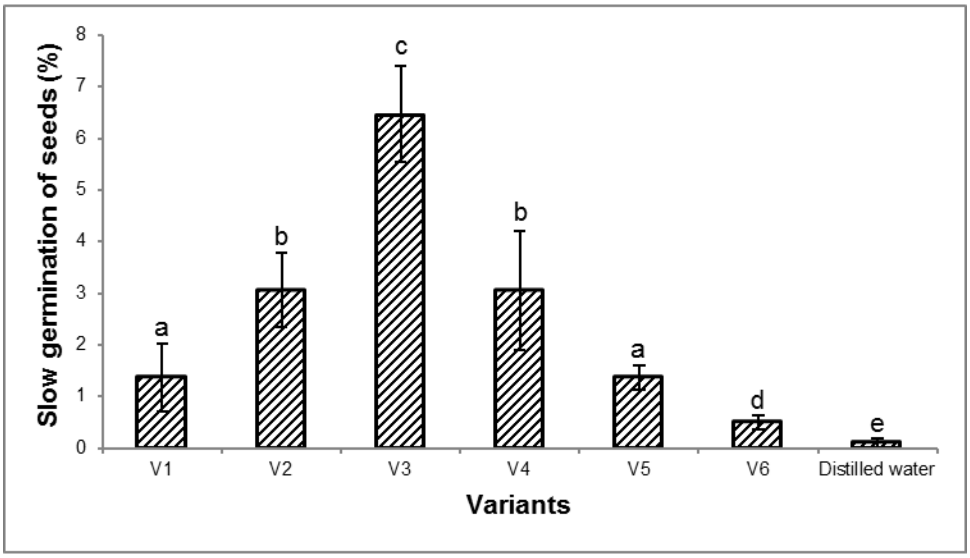
Potential differences in values of pH, EC and level of phytotoxicity were identified by one-way analysis of variance (ANOVA) in a combination with the Tukey´s test ($P<0.05$) All analyses were performed using Statistica 10 CZ software.

RESULTS AND DISCUSSION

Phytotoxicity

Biochar and organic-waste compost or the combined application of these matters significantly affected phytotoxicity in the amendment treated soil. Figure 1 presents the phytotoxicity (slow germination of seeds) of these soil amendments.

Figure 1 Inhibition of seed germination (mean ±SE, n = 3)



Comment for Figure 1: inhibition is expressed in %; distilled water represents control (without soil, compost, biochar etc.). Different small letters indicate a significant differences (P<0.05; ANOVA; post-hoc Tukeys HSD test) between individual variants.

The highest level of phytotoxicity was found in variant V3 (inhibition of seeds germination was over 6%), only B_{ch} was applied there. Consider significant differences in level of phytotoxicity between variant V2; where was only C_p applied and variant V3. These results indicate that the application of B_{ch} may have negative effect on soil phytotoxicity (consider level of phytotoxicity in variant V4; mixture of B_{ch} and S). Negative influence of B_{ch} application on soil phytotoxicity was studied and confirmed by Beesley et al. (2010) and Oleszczuk et al. (2012). Moreover the low level of phytotoxicity, which were found in variant V5 and V6 (significant lower in comparison with V2, V3 and V4) shows the potential effect of C_p addition on decrease of soil phytotoxicity. Combined application of C_p and B_{ch} represents new opportunities for decrease in phytotoxicity not only of B_{ch} but also of soil. Beesley et al. (2010) confirmed that the common application of C_p and B_{ch} can be used for decrease of soil phytotoxicity caused by heavy metals contamination.

The values of pH and EC in the soil solution and in the extracts of biochar and compost

The values of pH and EC are an important indicator of the soil state and they affect the chemical and physical processes in the soil. For example, the values of pH and EC have a direct impact on microbial activity and thus, they indirectly affect nitrification and denitrification (Elbl et al. 2014).

The alkaline pH (pH values greater than 7) was found only in variants with C_p and B_{ch} addition (V3 – V6). The lowest pH (acidic pH) was found in variant V1 (5.55; control without addition of C_p

or B_{ch}). According to Act No. 156/1998 (Fertilizers Act), which establishes the quality requirements for arable land in the Czech Republic, the optimum range of pH is from 6.6 to 7.2. Consider values of pH in variant V5 (soil with addition of B_{ch}) and V6 (soil with addition of C_p). These results indicate, that the application of C_p and B_{ch} can be used to modify of soil reaction. Zhao et al. (2015) state that biochar has positive effects as a soil acidity amendment. The positive effect of C_p application on soil reaction (attaining the values in the range of 6 to 7) was confirmed by Madejón et al. (2001) and Diaz et al. (2007).

Table 2 pH values of solution from individual treatments of experiment

Variant	pH	±SE	Mean differences
V1	5.55	0.045	a
V2	6.89	0.010	b
V3	9.39	0.070	c
V4	7.72	0.055	d
V5	6.29	0.121	e
V6	8.18	0.119	f

Table 3 Salinity of solution from individual treatments of experiment

Variant	EC ($dS \cdot m^{-1}$)	±SE	Mean differences
V1	0.109	0.045	a
V2	3.363	0.010	b
V3	2.307	0.070	c
V4	0.410	0.055	d
V5	0.322	0.121	d
V6	2.640	0.119	c

Comment for Table 2 and 3: different small letters indicate a significant differences (P<0.05; ANOVA; post-hoc Tukeys HSD test) between individual variants.

The above results of pH are very important, because there is the relationship between soil fertility (utilization of nutrients such as nitrogen, carbon, phosphorous) and soil reaction according to Brandy (1996) and Šimek et al. (2002). Moreover the effect of pH value on soil microbial community and their development in rhizosphere soil was studied and confirmed by Bloem and Hopkins (2006).

The highest values of EC were measured in V2 and V3. These results indicate high salinity of C_p and B_{ch}. There is a relationship between values of EC and the salinity level; this relationship was confirmed by Scianna (2002).

Table 4 Soil Salinity Classes by USDA (Scianna 2002)

Salinity Class	Salt content (%)	EC ($dS \cdot m^{-1}$)
Non-saline	0	0–2
Very slightly saline	0.00–0.15	2–4
Slightly saline	0.15–0.35	4–8
Moderately saline	0.35–0.65	8–16
Strongly saline	>0.65	>16

Table 4 shows the evaluation of soil salinity. Variants with or without addition of compost and B_{ch} (from V1 to V6) are ranked, according Table 4, from medium to high salinity. Control variant is non saline, variant only with addition of C_p (V2) or B_{ch} (V3) is very slightly saline and variants with addition of C_p and B_{ch} are non-saline. The differences between these variants are significant. Measured values of EC show the influence of C_P and B_{ch} addition on soil salinity, but this effect was not negative. This phenomenon is caused by chemical composition of C_P and B_{ch}. According to Akhtar et al. (2015) salinity is one of the major threats to global food security. Biochar amendment could alleviate the negative impacts of salt stress in crop during the season. Moreover Kim et al. (2015) reported that

B_{ch} can be used for reclamation of agricultural lands which contains high levels of soluble salts. The effect and potential risk of C_p application on soil salinity was described by Diaz et al. (2007). Elbl et al. (2014): high doses of C_p in combination with fertilizer can lead to salinization of arable land. If provided farmers will respect the recommended dose of C_p (for example in CZE 50 Mg ha^{-1}), salinity cannot increase. This fact was confirmed by Diaz et al. (2007).

CONCLUSION

Biochar acts directly on soil properties, through its physical and chemical characteristics. Due to this, authors focused on following parameters with significant explanatory value of the possible effects of biochar on: electrical conductivity, pH and phytotoxicity. The results obtained shortly after the fresh biochar addition to the soil showed possible negative influence on pH, EC and phytotoxicity. This risk can be partly avoided in the case of biochar application along with the compost. In addition, even when biochar have been freshly produced, it has been colonized by the various groups of microorganisms; particularly by the high amount of fungi and yeast in comparison with the control soil samples.

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