The effects of biochar on soil respiration in rhizosphere and non-rhizosphere soil

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Abstract: This paper presents the result from laboratory experiment (under controlled conditions), which is focused to influence of the burned plant biomass (biochar) to soil respiration in rhizosphere and soil without roots. The twelve Mitscherlich's containers were used and were filled with subsoil and topsoil from the area of Březová nad Svitavou. The experiment was divided into three variants: C presented the control variants without addition of biochar, V2 presented variants with 20 t of biochar per ha and V5 presented addition of 50 t of biochar per ha. It was used to nylon membrane for separating rhizosphere soil and non-rhizosphere soil.
Soil respiration was determined by the soda-lime method, when CO_2 is captured on the granules of soda-lime during anaerobic incubation. The results confirm the hypothesis that addition of biochar has positive effect on soil microbial activity and biomass production. The highest influence of biochar to soil respiration was measured in variant V5, the highest influence of biochar to biomass production was measured in variant V2.

Key-Words: biochar, soil microbial activity, rhizosphere soil, bulk soil, soda-lime, biomass

Introduction

Soil contains a huge amount of carbon. But soil carbon contained in soil organic matter is lost gradually due to poor land management. However, the quantity of organic matter and understanding the control on the dynamics of soil carbon is important because of the central role soil carbon plays in ecosystem sustainability, nutrient availability and the production of global greenhouse gases. The activity of the soil biota controls, in part, the release of soil carbon to atmosphere. Relatively little is known regarding how changes in microbial community composition or metabolic capacity may alter the types or amounts of soil carbon consumed and respired [1]. One of the possibilities how to increase the amount of soil carbon is application of biochar [2, 3, 4]. Biochar is a fine-grained material nature of charcoal, which is made by a process called pyrolysis. Pyrolysis is a thermal decomposition of the organic material at relatively low temperatures (300°-700°C) in the air deficiency conditions. Biochar is different from the coal, because for it's applied to the soil for purpose of changing soil properties including soil fertility and ecosystem change through the carbon sequestration. From the chemical point of view, biochar is carbon-rich product, which is more resistant to microbial degradation than other forms of carbon produces from biomass in the soil environment [5].

The authors [4, 6, 7, 8] reported a different knowledge about the effect of biochar to soil properties and soil microbial activity depending on a climatic conditions, soil type, type of vegetation and also on the properties of biochar. The chemical and physical properties of biochar can be different depending on the material from which biochar is made and the amount of the temperature during pyrolysis. For example, charcoals rich in volatile organic compounds or salts can be toxic for roots and soil microorganisms [9].

The work deals with a soil respiration - one of the indicators of soil microbial activity. It's expected that biochar added to the soil isn't inert but can provide a certain amount of labile carbon, which is readily available to microorganisms. This causes the soil respiration is stimulated in the early days of incubation by [10, 11, 12]. However, some sources [3, 7] indicates that application of biochar has no effect to soil respiration.

The aim of this work is determine how the various additions of biochar influence to 2 type of soil:

a) the soil stimulating by the growth of roots (rhizosphere soil)

b) the soil without roots (non-rhizosphere soil)

It's known that the soil near the root system has different properties than soil without roots (bulk soil). A series of soil processes is induced either by the plant's rhizosphere activities directly or by the plant's microflora. The roots aren't only a reservoir of nutrients which are transported to the shoot by the flow mass and diffusion but also the roots accept ions or water, which leads to a reduction or accumulation ions or water near roots. Roots also secreted H^+ or $(HCO_3)^-$ and CO_2, which causes changes in pH, the roots also accept or release O_2, which may cause changes in the redox potential. Furthermore roots secrete the low molecular root exudates rich in carbon substances and can mobilize the nutrients directly or indirectly supplying energy for the activity of microorganisms, which are in close proximity to the roots [13], [14]. Conversely, the microbial community in the bulk soil is thought to be carbon limited.

Material and Methods

Soil samples

The pot experiment was established in greenhouse on the 5th April 2014. The Mitscherlich's container with capacity 6 liters was used for this experiment. Each container was the same size and it was filled with 1l of subsoil and 5,5l of topsoil. The soil originated from locality Březová nad Svitavou.

The experiment consisted of 3variants: control variant without addition of biochar, V2: variant with calculated addition of 20 t of biochar per ha and V5: variant with 50 t biochar per ha. The variants had always 3 repetitions. Biochar was supplied by EKOGRILL®, the material was beech wood (Table 1). Biochar was sieved through a sieve (grid size 4mm) and homogenized. It was used a nylon membrane for separating the rhizosphere soil and soil without roots. The nylon membranes were in the shape of stocking and their diameter mesh were 0,4 µm. This type of mesh is impassable for roots and root hair but bacterias and fungal hyphae can penetrate it. The plant *Zea mays* was indicator plant.

Soil respiration

It was measured soil respiration weekly from 13th April to 31st July by the soda-lime method [14]. The principle of this method is absorbing of CO_2 which is exhaled through the soil microorganisms to the soda-lime granules. CO_2 is the ultimate product of the mineralization of organic substances in the soil. Therefore, the amount and the dynamics of CO_2 released from soil are considered as a significant measure of the intensity of mineralization processes in the soil and global activities of soil organisms. The weight gain of the soda-lime in incubated samples is directly proportional to the amount of CO_2 which is released by microbial activity of microorganisms in the samples. This weigh must be added further quantity of water which enters to the reaction between CO_2 and the absorbent. This water is evaporated during drying of the absorbent after incubation. Therefore it's necessary to multiply the resulting value by a coefficient of 1.43 [15].

The incubation lasted for 24 hours for each sample. There were measured the increase in the values of soda-lime between the individual measurements in the samples.

Table 1 Properties of biochar:

biochar material	beech wood
C	87,7%
H	2,6%
N	0,3%
S	< 0,1%
O	2,3%
H_2O	2,8%
ash	2,5%
pH (H_2O)	7,9%

Determination of dry matter biomass

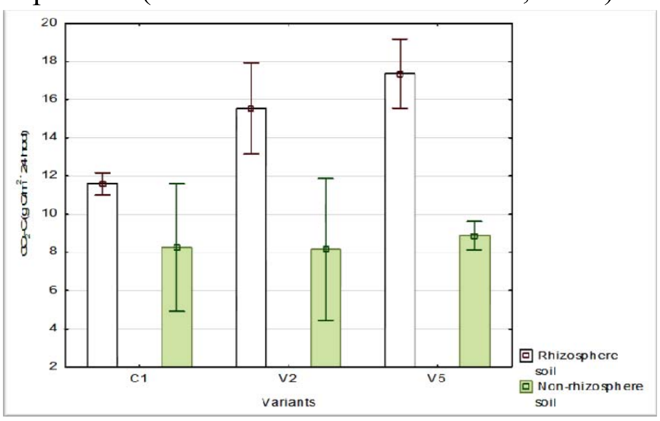
The individual samples of *Zea mays* were removed from the containers after the termination of experiment. The roots were washed by water. Aboveground and belowground biomass was dried in to constant temperature and it was weighed.

Results and Discussion

Soil respiration

The amount of CO_2 absorbed in soda-lime was determined at weekly intervals. The total amount of CO_2 absorbed by granules of soda-lime is shown at Figure 1.

Fig. 1 Cumulative production of CO_2 – basal soil respiration (mean values ± standard error, n = 3)

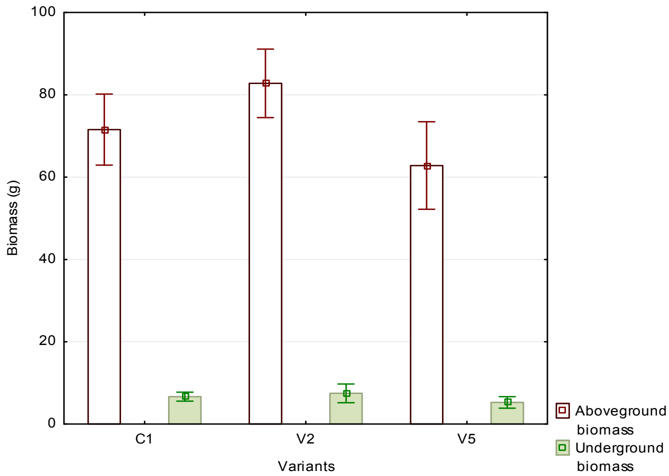


The graph shows statistically differences of soil respiration in rhizosphere and non-rhizosphere soil (between individual variants at the level 0.05; ANOVA; P<0.05). It corresponds to [13, 14, 16], when secretion of exudates by roots (rhizodeposition) allows 5–100 times more organisms per unit volume to be supported in the rhizosphere than in nearby bulk soil. As well, significant differences were observed at rhizospher soil at V5, when addition of biochar increased the microbial activity [10, 11, 12]. The influence of biochar on soil respiration in samples of non-rhizosphere wasn't statistically significant.

Biomass

Production of aboveground and belowground biomass is one of the factors which determined the influence of biochar on plant growth. Production values of biomass are shown at Figure 2, the values are expressed in g of dry weight. The uppercase letters indicate a significant differences in aboveground biomass and the small letters indicate significant differences in underground biomass (between individual variants at the level 0,05; ANOVA, p<0,05).

Fig. 2 Production of plant biomass (mean values ± standard error, n = 3)



The graph shows the highest aboveground biomass production in V2, while the lowest production in variants V5. This results correspond with [3, 4, 9, 10, 11, 12, 17], that addition of biochar have positive effect to plant grow, but high rate of biochar inhibit plant's roots or microbial biomass in soil. These results were observed at aboveground biomass and belowground biomass too.

Conclusion

This contribution presents the results of laboratory experiment to determine the effect of biochar on soil microbial activity. The measures values indicate the influence of biochar addition to soil respiration in rhizosphere soil and biomass production. The influence of biochar addition in non-rhizosphere soil has not been demonstrated.

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