

Effect of Soil Microorganisms on Carbon Fixation Capacity of Biochar

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Abstract. In recent years, the impact of climate change caused by greenhouse gases such as carbon dioxide, nitrous oxide and methane has led scientists to pay attention to the use of biochar. As a new type of fertilizer, biochar has been successfully applied in agricultural production and soil remediation. It can help remove greenhouse gases from the atmosphere, convert them into very stable forms, and store them in the soil for thousands of years, thus realizing carbon sequestration. The carbon sequestration capacity of soil can be influenced by soil microbes and biochar. Therefore, it is important to study the effect of soil microbes and biochar on biological carbon sequestration for mitigating greenhouse effect in the future. It is also necessary to clarify the relationship between soil microorganism and biochar for the effective utilization of biochar and the enhancement of soil fertility. In this paper, the mechanisms of carbon sequestration by microorganisms and biochar were summarized on the basis of previous studies, and the interaction mechanism between biochar and microorganisms was summarized. With the joint effort of microorganisms and biochar, carbon fixation capacity and efficiency can be significantly improved.

Keywords: Biochar, microbial, carbon sequestration capacity.

1. Introduction

Under the background of global warming, soil carbon sequestration has become one of the main ways to reduce greenhouse gas emissions. Biochar is a highly aromatic form of biomass produced by pyrolysis of biomass at high temperatures (typically between 300°C and 800°C) under anaerobic or anoxic conditions, a stable solid with rich carbon, large specific surface area and porosity, and abundant surface functional groups [1]. Lehmann points out that biochar can remain in soil for hundreds to thousands of years, thus converting the unstable organic carbon in biomass into stable biochar, achieving effective Carbon sequestration in the soil to and reducing emissions [2]. Soil can capture atmospheric carbon and store it in a stable carbon pool through both biological and abiotic processes called carbon sequestration. Soil microorganisms take part in the whole process of soil genesis and development, and play an important role in the maintenance of ecosystem services [3]. Studies have shown that biochar can increase soil organic matter content and increase crop yields by increasing soil fertility. It can significantly improve soil microbial diversity and activity, alleviate soil acidification, and improve soil structure. In addition, soil microorganisms, as a complex biological system, cannot only decompose organic matter, but also degrade some organic matter and produce a large amount of CO₂. Therefore, soil microbial research can better understand the organic carbon in the global scope of sequestration, turnover and recycling pathways. The organic carbon pool is affected by the presence of soil microbial metabolites and their interactions with environmental factors. At the same time, the organic carbon pool can be regulated by changing the structure and functional activity of microbial community. In addition, the active substances secreted by soil microorganisms have strong adsorption capacity and can interact with other biological factors to regulate the process of soil organic carbon metabolism, transformation direction and synthesis, etc. Therefore, it affects the process of soil organic carbon accumulation and dynamic change.

2. Soil Carbon Fixation Capacity

2.1. Basic Overview of Soil Carbon Sequestration Capacity

Carbon sequestration potential of farmland soil refers to the maximum capacity of soil to hold carbon under certain environmental conditions. It is affected by human activities, soil characteristics and natural environment. A significant way to cut carbon emissions, become carbon neutral, and slow down global warming is through soil carbon sinks. The soil carbon pool is five times larger than that of forests and other vegetation in the global carbon cycle, and it is three times larger than that of the atmosphere. The enormous soil carbon storage has a significant effect on the level of atmospheric CO₂ because it accounts for 60% of the carbon in soil's carbon pool [4]. The biological potential of optimal farmland management measures is also the carbon sequestration potential that can be achieved by technology, it is greatly disturbed by the outside world (such as high temperature, reduced input of external organic carbon, etc.), it is the maximum value of carbon sequestration of soil under the condition of optimization and adjustment of management measures (such as organic fertilizer input, straw returning, no tillage measures, etc.). Social and economic potential, which is an agricultural management measure that can increase soil organic carbon, that is, the achievable carbon sequestration potential, which is related to social factors and regional economic development.

2.2. Impact of Microorganisms on Carbon Fixation

Straw returning is an important agricultural measure for returning organic carbon to farmland, during the decomposition of straw returned to the field, part of it is discharged into the atmosphere in the form of CO₂ through microbial decomposition. Although straw returning can increase soil carbon sequestration, improve soil structure, and improve soil fertility, the current straw returning methods, such as surface covering and mixed application into the soil surface, may cause problems such as poor land reclamation quality and increased greenhouse effect due to improper returning and farming methods [5-7]. Soil can capture carbon in the atmosphere through biological and abiotic processes and store it in the carbon pool stably. This process is called carbon sequestration. Soil organic carbon (SOC) storage is closely related to environmental change, material and energy cycle in ecosystem and human production and life [8,9]. Among them, farmland greenhouse gas emissions are affected by environmental factors such as temperature, humidity and pH value, as well as many human factors, such as nitrogen fertilizer application, straw and organic fertilizer returning to the field.

Microbes can achieve carbon fixation through Calvin cycle, reductive tricarboxylic acid cycle, reductive acetyl coenzyme A pathway, 3-hydroxypropionic acid/4-hydroxybutyric acid cycle, etc. The Calvin cycle is an aerobic process, which can convert CO₂ into glyceraldehyde 3-phosphate, and is the most common way of carbon fixation. The RTCA pathway can convert CO₂ into acetyl CoA under anaerobic or hypoxic conditions.

2.3. Carbon Fixation by Biochar

Plants absorb CO₂ through photosynthesis when they grow, and finally their residues return to the soil when they die. The residues can be mineralized and decomposed into CO₂, and return to the atmosphere. The reduction of atmospheric C in the whole process is zero, and the cycle process is carbon neutral. If plant residues are pyrolyzed into biochar, only about 50% C of the pyrolyzed plant residues is converted into bioenergy and returned to the atmosphere; The other 50% C is converted into highly stable biochar and put back into the soil. About 5% of the biochar is decomposed into CO₂ and returned to the atmosphere, so that the whole cycle process is carbon negative. In short, biochar can remain in the soil for hundreds to thousands of years, so as to transform the unstable organic carbon in biomass into stable biochar, achieve effective "carbon storage" in the soil, and achieve the purpose of carbon fixation and emission reduction [2].

3. Effect of Microorganisms on the Degradation of Biochar

3.1. Basic Concept of Biochar Degradation

Microbial activity can promote the degradation of alkaline biochar. There are some microorganisms in the soil that cause plants to secrete acidic root organics, which indirectly affect the decomposition of biochar. Some microorganisms themselves can synthesize acidic substances, which can directly promote the degradation of biochar. It is found that microorganisms tend to use acidic soil with aromatic organic compounds, and the degradation of biochar increases [10]. That is to say, microorganisms existing in acid soil can inhibit the carbon fixation of biochar.

4. Effect of Biochar on Microorganisms

4.1. Mineralization

Biochar itself contains a large amount of carbon elements, so the addition of biochar to soil will change the composition, flow and transformation of soil carbon pool. The mineralization of soil organic carbon is affected by soil microorganisms, while the activities of soil microorganisms are related to the physical and chemical properties of soil [11]. The readily decomposable carbon components contained in biochar can be preferentially used by soil microorganisms as carbon sources, thus promoting the mineralization of biochar itself [11]. Increasing soil microbial biomass and activity, enhancing soil respiration and enzyme activity can effectively improve the mineralization rate of soil organic carbon. This has a positive impact on the carbon fixation of biochar.

In order to explore the influence of biochar on microbial degradation, they have found that phenol with the same volume and concentration of 110mg/L and 420mg/L was put into the inorganic salt medium containing *Pseudomonas citronella* under the same two conditions, respectively, and the phenol degradation rate was measured by adding the same amount of pyrolytic biochar at different temperatures, and the influence of biochar on degradation was analyzed [12,13]. Alkaline substances in biochar play a stabilizing role in soil pH during degradation [12]. The addition of biochar can weaken the toxicity of phenol to microorganisms through its adsorption and fixation properties. 3. High toxic substances such as polycyclic aromatic hydrocarbons contained in biochar will inhibit microbial activity to a certain extent [12].

5. Proposed Mechanism of Biochar Microbial Interaction and Environmental Impact of Biochar

Following are examples of how biochar and microbes interact and have an impact: (1) Biochar can be employed as a pore-structured microbial refuge; (2) Biochar can increase the soil's cation exchange capacity (CEC) and sustain nutrients for microbial development by adsorbing nutritional cations. The total amount of different cations that soil colloids may absorb is referred to as CEC. The number of substances containing different cations per kilogram of soil, or mol/kg, is used to express its worth. (3) Some soil microbes may be poisoned by the free radicals and volatile organic chemicals on biochar, which may also suppress soil-borne diseases and promote plant development; (4) Biochar can alter the growth mode of soil microorganisms by altering soil properties such as pH value, water content, and aeration conditions. (5) Biochar can adsorb enzyme molecules and affect the activity and element cycle of soil enzymes. (6) Biochar can adsorb and enhance the hydrolysis of signal molecules, disrupting microbial communication and altering the structure of the microbial community. (7) Biochar can enhance adsorption through the surface functional group.

The interaction between biochar and soil microorganisms can change microbial communities and their metabolic pathways which can be revealed through metagenomic analysis [14]. The input biochar can enhance the adsorption performance of soil, block and control N, P and other nutrient elements in soil and some pollutants, to reduce the biological effectiveness of pollutants, so as to

control the migration of pollutants in soil environment to water bodies and plant systems, which has high application value for reducing agricultural non-point source pollution caused by excessive fertilization in the environment, and stabilizing heavy metals and organic substances in contaminated soil. Combining the preparation of biochar with its land application cannot only alleviate the energy crisis, increase the carbon sink in the soil, but also improve the physical and chemical properties of the soil, increase the soil water holding capacity, improve soil fertility, and effectively control the migration of pollutants to other ecosystems.

6. Conclusion

First, in the process of biochar decomposition, microorganisms need to participate in and form soil structure, which can affect soil properties, and the process of microbial migration, metabolism and transformation in biochar is affected by many factors, including pH, temperature, moisture and nutrients. Second, biochar affects soil microorganisms in the following ways: One is to promote or inhibit the growth of microorganisms in the soil through the microorganisms in the biofilm; The second is to increase or decrease the content of soil organic matter through metabolic activity of microbes, and the third is to promote or restrain the decomposition rate of soil organic matter. Third, biochar itself has a protective effect on microorganisms. Besides, Biochar can be degraded by microorganisms. Last, to a greater extent, microorganisms interact with biochar and play a synergistic role.

In terms of development of biochar, due to the differences among different biochar species, identifying the mechanism of biochar in the environment from its composition and structure is a methodological difficulty. Second, it is found that biochar has a great effect on microorganisms by analyzing the action mechanism of different biochar additives on soil microorganisms. In addition, the influence of different biochar on the bacterial community structure is also different, which may be due to environmental factors. Third, In the future, it is necessary to establish and perfect the experimental system of the interaction mechanism between biochar and microorganism, so as to reveal the interaction mechanism better, and provide theoretical basis and technical support for the fertilization and soil improvement of biochar. Last, Future research needs to focus on: further understanding and clarifying the impact of biochar on agricultural production and environmental improvement from multiple perspectives; making good use of this impact, improving and optimizing the preparation technology and physical and chemical properties of biological carbon to promote its mechanism of action and application in agricultural production; revealing the impact of different types of biochar on environment by studying the synergistic effect of biochar and different environmental factors (such as temperature and moisture).

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