

Research progress on physicochemical properties of biochar and its effect on soil improvement

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Abstract. Soil is the foundation of human existence and development, an important carrier of nutrient circulation, and an important part of the earth ecosystem. China has a vast area of cultivated land, which is one of the largest agricultural countries in the world, but the farmland environment is facing a great threat. Biochar is a kind of material obtained by pyrolysis of raw materials under anoxic or anaerobic conditions, which has good properties and is widely used in soil improvement. In this paper, the modification and preparation methods of biochar were introduced, and the effects of adding biochar on soil infiltration capacity, evaporation capacity, soil nutrients, soil microbial and enzyme activities and the promotion of soil remediation were summarized. It was found that the effect of biochar on soil remediation was mainly related to raw materials, preparation conditions, addition amount and addition methods of biochar. At the same time, the future research direction is prospected, and it is proposed that all kinds of biochars should be reasonably classified, and then the best utilization mode of all kinds of biochars is discussed, which provides theoretical basis and basis for further popularization and utilization of biochars.

Keywords: biochar; Soil improvement; Soil microorganism; Soil remediation.

1. Overview of biochar

Bio-carbon is a solid particulate matter with stable physical and chemical properties, high carboxylic acid esterification and aromatization structure produced by pyrolysis of biological residues under anaerobic or oxygen-limited conditions. It has unique physical and chemical characteristics such as large specific surface area, porosity and abundant surface functional groups. It plays an indispensable role in improving soil structure, soil quality, increasing crop yield and income, carbon sequestration and emission reduction, and improving ecological environment. It has become a research hotspot in improving soil ecology, agricultural application and carbon sequestration and emission reduction. Scientific research shows that the surface of biochar is rich in base ions such as nitrogen, phosphorus, potassium, sodium, etc. to improve the cation exchange capacity of soil and increase the soil pH value. In addition, biochar can release a large amount of mineral nutrients into the soil after being applied to the soil, so as to improve the content of soil available nutrients. The adsorption of carbon can adsorb soil nutrient ions to reduce the loss of soil nitrogen and phosphorus, and release these nutrients slowly through desorption, so as to better supply the needs of crop growth. Moreover, this adsorption will also make biochar increase the retention of soil water and ensure sufficient water for crop growth. In addition, with the development of scientific research, biochar can not only retain nutrients in the soil, but also provide a place for the survival and reproduction of microorganisms, promote the growth of microorganisms, and ensure the dynamic balance of microorganisms in the soil environment.

2. Effects of biochar on soil chemical properties

A large number of studies on biochar show that biochar, as a special organic matter, can not only maximize the utilization of farmland wastes, but also have broad application prospects in soil structure optimization and agricultural production. Soil structure, nutrient status and other properties

depend on the process of soil formation, land use and the input of other exogenous materials. Biochar can not only sequester carbon and reduce emission, but also regulate soil pH value and soil fertility level, and optimize soil environment through various ways. A large number of studies have shown that the effect of biochar on pH value of acidic soil is much greater than that of alkaline soil, and it is closely related to the raw materials and preparation conditions of biochar. Many studies have also shown that biochar has strong adsorption capacity due to its large specific surface area. After being applied into soil, biochar can increase the soil's absorption of nutrients, thus reducing the leaching of nutrient elements in the soil. For example, biochar can adsorb soil nitrogen, alleviate and hold various forms of nitrogen-containing substances, enhance the ability of soil to store nitrogen, and further enhance the ability of soil to maintain nitrogen, thus promoting the effective use of nitrogen by crops, reducing the loss of nitrogen fertilizer in agricultural production process and non-point source pollution caused by nitrogen migration. The results of Feng et al. Showed that increasing the amount of cotton stalk carbon could make up for the shortage of nitrogen and improve the soil physical and chemical properties. Biochar can also affect phosphorus in soil. Biochar has a large number of organic functional groups and strong ion exchange capacity. Through adsorption exchange or coordination exchange of phosphorus containing anions, it not only greatly increases the content of available phosphorus in soil, but also promotes the availability of exogenous phosphorus in acid soil. Application of biochar to soil can effectively reduce the leaching of soil available phosphorus. Some studies have also pointed out that the improvement effect of biochar on soil is related to its own properties and soil types. For example, after biochar is applied to sandy loam soil, the content of potassium does not change significantly, while the application of biochar in alkaline soil will reduce the content of trace elements in plants.

3. Effect of biochar on soil biological characteristics

Soil microorganisms are the most active part of soil carbon pool, and they are particularly sensitive to changes in the external environment. Therefore, soil microorganisms respond more rapidly to biochar application than other organic matter. To explore the effect of biochar on soil ecosystem from the change of soil microbial biomass is one of the ways to study the benefits of biochar application. Many studies have shown that the porous characteristics and surface characteristics of biochar create a good environment for the growth and reproduction of microorganisms, which greatly increases the number and biomass of soil microorganisms, thus improving the soil biological activity.

The effect of biochar on soil microorganism is not only the change of microbial community composition, but also has an important impact on soil microbial biomass carbon and nitrogen. Soil microbial biomass is the main driving force of material cycle and energy flow in soil. It not only participates in and regulates the speed of material and energy transfer in soil, but also is a sensitive indicator reflecting the changes of soil microorganisms.

The results showed that the application of biochar could obviously increase the soil microbial biomass carbon and nitrogen, and it changed with time. However, some studies have pointed out that the higher the application amount of biochar, the lower the microbial biomass carbon content of soil with higher fertility (Chao Huang et al.). In addition, the high aromatic hydrocarbon structure of biochar is easy to become an ideal habitat for soil microorganisms, and provides energy materials for the life activities of soil microorganisms. Therefore, it can promote the number and community diversity of soil microorganisms. However, some scholars show that the application of biochar will reduce the diversity of soil microorganisms, and its changes are conducive to plant growth and disease resistance.

As one of the main components of soil ecosystem, soil enzymes mainly come from organisms and their secretions, and play an important role in soil nutrient transformation, fertility improvement and pollutant elimination. Their activities reflect the intensity and direction of various biochemical processes in soil.

From the research progress at home and abroad, the effects of biochar application on soil enzyme activities are concentrated in the following aspects: the effects of biochar on various soil enzymes, and the mechanism of biochar on soil enzyme activities. When studying the effects of biochar on various soil enzymes, the focus is on enzymes related to transformation, hydrolase and oxidoreductase. It was found that the application amount of biochar, biochar types, soil physical and chemical characteristics, crop types and other factors could affect the effect of biochar application on soil enzyme activities. Although biological application of carbon increased the soil enzyme activities related to the utilization of mineral elements such as N and P, it decreased the soil enzyme activities involved in ecological processes such as carbon mineralization in soil.

4. Outlook

The influence mechanism of biochar on soil microbial biomass, microbial community composition and soil enzyme activity is complicated, mainly due to the unique physical and chemical characteristics of biochar. However, at present, there are still some shortcomings in the research and technical popularization of biochar, which need to be further discussed:

There are many kinds of raw materials of biochar, and the properties of biochar products obtained under different preparation conditions are also completely different. The improvement effect on soil varies with the amount and way of adding biochar, especially the soil infiltration capacity and water holding capacity are also closely related to the soil texture. At present, most of the research conclusions focus on the research of apparent effect, but the results of internal mechanism are still rare. In the future research, various biochars should be reasonably classified according to certain conditions, focusing on the soil improvement effect and mechanism of different types of biochars, and further discussing the application threshold and the most suitable application mode of different types of biochars, so as to provide guidance for promoting the popularization and application of biochars.

The research on biochar mostly focuses on indoor simulation experiments, but less on field experiments. The research conclusions mainly focus on the single influence of soil physical characteristics, soil nutrients, soil microbial environment, etc. There are few studies on the comprehensive effects of several aspects, and the comprehensive evaluation of the effect of biochar on soil improvement has not been reported. In the future, we should consider multi-disciplinary cross-discipline, and comprehensively construct an evaluation system for biochar improvement.

The existing research cycle is relatively short, and there is a lack of long-term research. In the future, we should pay attention to the long-term effect of applying biochar on soil based on experiments and model simulations at different time and space scales, so as to provide theoretical basis for further extensive utilization of biochar.

As a new soil improver, the farmers' willingness to apply biochar in farmland is a problem worthy of consideration. Therefore, while studying the theory of biochar's effect on soil improvement, we should combine farmers' wishes and comprehensively consider the utilization mode of biochar based on social benefits such as economic input, so as to really improve farmland soil productivity and alleviate the current situation of food demand in China.

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