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Effects of Different Carbonaceous Conditioners on Soil Physical-Chemical Properties

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Abstract

The Biochar is a kind of carbon-rich material with a wide source of raw materials, low cost, and environmental-friendly. In recent years, carbonaceous conditioners has been widely concerned. carbonaceous conditioners improve soil nutrient status, which not only improves the physical and chemical conditions, but also can promote the growth of green plants. The materials used to prepare carbonaceous conditioners are from a wide range of sources, while the physical and chemical properties of carbonaceous conditioners from different materials vary greatly. Most of the carbonaceous conditioners prepared by different materials are applied in a small range, and the actual application is insufficient, which is the focus of the future research on carbonaceous conditioners. Therefore,We reviewed the effects of several soil modifiers, such as straw, organic fertilizer, biochar, and other carbonaceous conditioners, on the physical and chemical properties of soil, with a view to providing theoretical basis for the preparation and wide application of carbonaceous conditioners.

Keywords

Carbonaceous Conditioners; Soil Amendments; Straw; Organic Fertilizer; Biochar.

1. Introduction

Due to the increasing global population, the demand for food and agricultural products is also increasing. The global population is projected to reach 9.8 billion by 2050. According to the United Nations Development Programme (UNDP), 821 million people worldwide still suffer from hunger and malnutrition. The shortage of food and agricultural products is dire. Currently, 25% of the world's farmland is highly degraded, 44% is moderately degraded, and about 10% of farmland recovers from degradation.[1] Soil degradation, such as nutrient depletion, salinization, and reduced water retention, affects soil quality, thereby limiting food production. Low soil fertility is a major problem in most parts of the world, which has led to a more prominent contradiction between the supply and demand of food and agricultural products. Due to the high solubility, low thermal stability, and small molecular weight of traditional fertilizers, most of the nutrients are lost to the environment through surface runoff, leaching and volatilization, which not only reduces the utilization rate of fertilizers,

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increases the cost of conventional fertilizers, but also causes a certain degree of pollution to the soil and water environment. Charcoal-based soil amendments containing organic carbon have become a hot spot in domestic and foreign research, due to their cheap raw materials, abundant resources, and ability to increase soil organic matter content and improve soil structure. In recent years, straw, organic fertilizer, biochar, and carbonaceous conditioners composite have been widely used as soil amendments to improve plant growth. Studies show that applying biochar as a soil amendment to soil can adsorb more water and nutrients, improve soil nutrient holding capacity and water holding capacity, especially oxidized biochar, which can increase the water holding capacity of sandy soil and improve soil water holding capacity.[2] However, the effects and mechanism of different carbonaceous conditioners on soil physicochemical properties are not clear. Therefore, the effects of several carbonaceous conditioners on soil physicochemical properties are summarized in this paper, in order to provide theoretical basis and technical support for soil improvement and soil and water conservation.

2. Amendments

2.1 Straw

Straw is the rest of the crop after harvesting, accounting for more than 50% of the crop biomass, and its main components contain crude fiber and minerals, as well as small amounts of protein and oil. Straw is involved in soil as organic materials, providing a large number of nutrients for soil microorganisms and enzymatic reaction substrates, which can stimulate the activities of soil microorganisms and enzymes.[3] As an important way of straw utilization, straw returning to the field can balance soil nutrients, improve soil structure, physical and chemical characteristics, enhance soil water storage capacity and field water use efficiency through the action of microorganisms, which is conducive to the optimization of farmland ecological environment. Commonly used straw mainly includes corn straw, wheat straw, rice straw, soybean straw, etc. The method of returning straw to the field affects the improvement effect. Studies have shown that the application of crushed straw to the soil can effectively increase the soil organic matter content, reduce the soil volume and quality, improve the soil structure, increase the soil water holding capacity and water supply capacity, which achieves a better water-saving effect.[4] In addition, studies have shown that straw ammoniation technology can effectively reduce the C/N rate of straw, reduce the cellulose and hemicellulose content in straw, and accelerate the decomposition rate of straw, which is a comprehensive measure that can give full play to straw to improve soil structure and soil moisture characteristics. Crushing and ammoniating straw at the same time to improve soil has certain delays, and applicating soil can effectively reduce the soil volume mass of the tillage layer (15 cm), improve soil aeration and soil structure.[5] Chai reported that the soil improved by straw application significantly increased the soil saturated water content and field water holding capacity, while the total soil moisture reservoir capacity increased, and the ineffective reservoir capacity decreased, which improved effectiveness of the soil water storage capacity and soil moisture to crops.[6]

2.2 Organic Fertilizer

At present, organic fertilizer mainly includes homemade compost, compost, biogas fertilizer, commercial organic fertilizer, etc. Soil organic matter, a binder to form soil agglomerate structure content, is an important indicator of soil fertility and soil-crop ecosystem development, which can not only improve soil structure, absorption performance and physicochemical properties, but also provide certain nutrients for plants. Many studies have shown that organic fertilizer can enhance the ability of soil fertilizer retention and fertilizer supply by increasing the content of organic matter in the soil surface, forming a good aggregate structure in the soil, and improving soil nutrients, which compensates for the adverse effects of long-term tillage or soil poverty.[7] Studies have shown that organic fertilizers can effectively improve soil acidity. In the process of mineralization, a large number of organic acids and humus are produced in organic fertilizers, containing functional groups such as hydroxyl groups and phenol, which can consume proton hydrogen and reduce soil acidity by coordinate exchanging with hydroxyaluminum and iron hydrate oxides in the soil.[8] Organic fertilizer has a significant effect on soil structure improvement. Hou xiaona found that the nutrients contained in bio-organic fertilizer using straw and livestock manure as raw materials were slowly released under the action of microorganisms, and the humic acid could promote the formation of agglomerate structure, significantly increase soil total nitrogen and available nitrogen content, soil fertility, and improve soil structure and tillage.[9] Wang showed that bio-organic fertilizer and sesame cake fertilizer can significantly promote the release of soil nutrients, supply the growth needs of tobacco leaves, and significantly improve the activity of CAT catalase and PPO polyphenol oxidase in soil, thereby promoting the humification process of organic materials and organic matter in soil, which is conducive to improving fertilizer utilization.[10]

2.3 Biochar

Biochar, regarded as an ideal soil amendment, is a black carbon material with high carbon content and developed pore structure obtained by pyrolysis of plant biomass under hypoxic or oxygen-restricted conditions, which can maintain nutrients and water. The porosity and high specific surface area characteristics of biochar have a good effect on soil bulk density, soil porosity and soil water holding capacity. In addition, biochar has a regulating effect on soil pH, can also promote soil nitrogen and phosphorus conversion and adsorption of heavy metal ions. Biochar itself can also become a good habitat for soil microorganisms. The sources of materials for preparing biochar are wide, mainly including agricultural waste, animal manure, food waste, sewage sludge, bioenergy residue, etc. The physical and chemical properties of biochar prepared from different sources of biomass vary greatly. The researchers studied the effects of different input amounts of biochar on soil nitrogen loss through indoor soil column experiments, and found that different biochar types, different soil types, and different amounts of biochar addition had effects on nitrogen loss in soil. Xing Ying found that adding 1% eucalyptus charcoal to the soil could effectively reduce nitrogen loss, and the leaching loss of ammonia nitrogen and nitrate nitrogen in the soil column leachate was proportional to the input of biochar [11], while the results from Zhou zhidong show a contrary result, that lower biochar application promotes nitrogen leaching [12]. Biochar affects soil microbial activity and population development. Zheng found that biochar promotes microbial activity and the transfer of bacterial communities to rhizosphere beneficial taxa, and helps to improve plant growth and biomass, microbial activity and bacterial community diversity, soil carbon stability, phosphorus dissolution and nitrogen fixation.[13]

2.4 Carbonaceous Conditioners

Compared with traditional fertilizers, carbonaceous conditioners with biochar as the carrier can reduce the loss of nutrients and improve the nutrient utilization rate of crops. Lateef found that the preparation of biochar from corn cobs and loaded with a large number of elements and trace elements can effectively extend the sustained release time of nutrients.[14] Studies showed that the release rate of nutrient isolates depends on the pore size, ion binding capacity and adsorption capacity of the biochar carrier. El-Sharkawi report that N release from rice husk/H3PO4/ammonia biochar-based fertilizers is more stable compared to mineral fertilizers, thus minimizing leaching of N.[15] Zhong also found that compared with pure urea, molten urea-impregnated biochar of different diameters exhibited slow release characteristics, reducing the release rate of N in soil.[16] An noted that the release rates of K and P of cotton straw, bentonite, potassium phosphate biochar-based fertilizers prepared by co-cracking were lower than that of cotton straw/potassium phosphate biochar-based fertilizers.[17] This is because the presence of bentonite in co-fissure reduces the pores and channels of biochar, resulting in the formation of stable P and hydrophobic compounds. Singh compared the nutrient release rates of two types of biochar-based fertilizers, and found that the nutrient release rate was also affected by the type of raw material used to synthesize biochar-based fertilizers.[18] Rice husk biochar containing urea has been reported to show the highest release rate, with about 98% of urea being released within 72h. In contrast, straw biochar containing urea has a urea release rate of 91% after 72 hours of incubation in water. However, biochar-based fertilizers have suboptimal pH values that may limit their application in soil. To overcome this problem, it is possible to take advantage of adding alkaline sources to the formulation. Lustosa Filho neutralizes acidified phosphates by adding magnesium oxide (MgO) to the formulation, thereby reducing P release in water and improving the pH value of tropical soils and reduces soil adsorption of P, as well.[19] This is because with a value of 4-6 pH, the P binds more strongly in soil. In addition, alkaline biochar-based fertilizers have no significant effect on the pH value of soil when applied in alkaline soils such as calcareous soils. Study of El-Bassi showed that biochar-based fertilizers enhance soil properties and enzyme activity.[20] In conclusion, the nutrient release behavior of biochar-based fertilizer depends on the type of biochar carrier and the additives, binders, and synthesis methods, and the nutrient release behavior of biochar-based fertilizer in different soil types and soil-plant systems also needs to be investigated in depth.

3. Conclusion and Perspectives

The use of biochar to prepare carbonaceous conditioners may provide an important and feasible new way to solve the practical problems of agricultural production, such as soil degradation, acidification, salinization, agricultural non-point source pollution, heavy metal pollution, and pesticide residues. However, objectively, in view of the long-term, special and complex causes of soil obstacles and pollution, as well as the different soil types and application time, methods, dosage and other conditions, although the positive effect is significant, from the perspective of marketization and engineering application, it is still necessary to maintain a scientific and cautious attitude, and only on the basis of repeated and reliable preliminary tests can the engineering promotion and application be carried out.

(1) Traditional organic fertilizer is mainly made of livestock and poultry manure, crop straw by compost rot. It can increase the nutrient content in the soil and is conducive to improving soil structure after application. However, the type and degree of decay of compost raw materials directly affect the quality and safety of organic fertilizer, so when using organic fertilizer to prepare carbonaceous conditioners, attention should be paid to the selection of raw materials and the degree of decay.

(2) Due to the low nutrient content of biochar, the application of a high proportion of biochar is not agronomically and economically feasible, and it is necessary to develop fertilizers prepared from biochar as the carrier with reasonably added nutrients to prevent pollution.

(3) The material sources for the preparation of carbonaceous conditioners are wide, and the physical and chemical properties of carbonaceous conditioners from different materials are very different. The application of carbonaceous conditioners should be proportioned according to the type of soil to achieve the best effect of soil improvement.

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