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学位論文審査の要旨

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学位論文題名

Effect of biochar application on soil and plant

(バイオ炭施用が土壌および植物生育に及ぼす効果)

This thesis is composed of 84 text pages, 13 figures, 5 tables, and attached with 2 reference papers.

There is an urgency to establish effective agricultural management practices that increase food production, while preventing negative agricultural impacts on the environment. One approach is the use of biochar. Biochar is a product of the thermal degradation of organic material under oxygen-limited conditions. It is similar in its appearance to charcoal produced by natural burning but different by its use as a soil amendment. Biochar has unique properties that are expected to be a valuable soil amendment to sustainably increase the soil health and productivity as well as an appropriate tool for long-term carbon sequestration in soils.

Biochar is widely used as a soil amendment to increase crop yields, but its effects on the dynamics of microbial communities and minerals in the soil have not been fully investigated, particularly in soils with organic manure application. On the other hand, the application of biochar for mitigating greenhouse gas (GHG) emissions from paddy and upland soils has been studied extensively. However, little has been reported about the effects of biochar on GHG emissions from soils in converted paddy fields that may have different microbial community characteristics compared with general upland soils. Considering the points above, two experiments were conducted. First, a pot experiment was conducted to examine the effects of biochar on microbial community structure and mineral availability in soils growing different crop species under different organic manure treatments. Second, an incubation experiment was set up to investigate the potential effects of different types of biochar applications on GHG emissions as well as the soil properties under different soil moisture conditions using soils from rice paddy fields.

1. Effect of biochar application on the mineral and microbial properties of soils growing different plant species

The pot experiment was conducted using soybean and sorghum growing on four different soil treatment combinations (cattle farmyard manure with or without biochar and

rapeseed cake with or without biochar). This experiment examined the effects of wood biochar on the microbial community structure and mineral availability in soils. The application of biochar increased the growth of both species, particularly for sorghum growing on the rapeseed cake application. A principal component analysis using the data from Biolog EcoPlate^{TM} indicated that the biochar application changed the soil microbial community structure, particularly for soils growing sorghum. The biochar addition had little effects on the profile of ammonium-acetate-extractable mineral elements in soils with both types of manure application growing soybean. With sorghum, however, adding biochar to rapeseed cake with manure changed this profile. This change is caused by an increase in the extractable concentration of certain metals in the soil, including aluminum, cadmium, and zinc, possibly caused by an enhanced organic matter decomposition that produces metal-chelating organic compounds. These different changes in the soil properties by biochar addition may be directly or indirectly related to the different growth responses of different plant species to biochar addition with organic manure application.

2. Effects of wood and bone biochar on greenhouse gas emissions of paddy soils under waterlogged and upland conditions

A soil incubation experiment was conducted with the following treatments: soil treated with and without manufactured biochar (wood and animal bone) at two different soil moisture conditions [waterlogged for simulating paddy field conditions and 60% of the water holding capacity (WHC) for simulating upland fields converted from paddy fields]. Higher cumulative emissions of CH_4 and N_2O and lower emissions of NO were observed for waterlogged soils than those at 60% WHC. The addition of biochar to both soil moisture treatments significantly decreased the cumulative emission of CO_2, NO, and N_2O, although it enhanced the CH_4 emissions. Wood biochar was more effective than bone biochar in reducing CO_2, NO, and N_2O emissions, regardless of the soil moisture treatments. On the other hand, bone biochar enhanced CH_4 emissions more at waterlogged conditions, but markedly less at 60% WHC. Thus, our results suggest that in upland fields converted from paddy fields, there may be lower CH_4, and N_2O but higher NO emissions than those in paddy fields. The addition of biochar, particularly wood biochar, can reduce the emission of these GHGs. However, CH_4 emission can be enhanced by the addition of biochar.

Overall, this study provides novel insights into the effects of biochar on the soil microbial activity and the carbon, nitrogen, and mineral element dynamics. These results are useful as basic and practical information for promoting sustainable agriculture using biochar. Therefore, we acknowledge that the author is qualified to be granted the Degree of Doctor of Philosophy in Agriculture from Hokkaido University.