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# SUMMARY OF DOCTORAL THESIS

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Title: Effect of Biochar Application on Sandy Soil Improvement
(砂質土壌改良のための炭化材施用効果)

A study was conducted at the Arid Land Research Center, Tottori University, Japan to evaluate the application effect of biochar for sandy soil improvement in a combination of both laboratory and greenhouse experiments because information concerning the agronomic effects of biochar in drylands sandy soils is scarce.

In the laboratory study, the effect of black locust wood biochar pyrolysis temperatures (300, 400 and 500°C) on sandy soil hydraulic properties and nutrient retention were analyzed. Three application rates of biochar (0, 10 and 20 Mg $ha^{-1}$) were used. It was found that biochar amendment improved sandy soil hydraulic properties and nutrient retention. The application rate of 20 Mg $ha^{-1}$ reduced the hydraulic conductivity with increasing moisture content, as a result, the available water capacity increased by 97%, when compared to unamended sandy soil. The results of the study showed that biochar produced at 500°C pyrolysis temperature significantly improved sandy soil hydraulic properties better than other treatments whereas, biochar produced at 300°C had the highest nitrate retention among the treatments. In general, the results of the study demonstrated the importance of biochar pyrolysis temperature and biochar effect as sandy soil amendment that could be used to improve the agronomic side of the soil.

In the field study, the agronomic values of three biochars types produced from three different feedstock sources (black locust wood, cow manure and chicken manure) on maize production and sandy soil quality were investigated. The biochars were produced at 500°C pyrolysis temperature based on the laboratory study results. A randomized complete block design with four replicates was used. Four biochar application rates (0, 10, 15, and 20 Mg $ha^{-1}$) were used for each biochar type. It was observed that cow manure biochar significantly increased maize growth, yield, water use efficiency and nutritional quality as well as the physico-chemical properties of the post harvest sandy soil at the higher application rates of 15 and 20 Mg $ha^{-1}$. It was observed that the increases were significantly affected with increasing the biochar amendment rates. The increase in maize growth and yield was largely due to the improvement in the cation exchange capacity of the soil, a decrease in the hydraulic conductivity of the soil and an increase in the carbon, nitrogen and phosphorus contents of the soil. The 15 Mg $ha^{-1}$ had the highest effect on maize growth and yield and consequently on water use efficiency and grain nutrient uptake. This was attributed largely to the higher soil phosphorus availability in conjunction with higher nitrogen availability at 15 Mg $ha^{-1}$

rate, as compared to other application rates. The pH, phosphorus, total carbon and nitrogen, exchangeable cations (potassium, Calcium, and Magnesium) contents and the cation exchange capacity of the post harvest soil was significantly increased in the biochar amended soil whereas, the field saturated hydraulic conductivity of the sandy soil was decreased in the amended plots and this was considered an improvement in the physical property of the sandy soil.

In the study with chicken manure biochar, additional study on the effect of pyrolysis temperature (500, 600 and 700℃) on the yield and quality of chicken manure biochar was conducted. It was observed that pyrolysis temperature strongly affected the yield and properties of chicken manure biochar. Biochar produced at 500℃ had higher biochar and carbon yield (17-35%), and cation exchange capacity (500-581%) than the other materials pyrolyzed at 600 and 700℃. Biochar application significantly increased maize yield, water use efficiency and grain nutrient uptake at the higher application rates of 15 and 20 Mg $ha^{-1}$. The 20 Mg $ha^{-1}$ had the highest impact on the improvement of the yield components. It was observed that maize grain utilized more nitrogen than other nutrient elements and nitrogen uptake increased with increasing the biochar application rate and this suggests the ability of the chicken manure biochar to improve the supply of nitrogen. Biochar application increased the pH, total carbon and nitrogen, exchangeable cations (potassium, calcium and magnesium) and cation exchange capacity of the post harvest sandy soil. The field saturated hydraulic conductivity of the post harvest sandy soil was reduced as a result of biochar amendment.

In conclusion, it was observed that the effect of biochar on maize yield depended on the feedstock biomass source. The results also indicated that maize yield and nutrient uptake were significantly improved with increasing the biochar mixing rate. In general, it was observed that biochar effect on soil phosphorus availability was the dominant driver of yield increases. The cow manure and chicken manure biochars significantly improved maize yield than the wood biochar. This was because cow manure and chicken manure biochars improved sandy soil nitrogen and phosphorus availability, and exchangeable cations and cation exchange capacity more than the wood biochar. Generally, cow manure biochar significantly improved maize yield than other biochars and this was observed to be because of the ability of cow manure biochar to increase the sandy soil CEC more than other biochars. Therefore, the application of cow manure biochar at the rate of 15 Mg $ha^{-1}$ was suggested as the best treatment to improve crop yield and sandy soil quality. Thus, the conversion farm wastes to biochar, as evaluated in these studies, can be considered a sustainable alternative to the easily degradable agricultural wastes, thus, a strategy for sustainable dryland sandy soil improvement, and also for carbon sequestration.