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SUMMARY OF DOCTORAL THESIS

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Title: ASSESSMENT OF BIOCHAR NUTRIENT COMPOSITION PYROLYZED AT DIFFERENT TEMPERATURES FOR IMPROVEMENT OF PADDY SOIL AVAILABLE SILICON

（水田土壌中可給性ケイ素の改善に向けた異なる温度で炭化されたバイオ炭の養分組成の評価）

Rice is an increasing important crop in many countries in Sub-Saharan Africa (SSA) including Nigeria. This is because of all the staple crops; rice has risen to a position of preeminence due to change in consumer's preference. However, domestic production has never been able to meet the demand, leading to considerable imports. Silicon (Si) has been proven by many researchers to be a beneficial element for rice but local farmers in SSA are not concern on the use of Si fertilizer despite the Si risk deficiency in the area. This may be attributed to the unawareness of farmers on the high demand of Si by rice plant. Aside from Si deficiency risk, soil degradation is also a major challenge facing local rice farmers in SSA. SSA soils are generally low in soil nutrient due to high organic matter mineralization. Application of fertilizers is recommended to tackle the challenges facing low rice production in SSA but the high cost of the fertilizers makes its application difficult for local farmers. To sustain rice production in SSA, there is need to research on alternative local source which are locally available and affordable. The conversion of wastes generated from agricultural produce into biochar and returning it to fields is a practical solution. This is a potentially valuable agricultural practice that can positively affect both the physical and chemical properties of the soil as well as enhance carbon sequestration into the soil. This waste conversion approach will benefit not only the agricultural sector but also play a very important role in handling environmental issues like waste management.

This study examined change in the elemental composition of rice husk biochar (RHB) and sugarcane bagasse biochar (SBB) at varying pyrolysis temperature, with emphasis on evaluating the potentials of these biochars to improve the nutrient status of the soil as well as its uptake by rice plant. In this study, the rice husk and sugarcane bagasse, used were pyrolyzed at 300 – 700°C and 350 – 700°C for RHB and SBB using an experimental electric furnace, respectively.

In an exploratory study, the effect of pyrolysis temperature on two agricultural wastes was assessed. This was done to ascertain possible change in the elemental composition of the produced biochar that can improve rice plant growth and yield. The result reveals that pyrolysis temperature changes induce change in the elemental composition of the used agricultural waste biomass (rice husk (RH) and sugarcane bagasse (SB)). From the result, it was found that biochar yield and total nitrogen decreased significantly ($p < 0.05$) with increasing pyrolysis temperature. The biochar yield ranged from 55% at 300°C to 35% at 700°C and from 27% at 350°C to 22% at 700°C with total nitrogen ranging from 4.9 g kg^{-1} to 3.6 g kg^{-1} and from 6.0 g kg^{-1} to 3.8 g kg^{-1} as well in RHB and SBB, respectively. The ash content, pH, EC, total carbon, 1M ammonium acetate extractable (hereafter, extractable) Ca, Mg, Na, available phosphorus and Si were significantly ($p < 0.05$) increased with increasing pyrolysis temperature in both biochars (RHB and SBB). The maximum ash content (35.6%), pH (10.7), EC (0.40dS m^{-1}), extractable

Mg (29 mg kg^{-1}), extractable Na (38 mg kg^{-1}) and available phosphorus (1842 mg kg^{-1}) were from RHB at 700°C while maximum extractable Ca (180 mg kg^{-1}) was from SBB at 700°C. In RHB, extractable K increased significantly ($p < 0.05$) with increasing pyrolysis temperature, while in SBB it decreased. In RHB, the increased in extractable K ranged from 165 to 684 mg kg^{-1} while the SBB extractable K decreased significantly from 396 to 251 mg kg^{-1}. Among the three extractants (0.01M $CaCl_2$, 0.5M HCl and 0.1M citric acid) used for available Si, its maximum in 0.01M $CaCl_2$ was observed in RHB at 700°C (3124 mg kg^{-1}) while 0.5M HCl and 0.1M citric acid were from SBB (7262 mg kg^{-1} and 9313 mg kg^{-1}) respectively at 700°C. In summary, an increase in pyrolysis temperature leads to the generation of biochar with high nutrient content. In all, RHB at high pyrolysis temperature may produce nutrient-rich biochar, with high pH, EC, ash content, extractable base cations, available Si and phosphorus. It could be an option to increase Si availability through acid pre-treatment as the amount of Si extracted from biochar was higher in acid extraction.

Subsequently in this study, a pot experiment was conducted in an experimental glasshouse. The pot experiment aimed at investigating how pyrolysis could enhance the Si availability in rice husk for the improvement of soil available Si. RHB pyrolyzed at varying temperature (300°C – 700°C) was used for this experiment. The experiment units in the pot experiment were replicated into three and arranged in a complete randomized design. The result revealed that RHB could serve as a Si source as its effect on maintaining soil available Si remained after harvest. RHB at 400°C significantly ($p < 0.05$) increased the soil available Si by 61% compared to the original content (93.8 mg SiO_2 pot^{-1}) of the used soil. Also the application of RHB not only improve soil available Si but also improve Si uptake by rice plant. The cumulative amount of Si (soil available Si and the uptake by plant) ranged from 1971.7 of the control to 2478.8 mg SiO_2 pot^{-1} in RHB treatment. The increment in RHB treatments against the control ranged from 30.6 to 455.9 mg SiO_2 pot^{-1}. This increment is because of the cumulative Si release by the biochar throughout the cropping season and also enhancement of available Si release from the soil through the effect of RHB on soil physicochemical properties. In summary, the percentage Si release from treatments was much higher in RHB than RH treatments during the cropping season. Hence, the application of RHB as Si releasing agent to increase soil available Si will improve rice plant growth. The role RHB and SBB played in improving the soil fertility was also investigated in a pot experiment. The result revealed that even though RHB and SBB can be used as amendment; its efficacy could not be generalized. This is because the physical and chemical characteristics of biochar vary widely in the soil and their interaction with soils on improving crop and soil productivity need to be uniquely evaluated.

Finally, based on the results obtained from this study, pyrolysis of agricultural waste biomass is one of the strategies of locally source alternative to silicate fertilizer as well as soil amendment. The present studies confirmed that increasing pyrolysis temperature changes the elemental composition of the agricultural waste biomass. It also affirms that the application of its products (biochar) can improve soil available Si and Si uptake in rice. Therefore, developing an innovative process, which can control the best pyrolysis temperature, would be a key factor for the local communities for optimum utilization of the produced biochar.