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SUMMARY OF DOCTORAL THESIS

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Title: CHARACTERIZATION OF INDONESIAN LOCAL SILICON MATERIAL AND EVALUATION OF CONTROLLING FACTORS FOR SOIL SILICON AVAILABILITY

インドネシア産ケイ素資材の特性付けと土壌のケイ酸可給度の制御因子の評価

Rice is the main staple food in Indonesia in which Indonesia ranks third in rice production in the world. However, the domestic rice production is not enough to meet the demand. Although Silicon (Si) is a beneficial element for rice plant, Si fertilizer has never been used in Indonesia. Therefore, soil available Si in rice fields in Java Island has decreased by approximately 17-22 % during the period 1970-2003 (Darmawan et al., 2006). Application of Si fertilizer is recommendable, but not accessible to local farmers. For this reason, it is desirable to explore cheap and abundant local Si containing materials as Si fertilizer sources. In the present study, Si availability of 18 local materials, namely rice husk-burnt (RHB), rice husk-ash (RHA), rice husk-heated (RHH), media of mushroom (MM), cacao (*Theobroma cacao,* L.*)* shell - biochar (cacao SB), rice (*Oryza sativa*, L.) straw compost (RSC), bagasse, elephant grass, vetiver grass, bamboo leaf, sugarcane leaf and palm nut shell-biochar (palm nut SB), fly ash, steel slag, silica gel, volcanic ash, bottom ash, electric furnace slag (EFS), from different sources in Indonesia were determined by extraction and incubation methods and compared with Japanese silica gel (JSG) and Japanese silica fertilizer (JSF) as reference. The bioavailability was also examined by pot experiments of rice cultivation in the greenhouse. Based on the results of these experiments, factors of materials and soils controlling Si release from the materials were also discussed. In addition, methods to improve availability of Si of fly ash and bottom ash were also examined.

In general, Si release examined by incubation method was lower in organic materials than in inorganic materials. Release of Si from silica gel was the highest among the materials tested both in red and sandy soils. However, its use was not realistic as it is imported and costly. Among the local materials such as steel slag, RSC and RHB, and cacao SB could be used as Si amendments in paddy fields in Indonesia. Of the six extractable Si studied, Si concentration was higher in the order of 0.5N HCl> citric acid> acetate buffer pH 4.0> sodium phosphate> Na_2CO_3/NH_4NO_3> $CaCl_2$ for inorganic materials. The Si of the inorganic materials was more extractable in acid solution, while for organic materials, the Si was more extracted in alkaline solution with the order of Na_2CO_3/NH_4NO_3 > $CaCl_2$> sodium phosphate> citric acid> 0.5N HCl.

In the pot experiment examining bioavailability of Si in the local materials with paddy soil which was analyzed to be acidic, steel slag and JSG significantly increased silica uptake by rice plant compared with control. The amount of Si taken up by the plants at 37 DAT was closely related to the amount of Si extracted from the materials by Na_2CO_3/NH_4NO_3, sodium phosphate and 0.5N HCl depending on the types of the materials. Based on the results there is no universally accepted method to evaluate plant-available Si in materials. Three methods could be proposed to evaluate bioavailable Si as follows: (1) Na_2CO_3/NH_4NO_3 for silica gel, JSG, RHA, RHB, MM, and RSC, (2) sodium phosphate for fly ash and steel slag, and (3) 0.5N HCl for fly ash, steel slag, cacao SB, JSG, RHA, RHB, and MM.

In another pot experiment to examine the effect of steel slag application on plant growth parameters with 10 soils collected from different sites in Indonesia, three of the soils were identified to have low available silica (<500 mg SiO_2 kg^{-1}). Steel slag applied at the rate of 300 kg Si ha^{-1} significantly increased plant height for all the soils. In grain yield, the rice grown in three soils with lower available Si responded to steel slug application of 50 – 300 Si kg ha^{-1}, while rice in the other seven did not respond.

In the incubation experiment, JSG was used to test the interaction between Si solubility with the application of Ca and Mg. Results showed that Ca and Mg in the Si materials and soils could inhibit Si release in soil solution. Solubility of Si was negatively and positively correlated with pH and Fe concentration in the soil solution, respectively, which indicated these were also the controlling factors of the Si release.

In order to improve the Si availability of fly ash and bottom ash, silica gel was produced from these materials by Sol-gel technique and then extracted with HCl and Na_2CO_3/NH_4NO_3 to determine the silica content in the silica gel. Sol-gel technique of fly ash and bottom ash increased Si concentration and Si release than those in initial ones. Although the improvement method was found to be effective, it is needed to be tested in a pilot scale to evaluate the economic feasibility.

Based on the results obtained in the present study, steel slag could be the most realistic Si fertilizer source among the inorganic materials tested because of its high Si release potential and the abundance in Indonesia. For the organic materials, RSC and RHB showed relatively high Si release and are available everywhere, indicating that these can be effective Si sources in Indonesia. To increase Si release from RSC and RHB material on paddy soil, it was suggested that the application of the materials should be at least 1 week before planting as revealed by the incubation experiment.