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学位授与の要件	環境学研究科　社会基盤環境学専攻 （学位規則第５条第１項該当）
学位論文の題目	Improvement of Problem Soils in Agricultural Land by Using Soil Amendments and Land Drying Practice （土壌改良資材と圃場乾燥処理による農地の問題土壌の改良）
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学位論文内容の要旨

Salt affected coastal areas of problem soils in Bangladesh mainly include saline (>20%) and acid sulfate soils (>3%), which occupied >23% of the cultivable lands. Acidity and salinity within irrigated soils clearly limits productivity in vast areas of Bangladesh, Japan and other parts of the world. An incubation study was conducted with the topsoil of two (Cheringa and Badarkhali) different acid sulfate soils (ASSs) to evaluate the effects of basic slag (BS) on reduction of acidity and changes in water-soluble and exchangeable cations. These soils received BS at the rate of 0, 11, 22 and 33 t ha^{-1} under various moisture conditions (saturated moistures, wetting-drying cycles and moisture at field conditions), for 180 days of incubation. The application of BS was found to be increased the pH of soils from 3.6 to 5.1 for Cheringa; 3.9 to 5.2 for Badarkhali soils. The rate of increments of Ca^{2+} and Mg^{2+} were about 2-3 times higher for Ca and more than 2 times higher for Mg^{2+} compared with the control. The results indicated the application of BS not only increased the Ca^{2+} to the higher amount than that of the increment of Mg^{2+} in the soils but also improved Ca^{2+} and Mg^{2+} ratio in the soils. It also exerted significant effects on the decrement of Fe and Al toxicity in ASSs under saturated condition.

A pot and field experiment was conducted to evaluate the effect of sulfidic materials (SM) and Gypsum (G) at different rates of kg S ha^{-1} on the selected major nutrient uptake by rice cultivated in S-deficient soils. The contents of N, P, K, Mg and S in rice shoot at different growth stages were increased by the application of SM and G in both the pot and field experiments. But the increments were higher in case of SM compared to G. In addition, the applied SM increased the average organic matter and available S contents in the soils in S-deficient soils.

Soil slaking has long been studied from the stand point of stability of aggregates. However, it has not been studied from that of salt removal. A slaking test was carried out for evaluating the effect of slaking and its impacts on salt removal of salinized soil under various water contents. We prepared natural, air-dried and oven-dried soils to give different intensity of pre-drying. Those soils were dried to different moisture contents (60, 50, 40, 30, 20 and 10%). After 24 hours immersion in water, the soils never slaked at 60 and 50% moisture contents in natural soil whereas 88-89% of the specimens were slaked in air-dry soil under the same moisture contents. The slaking rate was the highest under 30% moisture contents in the natural soil. In air-dry soil 30 and 20% showed the higher slaking rate in compared to other water contents. The proportion of salt released into outer solution was also high at the same water contents. Since the natural soil did not slake until 40%, drying below 30% moisture content will be the most effective for the removal of salt from these soils.

The impacts of soil slaking and drying on cations release to outer solution and shift of cations during desalinization under different initial water contents (IWC) was examined. The lower water content (30%) around optimum slaking moisture content released maximum Na, and at the water content of minimum slaking rate the release of Na was the lowest. Most of the Ca^{2+} and Mg^{2+} stay in exchange site (60 to 80%) in soil and very few come out in outer solution. Water-soluble cations in slaked and unslaked soils followed the order of Na>> K> Mg> Ca whereas, the amount of exchangeable state cations followed Na^{+}> Mg^{2+}> Ca^{2+}> K^{+}. The proportion of Na released in outer solution followed natural>air-dry soils.

The effect of IWC on saturated hydraulic conductivity (SHC) in desalinization with slaking and drying was examined. The SHC was high under the water content below 30% in both the natural and the air-dry soils. The air-dry soil showed far smaller SHC than the natural soil. In outer solution, the highest SAR was noted at 30% in the natural and 30 and 20% in the air-dry soils. Significant decrease in ESP of the soils was also observed at the same water content. The natural soil showed lower ESP and higher porosity, which was considered as a reason for higher SHC of natural soil than that of air-dry soils. Field drying practice to the optimum slaking water content was found effective on salt removal without degrading permeability.

論文審査結果の要旨

バングラデシュの沿岸地域では農地の3%が酸性硫酸塩土壌、20%が塩類土などの問題土壌で占められ、農業生産を大幅に制限している。本論文は、これら問題土壌の改良に向けた研究であり、二つの内容から構成されている。

第一部では、2種の酸性硫酸塩土壌に、経済的に入手できる産業副産物である塩基性スラグを添加し、養生する水分条件を変えてその効果を検討した。添加量および水分量が高いほど効果が大きく、各土壌のpHを3.6から5.1へ、および3.9から5.2へと、増大させた。また、土壌中のCaを2～3倍に、Mgを2倍以上に増大し、Ca／Mg比を改良することを示すとともに、酸性硫酸塩土壌中のFeとAlの毒性を抑制する効果があることを見出した。次いで、硫黄欠乏土壌への硫黄性物質と石膏の添加が、稲の主要な養分吸収（N、P、K、Mg、S）を増加させることを、ポット試験と圃場試験で明らかにした。硫黄性物質の方が、石膏よりも効率的に土壌中の平均有機物含量と有効性硫黄含量を増大した。

第二部では、塩類土壌の除塩に対し、土壌を乾燥後、水浸した時に発生するスレーキングの効果を検討した。異なる強度の乾燥履歴（自然土、風乾土、炉乾土）を与えた粘性土を再加水し、10～60%の含水比まで乾燥し、これを水浸してスレーキングさせた。自然土では30%で、風乾土では20～30%で最大のスレーキング率を示し、この時、外液中に最大の塩分量が解放された。解放される量はNaが最も多く、最適スレーキング含水比で最大となり、最小スレーキング含水比で最小となった。一方、CaとMgは交換態として存在し、外液中へはほとんど解放されなかった。スレーキング後の飽和透水係数は、最適スレーキング含水比以下の水分量で最大で、自然土の方が風乾土よりも大きい結果となった。その原因が自然土の高い間隙率と低いESPによることを示した。

以上のように、本論文は副産物の土壌改良資材としての施用条件と効果を明らかにし、実用化に向けた重要な基礎的知見を提供したこと、および圃場の乾燥管理がスレーキングを通じて除塩を促進するという新しい事実を見出した点に、社会的および学術的貢献が認められる。したがって、博士の学位を授与するに値するものと判定する。