氏　　名	隅越（すみこし）　昌枝（まさえ）
学位の種類	博士（農学）
学位記番号	甲第３０２号
学位授与年月日	平成１５年　９月１９日
学位授与の要件	学位規則第４条第１項該当
学位論文題目	Some Chemical and Physical Factors Affecting the Hydraulic Properties and Aggregate Stability of Sodic Soils （ソーダ質土壌の水理学的特性と団粒安定性に影響する理化学的要因）
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学位論文の内容の要旨

Combating desertification is complex and requires an appropriate soil and water management. One of the soil characteristic features in arid and semiarid regions where desertification aggravates is sodic soil due to inherent factors（carbonate, primary minerals, saline rocks, saline water, depth of ground water）and human activities（irrigation management and reclamation procedure）.

Sodic soils have poor soil structures under wet conditions and hardness of the subsoil when dried. The ions composition and concentration of salt in the soil solution may influence the physical properties of sodic soils. In turn, the accumulation of cations that causes clay dispersion, such as Na, on the exchange phase affects the physical properties of the soils due to clay swelling or dispersion which alters the geometry of soil pores and thus affects intrinsic soil permeability and water retention. The deleterious effect of the exchangeable Na is more evident during the irrigation with low electrolyte concentration water or rain than that during the irrigation with high electrolyte concentration water.

The degree of swelling and dispersion of clay depends on the clay mineralogy, the composition of the adsorbed ions and the salt concentration in the soil solution. It is obvious, therefore, that any attempt to assess sodicity hazard in soils, the soil texture, the clay mineralogy, the exchangeable sodium percentage（ESP）and the total electrolyte concentration（TEC）of percolating solution should be considered. In order to deal with this problem, this work was proposed. The objective of this study was to seek to address the behavior of sodic soil as affected by water quality in arid and semiarid regions.

First, the effect of TEC of percolating solution on hydraulic conductivity（HC）

and infiltration rate（IR）of the smectitic and kaolinitic soils at ESP 0 and 30 was studied using soil columns and rainfall simulator.

The HC of the Niigata smectitic soil at ESP 0 decreased significantly with percolating distilled water（DW）, whereas a decrease in HC at ESP 30 was observed with the 10 $mol_c m^{-3}$ solution. The HC of the Tottori kaolintitic soil at ESP 30 dropped at the TEC equal to or below the Flocculation Value（FV）of 5 $mol_c m^{-3}$. These results indicate that even for non-swelling clay soils a severe reduction in HC can be observed when the soil with a relatively high ESP level is exposed to solution at electrolyte concentration below the FV due to clogging of conducting pores by dispersed clay particles.

The steady-state IR of the Niigata smectitic soil exposed to DW rainfall was strongly affected by the ESP, a much smaller effect of the ESP was observed for the Tottori kaolinitic soil. This is probably due to the fact that the aggregates are more stable than those of the Niigata smectitic soil at ESP 30. The lower steady-state IR for the soil at the higher ESP can be attributed to the higher FV of the soil at ESP 30. The ESP effect on steady-state IR was greater than that of HC when the soil was exposed to DW rainfall. This difference is probably due to the disintegration of soil aggregates and their compaction on soil surface caused by the impact of the raindrop.

The aggregates of sodic soils are not stable while testing their stability by the current wet sieving method when using water and nearly complete aggregate breakdown occur. Therefore, second, a modified wet sieving method, based on ethanol-DW mixtures, was suggested for relative aggregate stability assessment of sodic soils. The objectives of this study were（1）to modify the wet sieving method by using ethanol-DW mixtures and（2）to evaluate aggregate size distribution as affected by clay content and adsorbed cation composition.

Aggregates of two montmorillonitic soils, sandy clay loam and clay soils were immersed in ethanol-DW mixtures at ethanol concentration of 0, 25, 40, 50, 65, 75, 85 or 96%（to obtain various dielectric constants in the range between 81.7 and 25.6）or to NaCl and $CaCl_2$ solutions at total TEC of 0.1 and 1 $mol_c L^{-1}$ at SAR appropriate to the soils' ESP.

Aggregate stability decreased significantly with the decreasing of ethanol concentration in the aqueous solution. Higher fraction of unatable aggregates was observed with ethanol-DW mixtures after sieving in ethanol for 1 min when the wetting rate was 100 mm h^{-1} than for 4 mm h^{-1}. On the contrary, 4-6 mm aggregates of both soils were stable after sieving in ethanol for 1 min, when the wetting rate was reduced to 4 mm h^{-1}. These results indicate that wetting rate is an important factor in aggregate stability determination even when the wetting ethanol is used.

The fraction of stable aggregates > 4 mm decreased substantially in a relatively small range of ethanol concentration, having an inflection point at a stable aggregate fraction of 50%. The ethanol concentration in solution at the inflection point for the sandy clay loam soil was higher than that for the clay soil and increased with the ESP. The ethanol concentration at the inflection point indicates the aggregate stability as function of clay content and ESP. The higher aggregate stability in the presence of ethanol is due to the reduction in the dielectric constant or due to by bridging of adjacent clay particles through ethanol molecule interaction. The disintegration of aggregate at higher TEC indicates that the dominant reason in stabilizing larger aggregate is expected clay-ethanol molecule interaction.

論 文 審 査 の 結 果 の 要 旨

乾燥･半乾燥地域に発生する塩類上壌は､地域特有の自然的要因または人為的要因に基づいており、これらの要因によって土壌の理化学的特性が大きく異なる。塩類土壌の改良は土壌の理化学的特性を明確にすると同時に、適切な土壌管理と水管理が必要になる。塩類土壌のうち、特にソーダ質土壌の場合には、従来の土壌改良法（リーチング法や石膏施用法）だけでは十分でなく新しい基礎的研究の積み上げが必要とされる。本研究ではまずソーダ質土壌の理化学的特性について概説し、主として灌漑水や降水の水質によって影響されるソーダ質土壌の水理学的特性について検討した。次に我が国とイスラエル国で採取した数種類の土壌を取り上げ、団粒構造の安定性に関して検討を加えた。

1. ソーダ質土壌では湿潤条件下で土壌団粒が崩壊しやすく、乾燥条件下で逆に硬化しやすいユニークな現象が発生する。これは、土壌溶液中の塩類組成と濃度がソーダ質土壌の団粒構造に影響を及ぼすためである。即ち、ナトリウムイオンが吸着すると粘土が膨潤および分散するため、土壌の透水性は変化を生じ、高濃度の塩類を含む灌漑水よりも低濃度の灌漑水や降水等において大きく減少する。土壌のソーダ質化を評価するためには、粘土鉱物、土性、交換性ナトリウムイオン百分率（ESP)、浸透溶液中の全電解質濃度等の水理学的要因が必要であることを提案した。

2. 水質がスメクタイト質土壌とカオリナイト質土壌の透水係数および浸入速度に及ぼす影響について検討した。両土壌とも ESP が 0 の場合には、粘土の凝集値以下の水質でリーチングした時に粘土が分散し透水係数が低下した。ESP 30 の場合には、スメクタイト質土壌は膨潤性の粘土鉱物のため凝集値以上の水質濃度、カオリナイト質土壌は非膨潤性のため凝集値以下の水質濃度において透水係数が低下した。浸入速度についてはスメクタイト質土壌がより不安定な団粒構造を示すために、大きく減少することが明らかになった。また、雨滴の衝撃も浸入速度の低下を引き起こすことが確認された。

3. 次にソーダ質土壌の団粒構造の安定性について検討を加えた。ここでは各種の濃度のエタノール-水混合溶液（エタノール溶液）を用いて湿式団粒分析法を適用し、ソーダ質土壌の団粒分布を解析した。土壌団粒の崩壊はエタノール溶液濃度の低下に伴い促進された。下方からの飽和浸潤速度は 100 および 4mm/h を適用し、100mm/h では 4mm/h の場合よりも土壌団粒の崩壊が多くみられた。また土壌団粒量は、団粒径が 4mm 以上の場合エタノール溶液濃度の低下に伴って減少した。これは、エタノール溶液の誘電率の上昇により粘土粒子の電気拡散二重層の厚さが増加したためである。さらに、粘土含量が大きく ESP が低い土壌ほど土壌団粒の安定性が増加した。エタノールの代わりに、$NaCl$-$CaCl_2$ 溶液を用いた土壌団粒分布について検討した結果、溶液濃度が低くなるほど土壌団粒の崩壊が促進された。エタノール分子は粘土粒子の架橋構造を発達させ土壌団粒を安定させていることが明らかになった。

本研究ではソーダ質土壌における水理学的特性と水質（塩類濃度）との関係を詳細に検討し、団粒構造の安定性に影響するいくつかの基礎的要因を明らかにしている。これらは、今後乾燥地におけるソーダ質土壌の改良に不可欠な、土壌団粒の安定性評価に関する基礎的資料として大きな意義を有するものであり、学位論文として十分な価値があるものと判定する。