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journal or publication title	Tohoku journal of agricultural research
volume	60
number	1-2
page range	33-38
year	2009-12
URL	http://hdl.handle.net/10097/41176

Tohoku Journal of Agricultural Research
Vol. 60 No. 1-2, December 2009
Printed in Japan

Research Topics on Volcanic Ash Soils-Properties, Genesis, Classification and Utilization

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(Received, October 22, 2009)

Summary

Volcanic ash soils, many of them being Andosols or Andisols in Japan, show unique properties due to the abundant active aluminum and iron. Aluminum-humus is one of the major components of the A-horizon soil, and the Al is partly released from the Al-humus to produce an Al toxicity for sensitive plants especially in the non-allophanic Andosols. The large amounts of Si, Ca, Na, etc., are depleted during the Andosol formation while Al, Fe, Ti, rare-earth elements, etc., are concentrated in the Andosols as almost immobile elements. A useful digital file of the soil region map of Japan was made and uploaded to the laboratory website. Phosphorus foraging root growth of *Brassica* plants and buckwheat appears promising for improving the P fertilizer utilization.

Volcanic Ash Soils in Our Environment

Volcanic ash soils are some of the major soils in Japan which is located in the northwestern part of the Pacific ring of fire. Although the volcanic ash soils occupy only 0.7-0.8% of the world soils, they show unique morphological, chemical and physical properties. Hence, a group of the soils is classified as one of the highest categories in soil classification systems such as the Soil Taxonomy of the United States Department of Agriculture (ST) and World Reference Base for Soil Resources (WRB). Volcanic ash soils are also widely distributed soils in the Tohoku district of Japan. Thus, the "Properties, genesis, classification and utilization of volcanic ash soils" is one of our major research disciplines as well as "Soil-plant interactions". We outline some of our recent research topics related to volcanic ash soils. Regarding the terminology, we use volcanic ash soils for any soils derived from the volcanic ash as a major parent material. Andisols in ST and Andosols in WRB are primarily the volcanic ash soils that show unique properties due to the significant amounts of active aluminum and iron.

Properties : Roles of Aluminum (Al)—humus Complexes in Andosols

Andosols are divided into two major groups on the basis of their colloidal compositions, i.e., allophanic and non-allophanic Andosols. Although both types of the Andosols show common unique properties of volcanic ash derived soils, non-allophanic Andosols tend to be more strongly acidic when the base saturation is low, and possess a high KCl-extractable Al that is toxic to plant roots. The origin of the KCl-extractable Al (exchangeable Al) has been primarily attributed to Al ions adsorbed to permanent negative charges of the 2 : 1 minerals.

Studies on the Al release rate from soils and soil equilibrium in solution showed that the Al solubility of non-allophanic Andosols is mainly controlled by the Al-humus complexes, or the exchange reaction of Al ions and H^+ on the charges of humus. Accordingly, it was revealed that the amount of KCl-extractable Al depends on the soil pH values and the amounts of organically complexed Al, indicating the existence of an equilibrium of organically-complexed Al—Al in the soil solution—exchangeable Al (Takahashi *et al.*, 2003). Thus, most of the Al-humus complexes is stable, but a part of them is unstable. This is supported by the fact that even liming significantly decreases the organically complexed Al (Takahashi *et al.*, 2006).

Root growth of Al sensitive plants in synthetic Al-humus complexes showed that the complexes directly cause Al-toxicity to the plant roots (Takahashi *et al.*, 2007). These results indicate that toxic Al of non-allophanic Andosols is, at least, partly originates from the Al-humus complexes. The Al toxicity is considered to be mitigated by the presence of the allophanic materials (Ito *et al.*, 2009). With strong acidification, even allophanic Andosols provided an Al toxicity to plant roots. The Al solubility is also controlled by the Al-humus complexes (Takahashi *et al.*, 2008).

Non-allophanic Andosols accumulate large amounts of organic carbon (OC) due to the stabilization of Al-humus complexes, the low activity of the soil organisms due to the low soil pH and the high level of toxic Al, and the physical protection of OC by the high soil porosity. Changes in the land-use of Andosols will affect the ability of carbon accumulation. For example, liming increases the soil pH and decreases the Al toxicity and therefore the activity of the microorganisms will increase. Liming may accelerate the decomposition of highly humified organic matter because of the liberation of part of the Al-humus complexes. Nitrogen and phosphorus fertilizers will further activate the microorganisms and affect the positive or negative ability of the OC accumulation. The importance of the Al-humus complexes requires further investigations with the objective of determining the influential factors of Andosols for the regional and global environments.

Genesis : Changes in Element Concentration of Tephra with Andosol Formation

The element composition of the soil formation products in Andosols is far different from the original tephra. Andosol formation involves the rapid, abundant and *in situ* formation of non-crystalline materials, such as allophane, imogolite and ferrihydrite, from tephra deposits. A large amount of humus complexed with Al also accumulates in the A-horizons. As these materials are rich in Al or Fe compared to the parent tephra, the concentrations of the major and minor elements significantly change during the Andosol formation.

Based on an examination of the relationship between the active Al and Fe content and the concentrations of 50 or moe elements in allophanic Andosols, the Si, Ca, Na, etc., tended to decrease while many other elements tended to increase. As the elemental composition of fresh tephra is dependant on the rock type, characterized by the SiO_2 content, the andesitic group was chosen for a detailed study using the material balance equation in the open system. As shown in Fig. 1, at least 27 elements were enriched in the Andosols, and the increases in these concentrations were related to the total weight loss due to the soil formation processes (Nanzyo *et al.*, 2007). The weight loss during the Andosol formation is nearly equal to the loss of $SiO_2+CaO+Na_2O$ on an ignition residue basis. Many of the concentrated elements appear to be retained by the Andosol formation products as these elements are dilute acid-extractable.

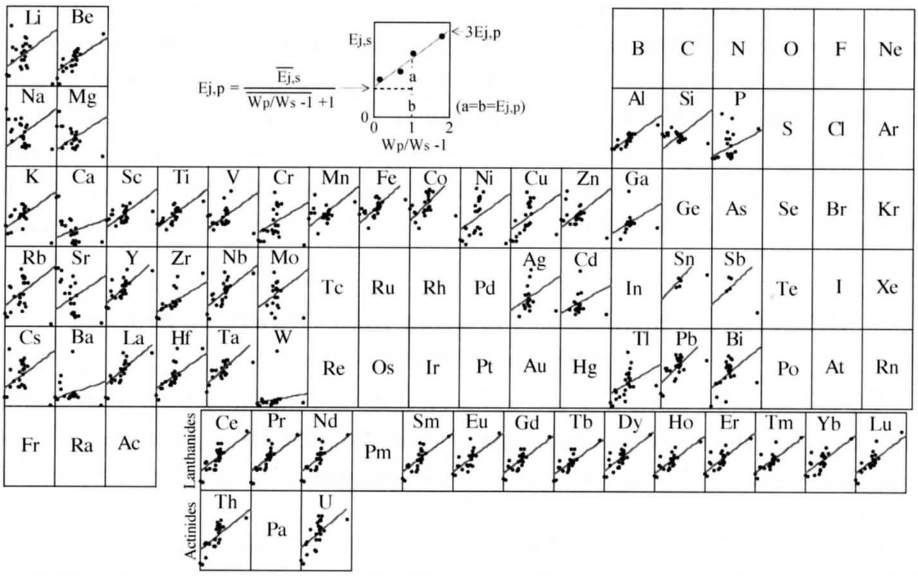

FIG. 1. Relationship between weight-loss (Wp/Ws-1) and the concentrations of elements in allophonic Andosols on an ignition residue basis.

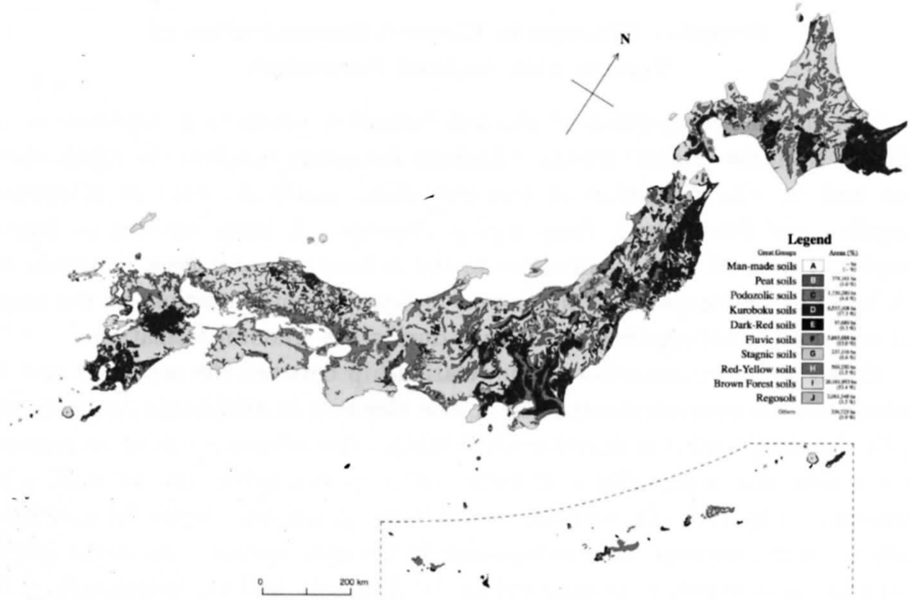

FIG. 2. Soil regions map of Japan based on a reclassification of the 1 : 1 million soil map of Japan (1990)

Classification : Soil Regions Map of Japan Based on a Reclassification

A soil regions map of Japan based on a reclassification of the 1 : 1 million soil map of Japan (1990) according to the unified soil classification system of Japan, 2nd approximation (2002), was made (Kanno *et al.*, 2008) and shown to the public on our laboratory website (http://www.agri.tohoku.ac.jp/soil/). The distribution of Andosols, i.e., Kuroboku soils in Japanese, is shown in a dark color as well as other soils in the different colors. This map is temporary until the new version is published. As the file size of the map is small and the map is suitable for scaling up and down, therefore, we expect that it is useful for many purposes.

Utilization : Phosphorus Foraging Root Growth of *Brassica* and Buckwheat Roots

Phosphorus (P) fertilizers are indispensable in obtaining high crop production using Andosols due to their high P fixation capacity. As we have scarce phosphate rock in Japan, we should use phosphate fertilizers with a high efficiency.

In a non-allophanic Andosol with a low available P content, the lateral roots of *Brassica* plants and buckwheat roots show spectacular growth at the interface between a P fertilizer and the soil. Although we used dicalcium phosphate dihydrate (DCPD) suspended in alginate gel beads, a similar root growth was observed when polyolefin-coated monoammonium phosphate was used as the P fertilizer (Nanzyo *et al.*, 2004).

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