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# Unique Properties of Volcanic Ash Soils and Perspectives on their Applications

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Soils are natural products on the land surface of the earth. They are made from a variety of parent materials including rocks, minerals, organisms and so on. Properties of the soils are, in general, dependent on climate, topography, periods of soil formation, and biological activities as well as parent materials (Jenny, 1941). Among these factors, effects of climate are approximately represented using precipitation and temperature on the analogy of those for vegetation (Brady and Weil, 1996). Cryoturbation and permafrost, leaching, clay translocation, and salinization may be intensified to the different directions as schematically shown in the precipitation–temperature diagram (Fig. 1). Biological production is high in the middle or higher precipitation and temperature ranges and humus accumulation is high under moisture–rich conditions. Alternate dry and moist enhance physical action of clays such as alternate shrinkage and swelling, and/or dispersion, eluviation and illuviation. These processes were positioned in the semi–dry regions of Fig. 1. Fig. 1 may be further extended for the distribution of 12 soil orders of the United States Department of Agriculture (USDA)–Soil Taxonomy as shown in Fig. 2. Occurrence of many soil orders such as Gelisols, Spodosols, Oxisols, Vertisols, Aridisols Mollisols and so on are strongly dependent on climatic conditions. In contrast, Entisols occur under any climate although they do not have permafrost. Inceptisols occur in any region except for aridic soil moisture regime by definition (Soil Survey Staff, 1999).

Andisols occur in the wide range of climate as reflected in the suborder members of Gelands, Cryands, Torrands, Xerands, Ustands and Udands. They cover dry to moist and cold to hot climatic regimes. This is due to the fact that Andisols are highly parent material–specific soils. And the definition of Andisols cover wide range of young to matured ones (Soil Survey Staff, 1999). Since the Andisol order was incorporated in the Keys to Soil Taxonomy in 1990, many monograophs and review papers (Van Wambeke, 1992; Shoji et al., 1993; Buol et all, 1997; Kimble et al., 2000, Ping, 2000; Harsh et al., 2002; Lowe et al., 2002; Dahlgren et al., 2004) and special issues (Matsumoto, 2002; Bartoli et al., 2003; Arnalds and Stahr, 2004; Oskarsson and Arnalds, 2004) were published.

Young volcanic ash soils are characterized by abundant volcanic glass that are colored or noncolored. Various kinds of soils can be formed from the volcanic ash depending on the individual set of soil forming factors at different sites (Shoji et al., 1993). Among these soils, Andisols or Andosols show unique properties mostly due to abundant noncrystalline materials such as allophane, imogolite, Al–humus complexes, ferrihydrite and so on. Highly porous structures made of aggregated

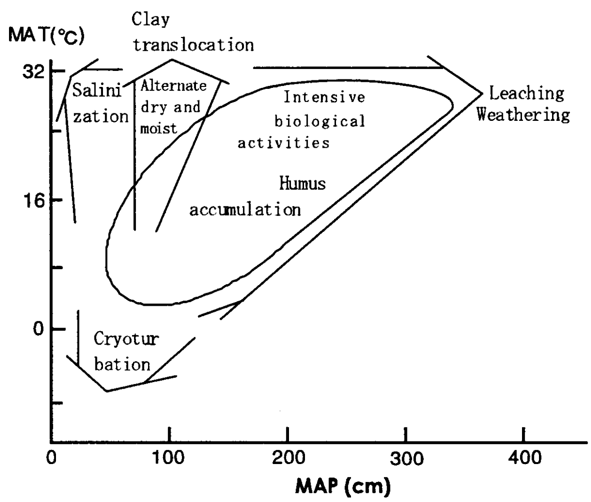


**Figure 1.** Schematic diagram showing relationship between soil formation processes and climatic factors.

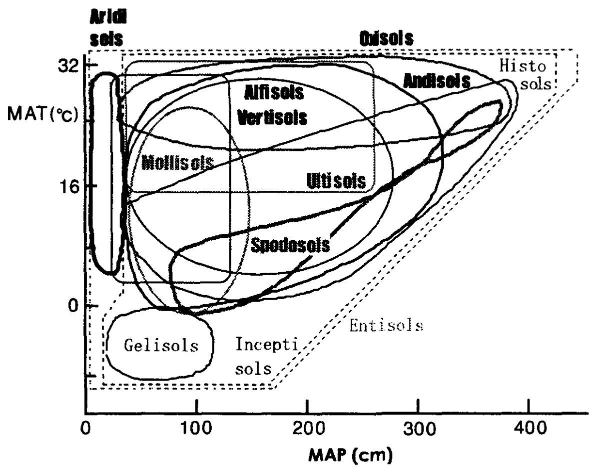


**Figure 2.** Schematic diagram showing relationship between soil orders of US Soil Taxonomy and climatic factors.

noncrystalline Andisols materials have a light fluffy nature, accommodating large amounts of both plant-available and hygroscopic water. They show many other unique physical properties different from other soils. Moreover, Andisols have unique chemical properties, including Al-rich elemental composition, large amount of humus accumulation in A horizons, variable charge characteristics, high phosphate retention capacity, high affinity for multi-valent cations, high KCl-extractable and water-soluble Al in nonallophanic Andisols at an acidic to weakly acidic pH range.

Some of these unique properties were not necessarily suitable for agricultural production in Japan. However, most of the problematic properties were improved now. Phosphate deficiency was amended by heavy application of phosphate fertilizers. Controlled release fertilizers are very effective to avoid rapid leaching of inorganic nitrogen under humid climate, that is one aspect of the variable charge characteristics. Al-toxicity was amended with liming. Deficiency of Cu and Zn was also amended by application of fertilizers containing these elements. Thus, Andisosl are now used for upland crop production and orchards.

Physical properties of Andisols are advantageous for these agricultural uses due to deep rooting zone, high air and water holding capacity, gradual water stress to enhance sugar content of some crops when the soil is dried (Shoji et al., 1993).

During Andisol formation, huge amount of Si is released to the downward ecosystems (Fig. 3). The $SiO_2$ concentration in the river water from the volcanic ash areas are as high as several tens mg $L^{-1}$ that is about triplicate of those in other river waters. The river water high in Si is beneficial to rice plants and many other crops when the water is directly used for irrigation.

Allophanic and nonallophanic Andisols show contrasting effects on the behavior of KCl-extractable and water soluble Al. These forms of Al are toxic to many sensitive crops (Saigusa et al., 1980), but show a suppressive effect against potato scab (Mizuno et al., 1998) and bean root rot (Furuya et al., 1999). Content of these forms of Al is high in nonallophanic Andisols and low in

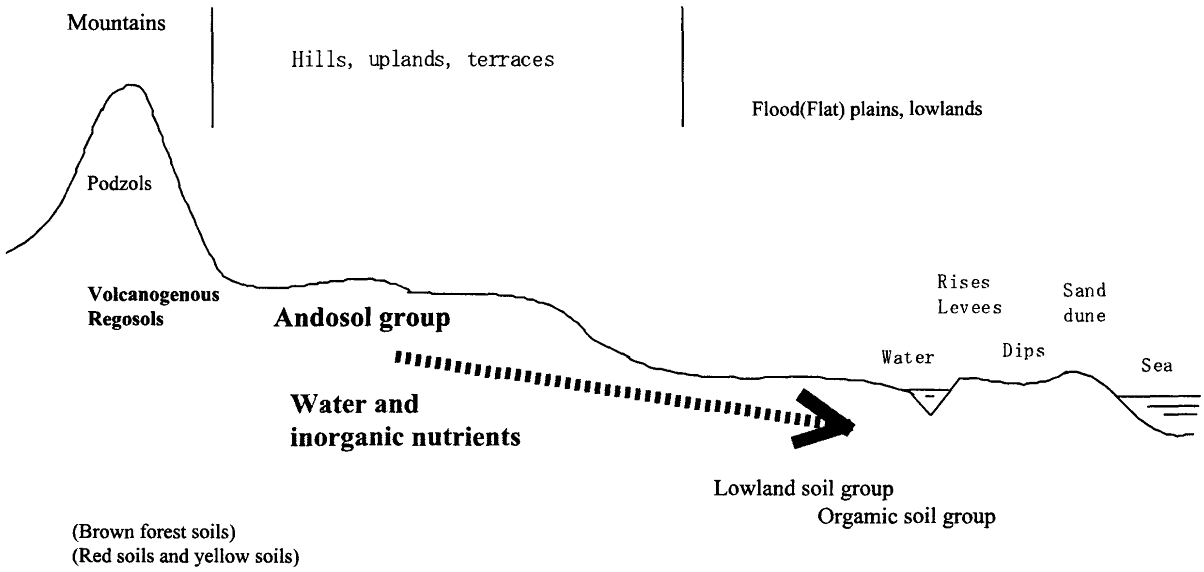


**Figure 3.** Contribution of volcanic ash soils to the downstream ecosystems. Names of soils and soil groups are represented by the classificatioin of cultivated soils in Japan (3rd revision, 1995).

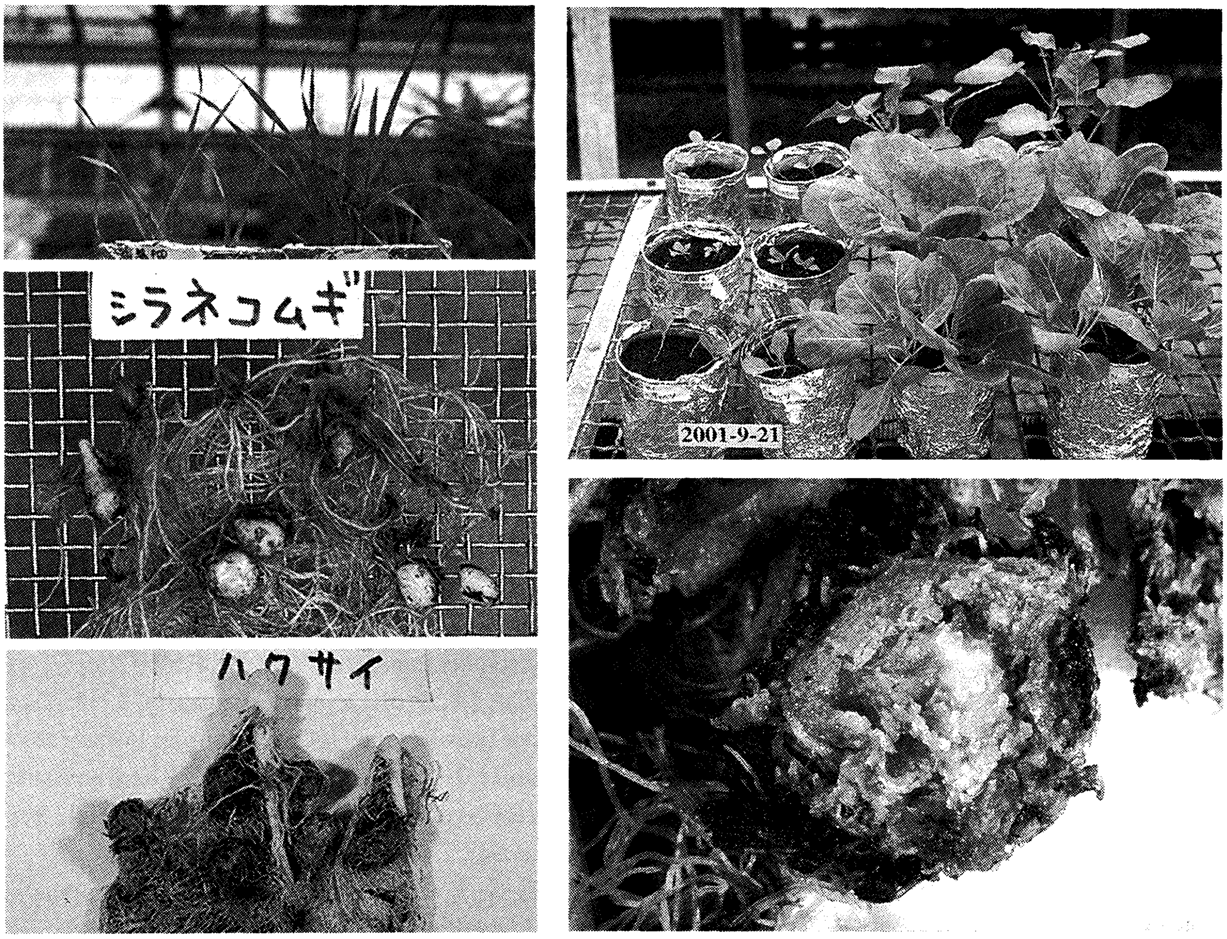


**Figure 4.** The upper left photo shows wheat growth with and without DCPD gel beads (P fertilizer). Growth improvement for wheat is not so much and contact between wheat roots and the DCPD gel beads was insufficient (middle left). In contrast, cabbage, Chinese cabbage and bloccoli, Brassica plants, showed conspicuous growth improvement with the DCPD gel beads (upper right). Chinese cabbage roots completely covered the surface of the DCPD gel beads (lower left) and there was no soil between the roots and the DCPD gel beads (cross section, lower right).

allophonic Andisols. High Al concentration of 0.3 mg $L^{-1}$ or more in the water extract is considered to provide resistance to potato scab. Although water-extractable Al is negatively correlated with soil pH values, soils with low to high levels of water-extactable Al are included between pH($H_2O$) levels of 5 and 6. The important factors affecting water extactable Al levels in this pH region were organic C content and Sio. The soils showing high water-extactable Al levels, contained a larger amount of organic C and a smaller amount of Sio than those with low water-extractable Al levels.

Under P deficient conditions in an uncultivated Andisols, Brassica roots show P-foraging root growth (Nanzyo et al., 2002; 2004). The thin lateral roots of Brassica pekinensis, L., completely encircled DCPD gel beads (a Ca-alginate gel in which a $CaHPO_4.2H_2O$ powder was suspended) and no soil are remained between the roots and the DCPD gel beads. This morphological plasticity of Brassica roots is suitable for improving the P recovery rate because the soil, a few mm thick, with a high P retention capacity between plant roots and P fertilizer reduces the recovery rate of P fertilizers by crops in a P-deficient soils. P-preferential root proliferation was also observed for Fagoppyrum esculentum Moench.

Allophanic clays adsorbed tobacco mosaic virus because adsorption of the virus was not observed after removal of allophonic clays with acid-oxalate treatment. Forms of active Al in Andisols may affect the behavior of the virus. Although the virus was not adsorbed by an A horizon soil of a nonallophanic Andisol, the virus ceased multiplication suggesting the soil had an anti-virus effect (Toriyama et al., 1995).