博　士　論　文　の　要　約

学　位　論　文　題　名

Contribution of various cellular components to aluminum tolerance in plants

（植物のアルミニウム耐性における細胞成分のはたらき）

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It is speculated that the world population will reach 9 billion until 2050, and to feed the growing world population increase of food production is an essential task. It has been considered that increasing food production in poor arable land could break through the food problem. To accomplish this, it is needed to improve such arable land suitable for crop production and/or to develop the crop species or cultivars tolerant to various environmental stresses. Acidic soil is one of the most serious and widespread problems in poor arable land. It occupies approximately 30 % of ice free land in the world. High aluminum (Al) concentrations in a soil solution are the most important factor in restricting plant growth in many acidic soils. Aluminum ion is a trivalent cation and has so strong positive charge that has significant impacts on other cations, anions and other compounds with electric charge in the cells, such as membrane, cell wall, and protein. As a result, root elongation is severely inhibited by Al at micromolar concentrations in a short time. Till date, various Al tolerance mechanisms in plants have been reported, such as Al exclusion and internal Al tolerance. Although the organic acid anion release from roots is a major Al exclusion mechanism in various plant species, it is not involved in major mechanisms of Al tolerance in some highly Al-tolerant species. It is very important to elucidate such extremely high Al-tolerance mechanisms in order to make the crops possible to grow in highly-acidic soils. Therefore in this study, three independent experiments were carried out to elucidate novel Al tolerance mechanisms.

In the first experiment, to elucidate how the proportion of some lipids in roots contributes to Al tolerance, Al tolerance of rice with modified lipid composition was investigated. Aluminum usually binds to phospholipid (PL) in plasma membrane (PM) resulting in increase of permeability. Therefore, it is hypothesized that plant with low PL proportion in root cells may show higher Al tolerance. It was reported that PL in PM is replaced by galactolipid under phosphorus (P) deficient conditions for recycling P. As hypothesized, Al tolerance of rice precultured under P deficient conditions had lower PL in root, and exhibited higher Al tolerance than that precultured under P sufficient conditions. In addition to lower PL proportion, higher proportion of sterol in root cells may also enhance Al tolerance because sterol works important roles in maintaining the

PM permeability. So, it was tried to increase sterol concentration in root by overexpression of *HMG*, encoding the key enzyme in sterol synthesis pathway. Some recombinants showed significantly higher Al tolerance than control and positive correlation between Al-tolerance values and sterol concentrations was observed. These results suggest that maintaining lower and higher concentrations of PL and sterol, respectively, in PM are one of the important Al-tolerance mechanisms in rice root.

Many plant species naturally growing in strongly acidic soils are extremely tolerant to Al but the known mechanisms cannot explain their Al tolerance. In addition to lipid in root, other cellular components such as cell wall and phenolics could be involved in Al-tolerance mechanisms. Therefore in the second experiment, to elucidate the relationship between these cellular components and Al-tolerance mechanism comprehensively, *Melastoma malabathricum* and *Melaleuca cajuputi*, both are highly Al-tolerant species growing in strongly acidic soils, were investigated. Both species contained lower and higher proportion of PL and sterol in roots, respectively, comparing with rice. Furthermore, phenolics concentrations in root of *M. malabathricum* and *M. cajuputi* were much higher than that of rice and their phenolics could make chelate with Al. The phenolics concentrations and composition did not change regardless of the presence of absence of Al in the medium, suggesting that higher concentration of phenolics is not a result of physiological response to Al but constitutive characteristics in these species. These constitutive characteristics of root cellular components could be cooperatively involved in their high Al-tolerance.

Melastoma malabathricum has also been known as an “Al-accumulator”. In the third experiment, Al-tolerance mechanisms in leaves of different Al accumulator species in Melastomataceae (*M. malabathricum* and *Tibouchina urvilleana*) and Symplocaceae (*Symplocos chinensis*) were investigated. Oxalate was at least partly involved in the internal Al detoxification mechanisms in leaves of all three Al accumulators, although the Al/oxalate ratio in Al-oxalate complexes differed among the three species. Oxalate has often been regarded as an end product that is not further metabolized or only slowly metabolized. Many Al accumulators may effectively use oxalate, which is less metabolically important, for internal Al detoxification in leaves, irrespective of the plant phylogeny.

In conclusion, this study provided new insights in relationships between Al and cellular components in Al tolerance mechanisms in roots and leaves. These results could develop understanding of complicated Al tolerance mechanisms in plant.