ABA is involved in aluminium stress responses of moss *Physcomitrella patens*

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Aluminium (Al) toxicity is a major problem reducing crop yields in acid soils. Improvement of Al tolerance in plants is required for the effective use of acid soils to increase the crop yield, however, the mechanism responsible for resistance is yet to be understood. Mosses have a simple body plan, and individual cells are directly exposed to environmental stresses. These features of mosses are useful for the study of mechanisms in stress tolerance of plants at the cellular level.

We investigated Al resistance of moss *Physcomitrella patens*. Protonemal cells of *P. patens* exposed to Al stress differentiated into brood cells that is a well-known effect of exogenously applied abscisic acid (ABA) in *P. patens*. We also observed the activation of an ABA-inducible *Em* gene promoter in response to Al stress. These results strongly suggested the involvement of ABA in Al resistance. To confirm this, protonemata were treated with ABA and Al resistance was evaluated. When ABA was applied to protonemata for 3 days prior to Al exposure, Al resistance was dramatically enhanced in a dose-dependent manner.

To determine whether endogenous ABA is involved in the Al resistance mechanisms in *P. patens*, we took two different approaches. First, we used an ABA biosynthesis inhibitor abamine to reduce ABA level of *P. patens*. Abamine has been shown to inhibit 9-cis-epoxycarotenoid dioxygenase (NCED) which catalyzes the cleavage of 9-cis-epoxycarotenoids to apocarotenoid and xanthoxin in higher plants. When protonemata were treated with abamine, Al tolerance was decreased significantly, suggesting that ABA biosynthesis is required for Al resistance. Second, transgenic *P. patens* lines that overexpress the Arabidopsis *abi1-1* gene, a negative regulator of the ABA-signaling pathway, were analyzed to evaluate Al resistance. The transgenic lines turned out to be highly Al-sensitive compared to wild type. Our results demonstrate that ABA and the signal transduction are involved in Al stress tolerance of *P. patens*.