Studies on distinct functions of plant borate transporters and development of plants tolerant to boron deficiency and toxicity

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To increase productivity of food and plant biomass under infertile soils, one effective strategy is to develop crop plants which have high yields under problematic soils. Boron (B) is one of essential micronutrients for plants but high levels of B are toxic. B-deficient and high-B soils are distributed over the world and reduction of plant production has been reported in these areas. Physiological differences in sensitivity among crop cultivars had been described, however, molecular basis for improvement of B-stress tolerance remained unknown. The present study aimed to reveal distinct functions and expressional control of borate transporters, and improve tolerance to B deficiency and toxicity by enhanced expression of transporters in *Arabidopsis thaliana*, a model plant.

Plants have evolved transport systems to cope with the nutrient conditions in soil environments. BOR1 was identified as the first borate exporter, which was required for efficient translocation of B from roots to shoots under limited B conditions in *A. thaliana*. Among the six *BOR1* paralogs present in *A. thaliana* genome, a closest paralog *BOR2* was shown to be essential for B distribution to cell wall, a B binding site, supporting root elongation under low B conditions[1)]. *BOR4* encodes a borate exporter localized in plasma membrane as was the case for *BOR1*, but the physiological function of BOR4 is distinct. BOR4 excludes toxic levels of B out of the cells to reduce B concentration in roots under high B conditions[2)]. These results has clearly revealed that homologous transporter proteins play distinct roles for adaptation to a wide range of B conditions.

To elucidate the mechanisms underlying regulation of B transport, expressional control of *BOR1* was focused. *BOR1* mRNA level is not changed by B status but BOR1 protein is decreased by high B conditions. In addition to B-dependent protein degradation, translation of *BOR1* was found to be also regulated in response to B conditions. It is demonstrated that the two post-transcriptional downregulations are beneficial for avoidance of overloading of B against B toxicity. This represents the plant system for fine-tuning of nutrient transport by control of transporter expression at multiple steps.

To examine the effects of overexpression of these borate transporters, the *A. thaliana* plants overexpressing BOR1 or BOR4 were generated. Overexpression of BOR1 and BOR4 successfully conferred tolerance to B deficiency and toxicity through enhanced translocation of B into shoots and exclusion of toxic B from roots, respectively[2,3)]. These were the first success of generation of low-B and high-B tolerant plants by modulation of the transporter expression.

Results obtained in model plants are applicable to other plant species and such knowledge will be useful for designing plants tolerant to nutrient deficiency and toxicity.

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2) Miwa K., Takano J., Omori H., Seki M., Shinozaki K. and Fujiwara T.: Science 318: 1417 (2007).
3) Miwa K.[1], Takano J.[1] and Fujiwara T.: Plant Journal 46: 1084-1091 (2006). ([1]equally contributed)