

Boron Transport Mechanisms in Plants

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Abstract

Boron is an essential nutrient throughout the plant and animal kingdoms. It is important in bacteria, yeast, lower and higher plants, and animals. The importance of boron to stabilize organic molecules suggests it is a primordial element with an essential role in the development of life (Scorei, 2012). Boron has received a lot of attention in agricultural studies because there is a narrow range between deficiency and toxicity. Studies involving the lab plant *Arabidopsis thaliana* have demonstrated boron transport genes that help this plant cope with deficiency as well as toxicity. Similar genes have been found across crop plants (tobacco, wheat, rice, alfalfa, etc), and those with modifications that make them successful in boron stressed environments are of great importance for food security. Boron is important for the pectic polysaccharide Rhamnogalacturonan II (RG-II) which is stabilized by borate as a cross-link that provides rigidity to a plants cellular structure. The proposed work will focus on boron uptake from the soil into the plant roots where genes like NIP5;1 and BOR1 have been shown to be instrumental in root health and elongation. Additional exporter genes like BOR2 have been shown to be important for transporting boron to the shoots in boron limited conditions. BOR4 is adapted for toxic boron conditions and removes borate from the plant system back into the soils. These genes are thought to control uptake and transport into and out of plants and the suggested mechanisms involve a pH control that can be tested using boron isotopes.

Boron has two naturally occurring isotopes, ^{11}B and ^{10}B , which are approximately 4:1 in abundance. Boron is never found by itself and occurs primarily as boric acid, $\text{B}(\text{OH})_3$ or borate, $\text{B}(\text{OH})_4^-$. The boron species are controlled by pH such that:



There is a 'fractionation' between boric acid and borate such that boric acid is isotopically heavier, and borate is isotopically light. The pH control on speciation, and the species preference for the heavy or light isotope establishes an incredibly useful fingerprint for processes that involve pH control such as is found in living cells. Knowing the isotope composition of the solution that plants obtain boron from, coupled with a knowledge of the fractionation factor, it is possible to predict the isotope composition of the boron species. A remaining question is the form of the boron species through the plasma membrane channels. The combination of selection for genetic modification, imaging of the boron distribution in plant tissue, and boron isotope analyses will offer unique insight into cellular processes and has importance well beyond the plants being targeted for this study.

Troy Rasbury is an isotope geochemist who has established a world class isotope laboratory that specializes in boron isotopes. Initial work on seaweed and tomato plants has established that plants in high boron environments select for borate, not boric acid as most models of boron in cells would indicate. However, most studies of boron genes have focused on boron deficient systems which may behave differently. The proposed work with Vitaly Citovsky, a plant cell biologist, is to obtain and culture readily accessible *Arabidopsis thaliana*, a lab plant with an established genome that has at least 7 boron transport genes that have been identified, to test hypothesis for the uptake and transport of boron in plants with boron isotope measurements of plants selected for their genetic modifications.