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Ionomics study of soybean

(ダイズのイオノミクス研究)

Soybean (*Glycine max* (L.) Merr.) is one of the most important seed crops in the world and supplies protein, oil, and mineral nutrients for human and animal consumption. The soybean ionome represents its mineral nutrients and trace elements of the plant, which is a dynamic network of elements that are controlled by the physiology and biochemistry of the plant, and ultimately controlled by the genome, in response to the various environmental factors. Any alterations in these processes that transport inorganic ions from the soil to the seed could affect the soybean ionome and could eventually influence human health through the food chain. Thus, it is important to investigate the linkages between the soybean ionome and agricultural practices to develop strategies for better nutrient management and food security of the sustainable agriculture. Fertilization and crop rotation are fundamental agronomic practices used to improve growth and yield in soybean cultivation, and as important environmental factors, they should have impacts on the ionome of soybean, also. Hence, three independent experiments were carried out to investigate the environmental control of ionome in soybean.

Firstly, field experiments were conducted to investigate the impacts of fertilizer applications on the concentration of 21 mineral elements of soybean shoots with 44 varieties. Soybeans were cultivated in the field with three different fertilizer treatments: manure (M, 20 t/ha), chemical fertilizer (20 kg N/ha, 80 kg P₂O₅/ha and 80 kg K₂O/ha) and only with potassium fertilizer (80 kg K₂O/ha). Sixty days after sowing, soybean shoots were sampled, and analyzed by using ICP-MS. On the basis of this experiments, the mean concentrations of the 21 elements in soybean shoots vary in the order N (nitrogen) > K (potassium) > Ca (calcium) > Mg (magnesium) > P (phosphorus) > Fe (iron) > Na (sodium) > Sr (strontium) > Mn (manganese) > B (boron) > Ba (barium) > Zn (zinc) > Cr (chromium) > Ni (nickel) > Cu (copper) > V (vanadium) > Li (lithium) > Co (cobalt) > Se (selenium) > Cs (cesium) > Cd (cadmium). The concentrations of P, K, Sr, Ba and B showed significant variation

associated with fertilizer treatments, whilst Cd was sensitive to soybean genotypes. Genotype $\times$ treatment interactions were indicated for other elements (N, Ca, Mg, Fe, Na, Mn, Zn, Cr, Ni, Cu, V, Li, Co, Se and Cs). Principal component analysis (PCA) revealed the ionic response of soybean shoots to fertilizer treatment, with the increase of P, K, Sr, Zn and Ba in manure treatment, and increase of Co, Fe, Cs, Ni, V and Cr in the chemical fertilizer treatment.

In the second experiment, the distribution of mineral elements in plant tissues during vegetative stages were detected by growing soybean (cv. Tsurumusume) in the field which previous cropped with arbuscular mycorrhizal (AM) host crop and P application. The experiment ran for two years with a split-plot design. AM host plant (sunflower) or a non-AM host plant (mustard) were cultivated in the field in the first year as the main plots, and 3 P levels (0, 50, 150 kg P₂O₅/ha) were set during the soybean growth season as split plots from both main plots. Soybeans were sampled at four important growth stages (seedling, late flowering, mid-mature, and mature) and separated into leaf, stem, root, pod and seed for the elemental analysis. Based on the experiment, it was found that large amounts of Ca accumulated in the shoots, especially in leaves, while Fe, Ni, Na, Co, Mo, Cd, Cr, Se, Li and Cs remained in roots during all the soybean vegetative stages. Moreover, Cu concentrations in soybean were significantly increased by prior cultivation with the AM host plant, regardless of the tissue and vegetative stage, suggesting that AM fungi has the ability of transporting Cu from soil to host plant.

As ionome of seed is a consequence of complex plant process and plant-environment interactions with serious nutritional implications to human health, the third experiment were conducted to investigate the effects of previous cultivation of an AM host plant and manure application on the concentration of mineral elements in soybean (cv. Tsurumusume) seeds. Soybeans were cultivated after growing either an AM host plant (maize) or a non-AM host plant (buckwheat) in the first year in the main plots, with manure application (0 and 20 t/ha) during the soybean season in split plots from both main plots. On the basis of this experiment, manure application significantly increased the available K and decreased the available Fe and Cs in the soil. However, higher concentrations of Cd and Ba and lower concentrations of Cs in the seed were induced by the application of manure. Cd levels in the seed were decreased by prior cultivation with the AM host plant.

In conclusion, this study offers detailed information of the elemental distribution and interactions in soybean, reveals genotypic and environmental control of the ionome of soybean, and develops the understanding of the correlations among the ionic study, agricultural practice, and food safety.