Critical compromise: Trade-off between symbiosis and water uptake

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What is the difference between legume crops and other crop species? Legume roots possess specialized organs, nodules where symbiotic rhizobia fix atmospheric nitrogen into ammonia for plants, and, in turn, rhizobia receives the carbon, photosynthetic product from plants (Tiwari et al., 2021). How do the legumes control nodule numbers? Conserved autoregulation of nodulation (AON) signaling is found in legumes, which maintains the optimal nodule number by following root-to-shoot and back-to-root circuit (Roy and Müller, 2022). Disruption of the AON pathway leads to the aberrant formation of nodules, disturbing the metabolic exchange between legumes and rhizobia (Gautrat et al., 2019).

A soybean AON-deficient mutant showed compromised root hydraulic conductivity and leaf water potential, indicating that AON contributes to water uptake and maintains leaf water status (Caroline Silva Lopes et al., 2019). Numerous investigations have been conducted on deducing the mechanism of AON; however, a few questions remain unanswered,

In this issue of Plant Physiology, Kawade et al. 2024 showed the role of AON in fine-tuning root nodule symbiosis in relation to shoot water availability. Initially, they showed that AON-defective mutants exhibit aberrant nodule numbers and stunted shoot growth. The authors observed that carbon demand in the shoot remains high even in AON-deficient mutants. To understand the carbon status in the shoot of an AON-defective mutant, the author performed the metabolomics in the shoot upper and lower parts. They found decreased glucose and fructose in the upper shoot while increased sucrose, maltose, mannitol, and sorbitol in the lower shoot part. Further, they also observed an enhanced accumulation of starch in the whole shoot, indicating a metabolic shift from sucrose to nonstructural carbohydrate (starch) in the lower shoot.

Nonstructural carbohydrates (NSC) are essential for meeting immediate carbon requirements in environmental conditions such as water-deficit stress. Lopes et al. 2019 showed that soybean AON-deficient mutants have poor ability to transport water from root to shoot, leading to less shoot water content and uncontrolled nodule number (Caroline Silva Lopes et al., 2019). These findings led to the hypothesis that the shoot of AON-deficient mutants is deprived of water. The authors performed the upper and lower shoot part metabolome of inoculated AON-deficient root with water supply to validate this hypothesis. They found no difference in sugar levels of the upper shoot and the lower shoot part and no excess starch, suggesting that water availability from the root positively improves shoot growth in the inoculated AON-deficient mutants.

Drought resilience is one of the most effective strategies for plants to survive in the limited water availability. To understand whether AON-deficient mutants opting for drought resiliency, water regain rate was observed in AON-deficient mutants and wild type (WT) plants. The authors found that the decline in water regain rate in AON-deficient mutants was improved when exposed to rhizobia infection. The findings indicate that AON-deficient mutants experience water-deficient stress, leading to enhanced drought resilience compared to WT shoots. Further, they found that water uptake ability was lower in AON-defective mutants than WT roots, possibly because of increased nodulation zone on roots that hindered water absorption. The findings suggested that the AON signaling is critical in maintaining the balance between root nodule formation and water uptake. The metabolic changes towards carbon reservation observed in AON-defective mutants showed how legume crops strategically optimize metabolic corporations and adapt to environmental conditions such as water availability.

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