Novel drought stress response mechanisms in plants

Drought is the most serious environmental stress that threatens crop growth and survival. Even a mild drought with no leaf wilting can significantly reduce crop growth and have a profound impact on yields. Therefore, early detection of such "invisible droughts" and appropriate measures such as irrigation are important for stable crop production. However, the response of crops to "invisible drought" in the field and its mechanisms have not been well understood. In this study, using a drought stress evaluation system with ridges we developed, we elucidated the plant response to the "invisible drought" that occurs in the field and its physiological significance through detailed analysis in the laboratory and using model plants.

To understand the plant response to the "invisible drought" that occurs in the field, we conducted RNA sequencing analysis using the leaves of soybean grown on flats and those grown on ridges. The data showed that a battery of phosphate starvation response (PSR) genes was up-regulated under mild drought conditions (Fig. 1). By elemental analysis of the leaves, it was demonstrated that mild drought stress reduces levels of Pi among the three primary macronutrients, N, P, and K, in plants in the field. In addition, we showed that the expression of PSR genes is induced in a soil water-dependent manner during the initial phase of drought stress in soybean grown in pots with controlled soil water contents. Furthermore, as drought stress intensifies, the expression of abscisic acid (ABA) response genes is induced (Fig. 2). Not only in soybean but also in *Arabidopsis thaliana*, the expression of PSR genes is induced in the early phase of drought stress before the expression of ABA response genes is induced, suggesting that the newly found phenomenon is universal in plants. In PSR-deficient *Arabidopsis* mutant plants, growth is significantly suppressed by mild drought stress compared to wild-type plants, suggesting that induction of PSR gene expression under mild drought stress plays an important role in maintaining growth during water stress (Fig. 3).

Phosphate content and expression of PSR genes are expected to contribute to the development of plant water sensors as early indicators of "invisible drought," but it is necessary to consider the possibility that environmental conditions other than soil moisture may also affect the induction of phosphate deficiency responses.

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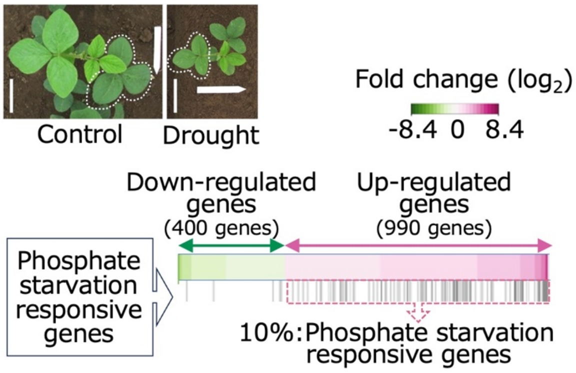

Fig. 1. Induction of PSR genes in soybean leaves under mild drought conditions in the field

Transcriptome analysis of soybean grown in a drought stress evaluation system using ridges in the field. The second leaf of soybean at 31 days after sowing (dotted line in the photo) was used for RNA-seq analysis. Bars in the photo represent 10 cm.

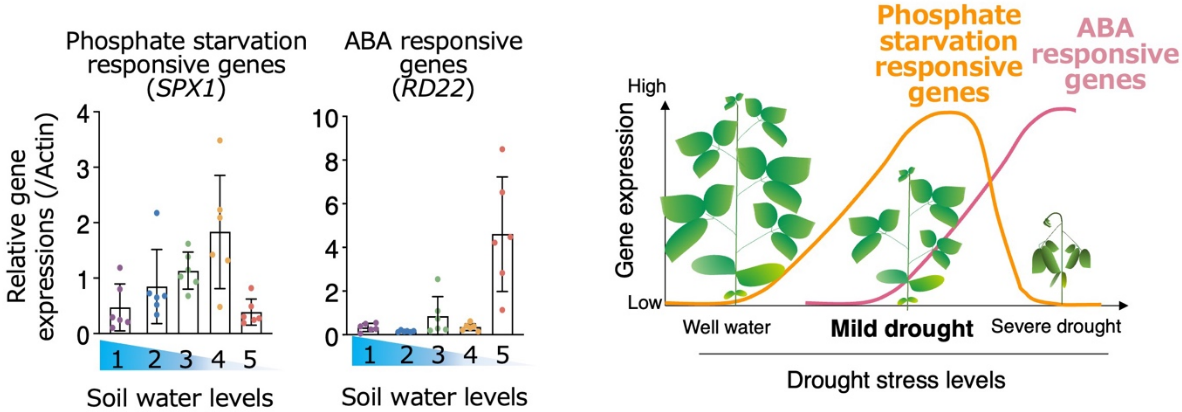

Fig. 2. Expression of PSR genes and ABA-responsive genes induced in a soil water-dependent manner during mild drought

(A) Gene expression analysis of soybean grown in a greenhouse under controlled soil water levels in pots (levels 1-5; higher values indicate less water and greater degree of drought). n = 6, error bars = SD. (B) Model diagram of a newly presented plant drought stress response.

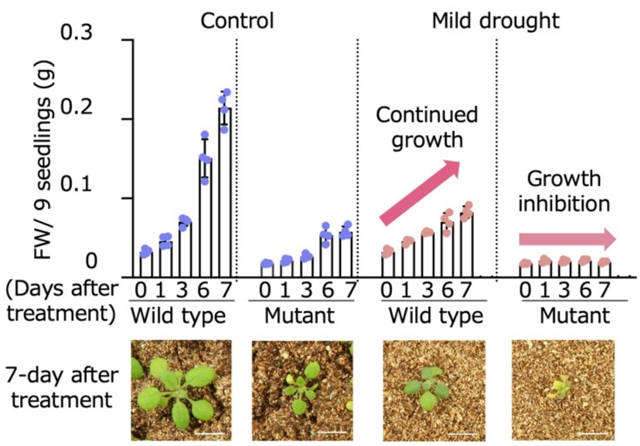

Fig. 3. Drought stress response of *Arabidopsis* PSR-deficit mutants

Growth changes in drought stress-treated *Arabidopsis* wild-type plants and PSR-deficit mutants in which the PSR genes are not induced. Aboveground biomass is shown at 1, 3, 6, and 7 days after drought stress treatment (after water supply to the growing pots was stopped). Bars in the pictures represent 1 cm. n = 4. Error bars indicate SD.

Reference: Nagatoshi et al. (2023) *Nature Communications* 14: 5047.