Identification of a gene that regulates growth under drought conditions in rice

Drought causes growth reduction in plants. Although drought changes expression of a variety of genes, the physiological and molecular mechanisms for plant growth restriction during drought conditions remain unclear. In this study, we identified a gene for a phytochrome (phy)-interacting basic helix-loop-helix transcription factor (PIF)-like protein, OsPIL1, which acts as a key regulator of reduced internode elongation in rice under drought conditions.

The level of *OsPIL1* mRNA in rice seedlings grown under non-stressed conditions with light/dark cycles oscillated in a circadian manner with peaks in the middle of the light period (Fig. 1). When drought started in the middle of the dark period, expression of *OsPIL1* was not elevated during the light period. When drought started early in the light period, the *OsPIL1* expression was drastically decreased to a level similar to that observed in the dark period (Fig. 1). We found that *OsPIL1* was highly expressed in the node portions of the stem using promoter-GUS analysis. Transgenic rice plants overexpressing *OsPIL1* (*OsPIL1*-OXs) showed promoted stem elongation, resulting in a strikingly tall plant (Fig. 2). This was mainly due to increased elongation in each internode. In contrast, transgenic rice plants with a chimeric repressor (*OsPIL1*-RDs) displayed short internode sections. The internode cells of *OsPIL1*-OXs were larger than those of non-transgenic control plants. Smaller internode cells were found in *OsPIL1*-RDs. The transcriptome analysis identified 1396 genes up-regulated (FCA > 2.0) and 1358 genes down-regulated (FCA < 2.0) in the 1st node portion of *OsPIL1*-OXs. Expression of more than half of the up-regulated genes was decreased under drought conditions (790/1396 genes), and expression of large numbers of the down-regulated genes was increased by drought (480/1358 genes), suggesting that these were down-stream genes for OsPIL1. The up-regulated gene set in *OsPIL1*-OXs was enriched for cell wall related genes responsible for cell elongation. Using the transient assay system, we verified that OsPIL1 could activate expression of the cell wall related gene via the G-box element. These data suggest that OsPIL1 functions as a key regulatory factor of reduced plant height via cell wall related genes in response to drought (Fig. 3).

The regulatory system by OsPIL1 may be important for morphological stress adaptation in rice under drought conditions. We think that the *OsPIL1* gene has great potential to produce crops with good growth even under drought conditions.

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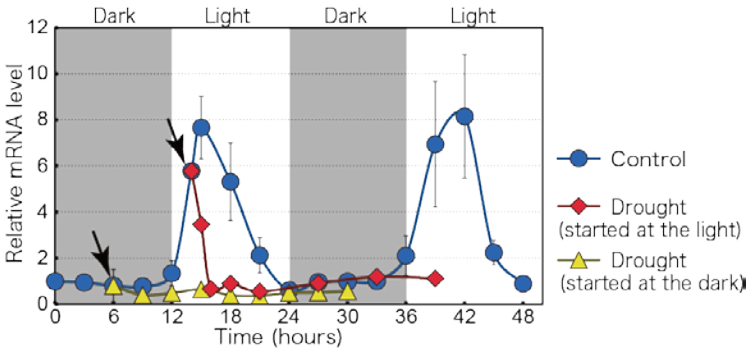

Fig.1. Expression analysis of *OsPIL1* under non-stress (Control) or drought (Drought) conditions by quantitative RT-PCR. Arrows indicate the starting point of the stress treatment.

Fig. 2. Plant heights of transgenic rice plants overexpressing *OsPIL1* (*OsPIL1*-OX) and vector control plants (Control).

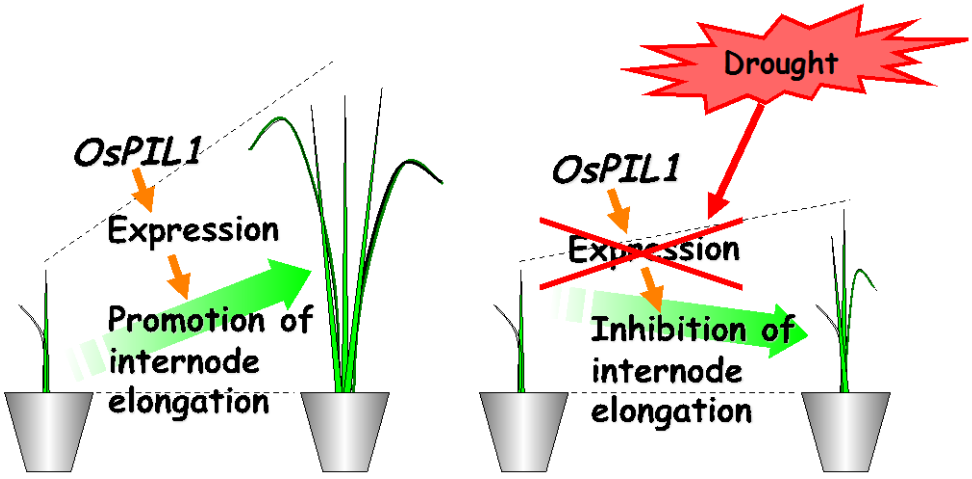

Fig. 3. A model for the plant height regulatory system of OsPIL1. The *OsPIL1* expression promotes internode elongation. Drought decreases the *OsPIL1* expression, resulting in inhibition of internode elongation. Consequently, the plant shows a dwarf phenotype.