IN BRIEF

A Bioinformatics Approach to Investigating Leaf Development

The question of how leaf form is established has long intrigued plant biologists and has important ramifications in both natural and agricultural systems. Heterochrony refers to developmental changes in the timing of events that lead to changes in the size and/or shape of an organ. Heterochronic genes control the temporal dimension of development, in contrast with homeotic genes, which control spatial patterns of development (Slack and Ruvkun, 1997). Chronological changes during leaf morphogenesis often are monitored using anatomical markers, such as trichomes, guard cells, and vascular cells. However, in mutants lacking these cell types it can be difficult to distinguish between factors affecting the progress of leaf maturation (heterochrony) and cell fate specification.

Efroni et al. (pages 2293–2306) introduce a bioinformatics approach to quantifying the stages of leaf development based on gene expression profiles. The authors make use of publicly available gene expression data to develop an algorithm for defining a leaf differentiation score, termed the digital differentiation index, which is based on expression patterns that change with leaf age. This approach is found to work surprisingly well on samples from different labs and different ecotypes, despite the limitations inherent in inferring physiological or morphological status solely from gene expression data.

The authors proceed to use this approach to investigate the role of CINCINNATA (CIN)-related TCP transcription factors in the control of leaf morphogenesis. CIN-TCPs have been implicated in regulation of surface curvature in Antirrhinum and in formation of tomato compound leaves (Nath, et al., 2003; Ori et al., 2007). To find a unifying theme for these functions, the authors used the digital differentiation index to examine Arabidopsis leaves in which the activity of all eight CIN-TCPs was downregulated by overexpression of microRNAs (miR319, which targets five of the eight TCPs [Palatnik et al., 2003], and an artificial microRNA designed to target the remaining three). Analysis of young transgenic lines with this approach implicated regulation of leaf differentiation as a prime role of these TCPs. In mature mutant plants, cell size and number was altered dramatically, suggesting that further stages of leaf differentiation were also delayed or inhibited in the absence of TCP activity (see figure). This work provides a new tool for the investigation of heterochronic pathways operating in plant organs or at the whole-shoot level and highlights the role of CIN-TCPs as heterochronic regulators of leaf development.

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REFERENCES


Downregulation of eight TCP genes in Arabidopsis by overexpression of microRNAs resulted in large, deeply lobed, and highly serrated rosette leaves (right) compared with the wild type (left), showing that these genes play an important role in leaf maturation and are required for programmed arrest of blade growth.