Role of ABA and ABI3 in Desiccation Tolerance


To survive on land, the earliest land plants had to develop mechanisms to tolerate desiccation. Modern vascular plants possess an array of morphological features to retain water (such as conductive tissues, cuticle, and stomata) and have retained desiccation tolerance in only a few specialized structures (e.g., seeds). Present-day bryophytes (mosses), in contrast, lack water transport and retention tissues, presumably like early land plants. As a result, their vegetative state is at equilibrium with the surrounding air, creating a water-deficit condition that most angiosperms could not tolerate. Phyllogenetic analyses suggest that desiccation tolerance in vegetative tissue of bryophytes was lost in the first vascular plants. Here, we evaluate whether desiccation tolerance in angiosperm seeds and in vegetative tissues of the moss Physcomitrella patens use similar regulatory pathways.

The phytohormone abscisic acid (ABA) protects seeds during water stress by activating genes through transcription factors such as ABSCISIC ACID INSENSITIVE 3 (ABI3) (3).

ABA is also found in nonseeds plants such as algae and P. patens (4) and uses similar signaling pathways. For example, a wheat ABA-responsive promoter can be activated by ABA in cells of P. patens (5), and one of three homologs of ABI3 found in P. patens partially complements the Arabidopsis abi3-6 mutant (6).

Unwouted-type (WT) filaments of P. patens can survive up to 92% water loss (7) but cannot recover from complete desiccation (Fig. 1A). We generated two independent lines (Δabi3-1 and Δabi3-2) in which all three P. patens ABI3 genes (A, B, and C) were deleted by using sequential gene targeting (fig. S1) (8, 9). WT lines survived if incubated with ABA (10 to 100 μM) for 24 hours before desiccation, whereas two Δabi3 lines did not survive, even at 100 μM ABA (Fig. 1A). The Δabi3 lines were also responsive to an ABA-responsive promoter from moss (PpLEA1a-GUS), whereas WT exhibited an increase (fig. S2). Expression of 22 ABA-up-regulated genes from WT P. patens (that are presumably required for tolerance) were compared with those of Δabi3 at 24 hours after ABA treatment, 24 hours after drying, and 5 and 15 min after rehydration (Fig. 1B). Without PpABI3, only a few transcripts had reduced expression after ABA treatment and drying, whereas the others maintained their expression. The loss of PpABI3 had little effect on this subset of ABA-up-regulated genes before rehydration. However, all 22 genes assayed at 5 and 15 min after rehydration showed drastically reduced transcripts or none at all in the Δabi3-1 line when compared with WT (Fig. 1B).

ABA and ABI3 are required for P. patens vegetative tissue to survive desiccation. Because the P. patens genome lacks the transcription factors FUS3 and LEC2 (10) that are required for seed maturation like ABI3 (3), the role of ABI3 in this nonseed plant appears to be directly in desiccation tolerance, primarily in the recovery stage. Our working hypothesis is that gene regulatory pathways that include both ABA and ABI3 originally evolved for cellular protection from water deficits but independently have been used to provide desiccation tolerance in vegetative tissues of bryophytes and in angiosperm seeds.

References and Notes
4. S. A. Rensing et al., Science 319, 64 (2008); published online 13 December 2007 (10.1126/science.1150466).
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References
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