Decoupling Active Control and Passive Mechanics in Apical Hook Maintenance

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Abstract

The young stem of many plants, a slender rod-like organ called hypocotyl, develops an apical hook after germination and before soil emergence to protect the apical meristem. Remarkably, the apical hook maintains a bent shape even as cells are elongating and flowing through it, acting as a growing structure with a self-similar stable geometry. It is generally thought that Auxin, a main plant morphogen, generates the macroscopic curvature by locally impeding axial growth on the inner concave side of the hook. Nevertheless, it remains unclear what initially drives the active localization of Auxin and how the tissue that grows out of the hook straightens its curvature.

Here, we employ a multiscale approach to investigate the self-similar growth, or maintenance phase, of the apical hook. Using 4D microscopy, we quantify the cellular growth rates in apical hooks of *Arabidopsis thaliana* and connect the recorded inhomogeneous axial growth profiles to the macroscopic curvature dynamics. Then, we utilize recent morphoelastic models of growing rod-like organs to examine how Auxin-induced bending affects the macroscopic shape dynamics, and whether gravitropism, an active turning towards or away from gravity, can control the hook development.

Our efforts demonstrate that the self-similar bent shape emerges naturally in a large subset of morphoelastic rod models. By analytically solving the spatiotemporal dynamics of curvature, we show that gravitropism is unlikely to control the dynamics, and that autotropism, a mechanism that straightens plant organs with growth, is necessary for the stability of the hook geometry. Furthermore, as the underlying mechanisms responsible for autotropism are unknown, we present novel theory and FEM simulations, performed in the open-source Organism-Tissue Simulator, suggesting that autotropism may be related to tissue mechanics and axial residual stresses within the organ.

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