A Continuum-Mechanics Model of the Arabidopsis Shoot Apical Meristem as a Pressurized Shell

Att Atchariyamontree
Faculty of Agricultural Technology, Chiang Mai Rajabhat University,
Chiang Mai 50300, Thailand
att_atc@cmru.ac.th

Pasin Marupanthorn*
Department of Mathematics, Faculty of Science
Chiang Mai, Thailand
quantfilab@gmail.com

Kulisara Marupanthorn
Faculty of Agricultural Technology, Chiang Mai Rajabhat University,
Chiang Mai 50300, Thailand
kulisara_mar@cmru.ac.th

Abstract. Plant organs develop under high turgor pressure, and their tissue-scale mechanics depend on how pressure-driven loading is carried by connected cell walls. A long-standing question in plant biomechanics is whether a growing apex behaves mechanically as a homogeneous bulk solid or as a surface-dominated structure in which the epidermis carries most of the tensile load. This paper presents a compact case study of the Arabidopsis shoot apical meristem, abbreviated as SAM, using a special-case continuum idealization in the form of a pressurized, membrane-dominated thin shell. A minimal forward model is implemented in which a spherical-cap surface mesh represents the load-bearing layer, internal pressure applies outward traction, and quasi-static indentation is imposed with a rigid spherical indenter under frictionless penalty-based contact. Equilibrium configurations are obtained by damped dynamic relaxation, yielding synthetic force-indentation curves and three-dimensional deformation visualizations. A factorial sweep over internal pressure and effective membrane stiffness shows that global indentation resistance increases systematically with the tension scale captured by the dimensionless group, whereas step-to-step force irregularities primarily arise from discrete contact activation and finite numerical tolerances. The results provide a reproducible mechanistic demonstration of how the pressurized-shell hypothesis links indentation signatures to epidermis-dominated load bearing and motivates connections to stress feedback and wall remodeling during organ initiation.

Keywords: plant biomechanics; turgor pressure; thin-shell mechanics; indentation; shoot apical meristem