Plant tendril writhing under external load : where Kirchhoff meets Lockhart

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The connection between plant growth and mechanical stresses remains a puzzling problem, particularly in tendrils. Their coiling ability depends on the interplay between growth patterns and mechanical forces. Tendrils—rod-like organs in plants like cucumbers, vines, and passionflowers—undergo a writhing transition after attaching to a support, forming two helices with opposite chiralities.

Experiments on about 100 cucumber tendrils monitored curvature evolution over three days under controlled axial traction. Results showed that above a critical load, writhing failed, and at this threshold, the transition to successful writhing exhibited a significant jump in the generated curvature.

In a simplified geometry, differential growth in tendrils was modeled at the cell scale using the Lockhart growth model, combined with Kirchhoff rod theory to reduce growth dynamics to a two-dimensional dynamical system describing mean longitudinal growth and curvature generation. A bifurcation diagram revealed that the transition between failed and successful writhing can either be subcritical or supercritical, depending solely on the tendril's twist-to-bend ridigity ratio, matching experimental data. The derived stress-dependent curvature equation may extend to other tendril species and broader curvature-generation mechanisms in plants.

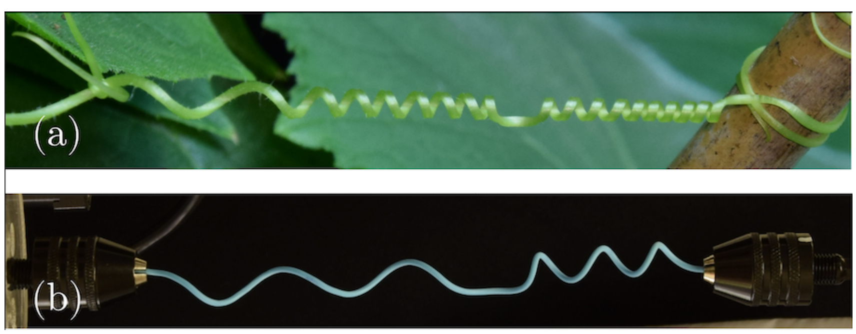

Figure 1. (a) Cucumber tendril presenting helical patterns of opposite chiralities (b) Elastomeric rod with helices of opposite chiralities

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