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Trees acclimation to strains induced by wind: from genes expression to stem structure

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An integrative model of mechanosensing: $S^2m$

Mechanical signals are important factors that control plants growth and development. External mechanical loadings, such as wind, lead to a decrease of primary growth, an increase of secondary growth, modifications of stems mechanical properties and biomass reallocation to roots. Biomechanical studies on tomato and poplar demonstrated that tissue strains are sensed by plants (1), (2). A biomechanical model was proposed, assuming that each cell produces a signal (d$S$) whose intensity depends on strain level (ε), volume and sensitivity of the cell. At organ or tissue level, the integrative thigmomorphogenetical signal $S$ can be predicted by integrating the longitudinal strains (Sstrains), applied to the tissue (3).

$$ S = k \int_{-\infty}^{\infty} \varepsilon_{ij}(z) dz $$

Controlled stem bending

Experimental bending device which allowed to quantify the level of longitudinal strains during the stem bending.

Plants accommodation to repeated mechanical stimuli

Response of secondary growth to repeated daily bending. Open circles represent growth response to one single bending (1B). Closed circles represent growth response to 9 successive bendings at 1-day intervals (9B-1d). Each square, model of additive effects (linear time integration, 9x1B). Open squares, model with a sensitivity shift after 3 daily bendings (3x1B; accommodation).

In nature, mechanical stimuli do not occur as a single bending. In this experiment, successive bendings were separated at day scale, mimicking the alternance between windy or quiet weather.

As soon as a second bending was applied, a diminution of growth and molecular responses to subsequent bending were observed. Our results show that plants acclimate rapidly to mechanical loadings and a desensitization period of a few days occurs after a single transitory bending. This acclimation process provides a basis for a mechanistic analysis of response sensitivity to mechanical loadings such as wind (4).

Multiple mechanical stimuli affect anatomical pattern and secondary growth rate

Cambial activity induced by local strains applied to the stem: experimentations and modelling.

Plants were subjected to 3 successive daily bendings per week during 4 months. (a) Transversal section of a stimulated plant. (b) Relative ovalisation induced by bending. (c) cambium field for living tissues. (d) Weekly growth rate measurements (blue lines) and growth rate modeling (red lines).

$\Delta R(t) = \Delta C(t) + \alpha \varepsilon_{ij}(t)$

References :