

Internship or PhD proposal

Physique et Mécanique des Milieux Hétérogènes

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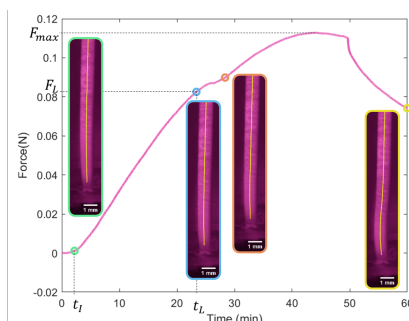
Location: Laboratoire PMMH, Barre Cassan, Bâtiment A, Campus Sorbonne Université

Biomechanical responses of plant root growth to mechanical stresses

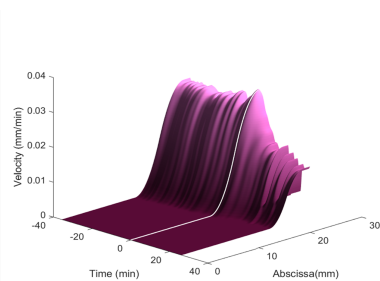
Responsiveness to change in environmental cues, called developmental plasticity, is markedly large for plant roots. Root system development is highly modulated by biological (competition and symbiosis with other organisms), chemical (nutrient availability, oxygen supply, pH...) and physical properties of soils. The architecture of the root system, that is its three-dimensional shape, largely derives from the distribution and diversity of individual root apical meristems, which continuously sense and adjust their growth according to their local environment. In particular, root growth is affected by the mechanical strength of the soil and by the presence of obstacles which scale match or exceed that of the root. As a consequence, the presence of zones of high mechanical resistance in the soil is one of the most common physical limitations to soil exploration by roots, with direct consequences on the C sequestration but also on the agricultural yield.

In the PMMH laboratory, we developed model experimental systems to study how the root changes its growth when encountering a single or a collection of obstacles mimicking the mechanical heterogeneities in a soil. In particular we investigated the growth response of a root (i) pushing against a single obstacle such as a force sensor or (ii) growing inside a 3D-printed array of stiff obstacles. For instance, by coupling force (Fig. i1) and kinematic measurements under infra-red lighting (Fig. i2), we probed the force-growth relationship of a primary root contacting a stiff resisting obstacle, that mimics the strongest soil impedance variation encountered by a growing root.

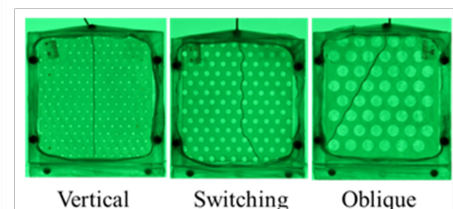
Different subjects are possible around the interaction of roots with mechanical obstacles. One possible topic is 1) to investigate the response of the root to prescribed indentation steps to study its time-dependant mechanical properties and 2) to decouple the mechanical and biological responses by using a feedback loop on the applied force on the root.



(i1) Evolution of the axial force exerted by a growing root pushing against a force sensor (acting as an obstacle) and visualization under infra-red lighting of the root texture.



(i2) Local growth velocity along the root length (obtained from a PIV-derived technique of the root texture) at different times, before and after contact (indicated by the white line).



(ii) Maize root growing in arrays of 3D-printed cylinders embedded inside an agarose gel. The root's diameter is around 1 mm.

Expected skills: The project is primarily experimental, with some modelling (soft matter, biomechanics).