Plant Systems Modelling

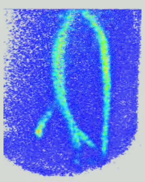
Background

Plants have developed sophisticated mechanisms to capture and use resources efficiently: complex internal molecular/biochemical mechanisms mediate the transport, accumulation, transformation of nutrients, specialised structures are formed to exploit resources availability in space and various biophysical processes facilitate the exchanges with the soil/atmosphere at the plant interface.

We are developing new quantitative approaches to understand and predict the precise nature of the couplings between these genetic and biophysical processes.

(a) SCRI living technology
(b) University of Abertay Dundee
(c)
(d) University of Cambridge
(e) BioSS
(f) University of Dundee

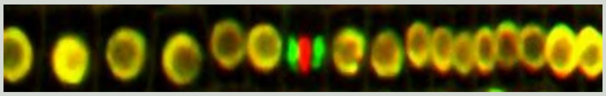
Imaging plant architectural development



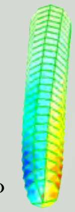
Optical projection tomography (OPT), Dupuy L.[a], Drinev D.[b], *Gill A.[a], Tracy V.[a]*. We have developed OPT microscopy to image plant root growth. OPT is fast, suitable for large specimens and can utilise epifluorescent microscopy, which makes it a powerful tool for integrating cell processes at the scale of the root architecture.

Biospekle laser imaging *Braga R.[b], Dupuy L.[a]* Laser biospeckle are interference patterns formed when a biological specimen is irradiated by a laser source. We showed that biospekle can be used to highlight areas of high biological activity in roots (1). In the future, this would allow high throughput inexpensive techniques to be developed for genetic screens and characterization of root growth.

Differential imaging *Dupuy L.[a], Federicci F.[d], Wiesel L. [a], Bengough G. [a]., Haseloff J. [d]*. Plants tissues rigidify during cell differentiation process, and this phenomenon can be exploited to highlight regions of growth by combining consecutive images. We are using this approach, named differential imaging to track root tips and dividing cells from live imaging datasets (2).

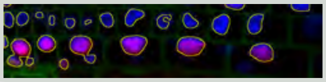


Quantitative analysis of growth and development

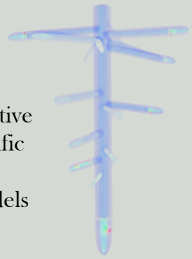


Kinematics of root growth *Dupuy L.[a], Bengough G. [a]., Gill A.[a]* We combine Particle Image Velocimetry and OPT microscopy to analyze the 3D kinematics of circumnutation. We showed that cirumnutation results from specific expansion, torsion and bending deformations along the root.

Linking gene activity to growth *Federici F.[d], Dupuy L.[a], Haseloff J.[d]* We have developed a novel approach to automate the extraction of numerical descriptions of cell growth and genetic activity across living tissues, using a balloon algorithm and particle segmentation in combination of fluorescent reporters targeting the nucleus the plasma membrane.

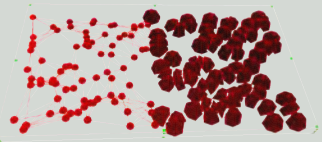


Models of the plant development

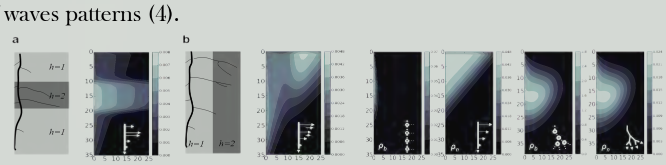


Computational models of development *Dupuy L.[a], Karley A. [a]* It is essential for models to provide predictive outputs to incorporate an understanding of how a specific genotype influence developmental processes and responses to the environment. We are developing models that explain the genetic control of plant architectural development.

Simplified whole plant models *Dupuy L.[a], Helps J.[a], Begg G. [d], Hubbard, S.[e]* We develop computationally efficient deformable domain based models to study plant environment interactions. The approach use semi-Lagrangian approach to the differential equations describing the conservation of root quantity in space.



Mathematical models of meristems dynamics *Dupuy L.[a], Vignes M.[e], Mackenzie B.[a], White P. [a]*. We have developed a continuous mathematical model incorporating root expansion, branching and gravitropic concepts, describing the dynamics can exhibit different types of waves patterns (4).



Conclusion

Understanding the numerous dynamic interactions between a plant 's innate developmental programme and resource availability in the environment is complex. We are developing quantitative approach combining image acquisition, processing and modelling to reveal the nature of these interactions.

1. Bragga et al (2009) European Biophysics Journal
2. Dupuy et al (2009) PNAS *(submitted)*
3. Federici et al (2009) Nature method *(submitted)*
4. Dupuy et al (2009) Plant Cell Environment *(submitted)*