PhD Project Advertisement

Project title: Breaking new ground: using X-rays to study how roots penetrate through soil parent materials
Project No: FBS2023-43-Otten-cs

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Project description:

Soils are important for the safe, healthy, and sustainable production of food. They help to cycle key nutrients, store carbon, clean water, and host key microbial communities. However, soils around the world are in poor health. For many soils globally, erosion rates exceed the slow rates at which they form, which means that soils are thinning. A large proportion of global agricultural land are characterised by shallow soils (i.e., <30 cm) which threatens food production. This project aims to investigate a potential game-changer to sustain food production on critically shallow soils. It will examine the capacity for crop roots to penetrate through, and mine nutrients from, soil parent materials. These are the resources underlying soil profiles, and from which soil is continuously formed (e.g., bedrock, river sediments, glacial deposits, wind-blown dust). Exciting research across the plant and soil sciences has demonstrated that some plant species have developed strategies to penetrate soil parent materials. In desert environments, for instance, plant can grow deep into parent materials to access vital deep-water reserves. However, we still don't have good understanding about the root traits and mechanisms which may allow agricultural crop roots to penetrate and mine the soil parent materials in shallow soil contexts. Likewise, we don't understand how the biological, chemical, and physical properties of different parent materials may promote or hinder root development.

This studentship will make a significant contribution to our knowledge of both root- and soil-based mechanisms which govern root penetration through soil parent material. There are four key objectives in this project, combining literature synthesis, fieldwork, and laboratory experiments.

- Objective 1: the student will assess the current state of knowledge about the soil- and root-based mechanisms promoting root growth through soil parent materials.
- Objective 2: the student will obtain in-tact cores of different soils and soil parent materials across the UK, and will analyse how the biological, physical, and chemical properties change across the soil-parent material boundary.
- Objective 3: the student will setup a laboratory experiment by growing a range of different food crops in cores packed with soils and different parent materials. A microdialysis probe will be installed into the cores to collect porewater adjacent to the root tips. The chemistry of this porewater will be used to assess how rhizosphere processes (those immediately surrounding the roots) responds as the root crosses the interface between soils and parent materials.
- Objective 4: the student will have an unique opportunity to conduct an experiment using X-ray CT scanning. Over the past decade, this technique has transformed our ability to non-destructively observe root growth through soils at impressive space and time scales. Based at the Diamond Light Source facility, the student will grow different food crops in columns packed with soils and parent materials, and these will be imaged using CT scanning to produce time-lapse 3D images of root development. Analyses of the 3D images will be used to highlight where and how roots grow through parent materials.

The scientific advances coming out of this project are likely to have far-reaching impacts across the agri-food sector. For example, being able to optimize crop species decisions based on the ability for roots to grow through the underlying parent material will help farmers to sustain yields, enhance crop health, as well as to address intensifying pressures to

combat food security issues, and mitigate the damaging effects of global soil degradation. Throughout the project, the student will receive unparalleled opportunities to network with, and showcase their research to, leading companies within the UK's agrifood sector including ADAS, Syngenta, and Agrii. There will also be opportunities to discuss the implications of this research for land management with UK policy makers. In addition, the student will have diverse opportunities to present research at national and international conferences, as well as through peer-reviewed and open-access journals.

Training opportunities:

The student will receive world-class, hands-on plant and soil science training at Cranfield and Reading. This will include exclusive access to Cranfield's LandIS soil data resources, which will be used to inform fieldwork sampling. Training will be provided for key analyses (e.g., soil carbon, pH, nutrients, microbial biomass). The student will also have opportunities to advance their training through the British Society of Soil Science.

Unique to this project is the extended visit to the Diamond Light Source, one of the most advanced facilities in the world. The student will be trained to use the synchrotron to capture and analyse root development in 3D time-lapse images.

The student will have unrivalled opportunities to enhance science communication skills, and will work with a commissioning editor for *The Conversation* to publish a piece on their research. They will also spend a half-day with Defra for training on writing policy briefs. Finally, the student will have the chance to showcase their research at agri-food events (CropTec and REAP).

This project has fully flexible arrangements in place (e.g., options for those unable to move location). The supervisory team will work closely with the student to ensure the project plan meets all the student's needs.

Student profile:

This project would be particularly suitable for students with a BSc honours degree (Upper second-class or equivalent) in biology, environmental science (and biology), (physical) geography, soil science, agriculture/agricultural sciences, plant science, or food engineering.

Stipend (Salary):

FoodBioSystems DTP students receive an annual tax-free stipend (salary) that is paid in instalments throughout the year. For 2022/23 this will be £17,668 and this will increase slightly each year at rate set by UKRI.

Equality Diversity and Inclusion:

The FoodBioSystems DTP is committed to equality, diversity, and inclusion (EDI), to building a doctoral researcher (DR) and staff body that reflects the diversity of society, and to encourage applications from under-represented and disadvantaged groups. Our actions to promote diversity and inclusion are detailed on the FoodBioSystems DTP website.

In accordance with UKRI guidelines, our studentships are offered on a part time basis in addition to full time registration. The minimum registration is 50% FT, and the studentship end date will be extended to reflect the part-time registration.

References:

1. FAO (2012) World Agriculture Towards 2030/2050: The 2012 Revision. Available at: https://www.fao.org/3/ap106e/ap106e.pdf (Accessed: 28 October 2022).
2. Evans, D. L. et al. (2021) 'Sustainable futures over the next decade are rooted in soil', Eur. J. Soil Sci, 10.1111/ejss.13145.
3. Evans, D. L. et al. (2020) 'Soil lifespans and how they can be extended by land use and management change', Environ. Res. Lett, 15(9), 10.1088/1748-9326/aba2fd
4. Graham, R. C. et al (2010) 'Rock to regolith conversion: Producing hospitable substrates for terrestrial ecosystem', GSA Today, 20(2), pp. 4-9
5. Ahmed, S. et al. (2015) 'Imaging the interaction of roots and phosphate fertiliser granules using 4D X-ray tomography', Plant and Soil, 401, pp. 125-134.

For up to date information on funding eligibility, studentship rates and part time registration, please visit the FoodBioSystems website.