PhD Project Advertisement

Project title: ***Beyond nitrogen and the nodule: How rhizobial trait diversity enhances crops, soil and environmental health***

Project No: FBS25-42-Shaw-rc

Lead supervisor: Professor Liz Shaw, Geography and Environmental Science, University of Reading

Email: e.j.shaw@reading.ac.uk

Co-supervisors:

Dr Mark Pawlett, Centre for Soil, Agrifood and Biosciences, Cranfield University

Dr Tim Mauchline, Sustainable Soils and Crops, Rothamsted Research

Dr Ian Clark, Sustainable Soils and Crops, Rothamsted Research

Project description: The global demand for food is set to double by 2050, creating an urgent need for sustainable farming solutions. Rhizobia, bacteria well-known for their ability to form symbiotic relationships with legumes and fix atmospheric nitrogen, already play a vital role in this context, cutting down the need for synthetic nitrogen fertilizers.

However, beyond nitrogen fixation, rhizobia possess lesser-known traits that can enhance soil health and crop productivity. These include nutrient solubilization, exopolysaccharide (EPS) production to improve soil structure, pathogen suppression, and reduction of greenhouse gas emissions.

Microbial inoculants offer promise for sustainable agriculture through various traits which enhance nutrient cycling, promote plant growth, and boost resilience, while reducing the need for chemical inputs. However, their potential is not always fully realized due to inconsistent field performance through poor survival or expression of beneficial traits in competitive soil environments. Rhizobia have an advantage over other microbial inoculants in this respect due to their dual presence within root nodules and as free-living bacteria in the root zone. Free-living rhizobia benefit from enriched root exudates resulting from the rhizobia-legume symbiosis, which supports their survival and activity. This unique relationship between free-living and nodule-bound forms make rhizobia a particularly robust inoculant candidate for improving agricultural sustainability.

Despite this promise for sustainable agriculture, rhizobial traits, beyond those directly related to nodulation and nitrogen fixation and their benefits for plant and soil health remain poorly understood. By addressing these unexplored aspects, this project aims to expand the use of rhizobia from nitrogen fixation alone to a broader multifunctional role in sustainable farming practices.

The research will explore:

1. Variation in Traits Across Rhizobial Species - Identifying and characterizing differences in functional traits using phenotypic and genomic analysis.

2. Trait Expression in the Plant Root Zone - Investigating how soil conditions and plant root exudates influence the expression of key traits in free-living rhizobia.

3. Impact on Plants and Soil - Evaluating the contribution of these traits to plant growth, soil aggregation, carbon sequestration, and mitigation of greenhouse gas emissions.

Training opportunities: This studentship provides comprehensive training across microbiology, molecular biology, genomics, transcriptional analysis, plant root zone biogeochemistry, and soil science. Training in experimental design, hypothesis generation, and statistical analysis will also be provided. Specialized training includes soil functional assays, ^{15}N isotope techniques for quantifying nitrogen fixation, greenhouse gas analysis, and creating artificial rhizospheres. Method development opportunities, such as novel EPS assays, are also included. Partnership with Rothamsted Research will provide additional training opportunities in high throughput phenotypic assays, gene-expression analysis, and

molecular biology techniques, such as knockout mutagenesis, alongside X-ray CT imaging to study soil structure impacts. Broader training, including MSc modules on sustainable agriculture, soil health, and climate-smart farming, will contextualize the research.

Project supervision style: As lead supervisor, LS will conduct weekly one-on-one meetings, beginning with an initial learning needs analysis and discussions about wider training needs. LS will support the student's integration into the soil biogeochemistry group @UoR, which meets fortnightly, and provide hands-on training in laboratory techniques like carbon biogeochemistry, isotope methods, and artificial rhizospheres. Wider supervisory meetings will involve the entire supervisory team and occur online, fortnightly to monthly. When the student is on placement at Rothamsted, Rothamsted supervisors will lead the weekly and whole team supervision meetings. The student will be encouraged to write regularly: literature review sections and document their experimental work in real-time, with planned deadlines for submission. This will allow supervisors to provide timely feedback within one week of submission.

Stipend (Salary):
FoodBioSystems DTP students receive an annual tax free stipend (salary) that is paid in instalments throughout the year. For 2024/25 this is £19,237 (£21,237 at Brunel University) and it will increase slightly each year at rate set by UKRI.

Equity Diversity and Inclusion:
The FoodBioSystems DTP is committed to equity, 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 and include:

- Offering reasonable adjustments at interview for shortlisted candidates who have disclosed a disability or specific learning difference.
- Guaranteed interview and applicant mentoring schemes for applicants, with UK home fees status, from eligible under-represented ethnic groups.

These are opt-in processes**.**

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.

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