Phosphorus partitioning in semi-natural grassland

Supervisors: Professor David Johnson, Professor Richard Bardgett

External supervisors and institution: Professor Nick Ostle, Lancaster University

Primary Contact Name and Email: David.johnson-2@manchester.ac.uk

Introduction

This proposal will lead to a better understanding of how plants acquire native forms of phosphorus (P) from soil. This aim is crucial because i) most agri-ecosystems are entirely dependent on imports of non-renewable rock-phosphate, the production of which is predicted to peak by 2033, ii) agricultural policy continues to shift towards the adoption of more sustainable management practices that provide a greater degree of food security with reduced environmental impact, and iii) there is widespread limitation or co-limitation by P of plants across the globe, a situation that will only accelerate as a result of continuing atmospheric nitrogen deposition. There is clearly an urgent need to develop management strategies that are more effective at using native P forms, especially in those soils where inorganic P limits or co-limits plant productivity (the majority of extensively-grazed pasture grasslands). Moreover, these challenges need to be met under projected global climate change scenarios. For example, in many parts of the globe, increased severity and frequencies of summer drought events are predicted, and this perturbation is likely to impact the ability of particular species and communities to acquire nutrients including P. Thus, we must gain a better understanding of how native pools of P are utilised in grassland, and how these processes respond to drought.

It has been hypothesized that differential utilisation of the wide range of chemical forms of P found in soil could explain the coexistence of plant species, especially in P-limited ecosystems (Turner 2008 J Ecology). This hypothesis has been supported in simplified pot-based experiments using heathland plants (Ahmad-Ramli et al 2013), but not under more realistic conditions in species-rich systems, where plant diversity is likely to be a key factor regulating P partitioning. For example, in grasslands, one of the key functional characteristics of plants is the ability to form mutualistic associations with arbuscular mycorrhizal (AM) fungi. The hyphae produced by AM fungi enable them to exploit the soil environment and acquire P in soil solution very effectively and different species of AM fungi differ in their ability to acquire P. In this project, we will determine i) how preferential utilisation of specific forms of inorganic and organic P contributes to the maintenance of plant diversity in species-rich grassland, ii) how AM fungal colonisation facilitates differential P utilisation, iii) the extent to which carbon allocation to mycorrhizal fungal mycelium regulates P utilisation, iv) how interactions among coexisting plants and AM fungi in species-rich grassland feedback to regulate P acquisition and turnover, and v) how these interactions and P acquisition strategies are regulated by drought.

Project summary

The project will make use of an established field-manipulation of plant species richness in the Yorkshire Dales and will be based around four sets of experiments. 1) *Plant utilisation of P from organic sources*. This experiment will test the response of plants to different P forms commonly found in grassland soils. 2) *Quantifying P uptake via AM fungal mycelium*. This experiment will use a subset of plants from the species pool representing the main mycorrhizal functional types, and will involve a laboratory drought manipulation. 3) *Determine the relationship between carbon allocation to AM fungal mycelium and P acquisition*. This experiment will simultaneously quantify carbon flux to external AM fungal mycelium and P transfer to host plants. 4) *P turnover by defined assemblages of plants in response to drought*. This experiment will focus on the field manipulations of plant communities and drought.

The student will join active research groups and will have the opportunity to gain experience and training in a range of cutting-edge and conventional techniques in plant-soil interactions, notably: using isotopic tracers, establishing AM fungal culture collections, and soil and plant elemental analyses, designing and executing both field and laboratory experiments. We will encourage development of their own ideas which will be facilitated by becoming associated with the multi-disciplinary and multi-institutional on-going research programmes that use the core field sites. The student will also enrol in the formal training programmes offered by both partner Universities. We will encourage the student to produce a range of outputs from the work, but the emphasis will be on sustained publication of high-profile papers in international journals.

References

Ahmad-Ramli MF, Cornulier T & Johnson D (2013) Partitioning of soil phosphorus regulates competition between Vaccinium vitis-idaea and Deschampsia cespitosa. Ecology and Evolution 3, 4243-4252. DOI: 10.1002/ece3.771

Turner BJ (2008) Resource partitioning for soil phosphorus: a hypothesis. Journal of Ecology 96, 698-702. doi: 10.1111/j.1365-2745.2008.01384.x

Fig.1: Experimental drought and diversity treatment at Colt Part National Nature Reserve