Project title: Next generation fertilisers for recovering and reusing phosphorus from wastewater – do they work and how do they do it?

Supervisors:
Prof. Kate Heal (University of Edinburgh, School of GeoSciences)
Dr Saran Sohi (School of GeoSciences and UK Biochar Research Centre, UKBRC)
Dr Marc Stutter (James Hutton Institute, JHI)

CASE partnership: None

Primary supervisor contact email: k.heal@ed.ac.uk

Project background

The concurrent problems of phosphorus (P) scarcity for food production and leakage into aquatic systems causing eutrophication require more efficient recovery and use of P in human-environment systems (Shepherd et al., in press). The technical solutions proposed include using materials to recover P from wastewater and then using this P in fertilisers (Dobbie et al., 2005). However, understanding interactions of alternative P fertilisers with native soil P and with plants as mediated by soil properties is required to underpin more efficient P cycling (Barrow, 2015). Conventional P fertilisers are comprised of highly soluble compounds which ensure crops have immediate access to P, but rapid reactions with soil particles can render much of this P inaccessible. A number of studies have examined plant P availability of alternative fertilisers in controlled small-scale experiments with artificial soils (e.g. Brod et al., 2015; Stutter, 2015). Nevertheless, the results require validation in larger-scale field settings and in relation to appropriate indicators of crop yield.

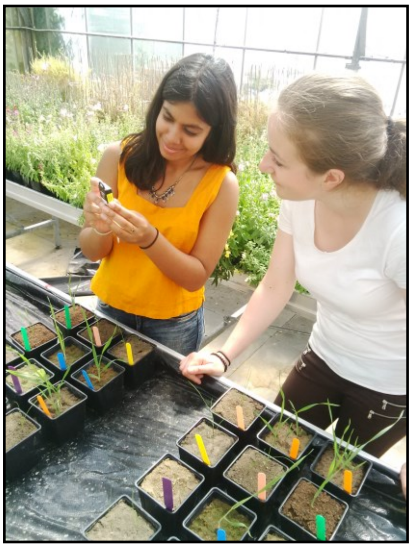

Fig. 1. Pot experiments with different biochar treatments

Fig. 2. Stage 3 UKBRC pyrolysis facilities *(image credit: maverick Photograph)*

This project will focus on novel biochar-based fertilisers which aim to help close the P cycle through capturing and recycling P from wastewater treatment plants. It aims to investigate the response of crop yields and soil quality to these fertilisers, compared to conventional P fertilisers, and understand the processes of P availability to plants in these systems.

Research questions

1. What are the desirable characteristics of alternative P fertilisers to optimise plant-available P and crop yield, whilst minimising P leaching and maintaining soil quality?
2. What is the effect of different soil characteristics (e.g. pH, texture, organic matter content, native soil P content) on plant-available P from alternative and conventional P fertilisers?

Methodology and Timeline
The successful PhD candidate will initially design and conduct lab-scale experiments in controlled conditions. These are expected to involve chemical extractions and bioassays with plants (Fig. 1). A matrix of agricultural soils with contrasting characteristics and biochar-based alternative P fertilisers identified from ongoing and recently-completed work in the UK Biochar Research Centre (Shepherd et al., submitted). There is potential to use UKBRC pyrolysis facilities (Fig. 2) to produce further novel biochars for testing.

Probing the processes of P availability to plants in the different treatments could involve the use of techniques such as SEM/TEM to visualise P plaques and precipitates on soil/biochar particles and plant roots, in addition to chemical analyses to identify P forms in the soil. The results of these experiments will form the basis for a journal paper, giving the student early experience in paper writing and publication. There is also potential to apply for beamtime at the Diamond Light Source for nano-scale probing using K-edge XANES of P speciation in the soil, rhizosphere and soil-root interface. In Years 2 and 3 of the PhD, alternative P fertilisers demonstrated to be effective in the lab experiments will be tested in replicated field plot experiments compared to conventional P fertilisers to validate effects on P availability, crop yield and soil quality.

Training
A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The candidate will be participate in regular UKBRC group meetings and will present their research at national and international conferences, such as the Sustainable Phosphorus Summit series. JHI can provide access to complimentary analytical and field trial facilities, expertise in P speciation and availability testing and crop--phosphorus interactions, plus knowledge exchange with farmers.

Requirements
An excellent first degree in BSc Environmental Chemistry, Environmental Science, Geoscience, Soil Science, Plant Science, Ecological Science, or related discipline. Candidates should have proven skills in experimental design, conduct and analysis.

Further reading

Barrow, N.J. (2015). Soil phosphate chemistry and the P-sparing effect of previous phosphate applications. *Plant Soil* doi:10.1007/s11104-015-2514-5

Brod, E., Øgaard, A.F., Hansen, E., Wragg, D., Haraldsen, T.K. and Krogstad, T. (2015). Waste products as alternative phosphorus fertilisers part I: inorganic P species affect fertilisation effects depending on soil pH. *Nutr. Cycl. Agroecosyst.* 103,167–185.

Cooper, J & Carliell-Marquet, C. (2013). A substance flow analysis of phosphorus in the UK food production and consumption system. *Resources, Conservation & Recycling* 74, 82-100.

Dobbie, K.E., Heal, K.V. and Smith, K.A. (2005). Assessing the performance as a fertiliser and the environmental acceptability of phosphorus-saturated ochre. *Soil Use and Management*, 21, 231-239.

Shepherd et al. (in press). The future of phosphorus in our hands *Nutr. Cycl. Agroecosyst.* doi: 10.1007/s10705-015-9742-1

Stutter, M.I. (2015). The composition, leaching and sorption behaviour of some alternative sources of phosphorus for soils. *Ambio* 44 (Suppl. 2): S207-S216.

A project summary: Contribute to more sustainable phosphorus cycling in a circular economy by answering fundamental questions about how plants access alternative phosphorus fertilisers in soil.