Structure and function of microbial communities at the soil-atmosphere interface

Christopher O'Grady [1], Mark Day [1], Sam Marshall [2], Irene Bramke [2], Hendrik Schäfer [1], Chris van der Gast [3], Gary Bending [1]

School of Life Sciences, University of Warwick [1]. Syngenta, Jealott's Hill International Research Centre [2]. Manchester Metropolitan University [3].

INTRODUCTION

- The soil surface is the first point of contact that most chemicals have with the environment
- The top few millimetres of soil forms a microbiotic layer, known as the Biological Soil Crust (BSC), comprised of phototrophic communities [1]
- BSCs play critical roles in Nitrogen and Carbon fixation, water infiltration, determining local hydraulic patterns and protection from soil erosion [2]
- BSCs are widespread in agriculture (figure 1), yet their temporal and spatial development remains uncharacterized in temperate regions

Figure 1. *A biological soil crust on a wheat field, Wellesbourne*

- OECD guidelines that examine the aerobic and anaerobic transformation of chemicals in soil are performed in the dark on sieved soil, which disregards the impact of phototrophic BSC members on degradation
- We lack understanding of how the BSC influences chemical fate in real-world field systems

Aim of the project

- 1. To unravel the temporal dynamics in BSC community composition within agricultural fields across a growing season
- 2. To investigate the roles that phototrophic communities, which are abundant in BSCs, have on the degradation of pesticides

[1] Yeager, C., Kornosky, J., Housman, D., Grote, E., Belnap, J. and Kuske, C. (2004). Diazotrophic Community Structure and Function in Two Successional Stages of Biological Soil Crusts from the Colorado Plateau and Chihuahuan Desert. *Applied and Environmental Microbiology*, 70(2), pp.973-983.

[2] Belnap, J. (2006). The potential roles of biological soil crusts in dryland hydrologic cycles. *Hydrol. Process.*, 20(15), pp.3159-3178.

[3] Couradeau, E., Karaoz, U., Chien Lim, H., Nunes da Rocha, U., Northen, T., Brodie, E. and Garcia-Piche, F. (2016). Bacteria increase arid-land soil surface temperature through the production of sunscreens. *Nature communications*, 7, 10373 (2016).

METHODS

Aim 1

- For a whole growing season, soil cores were sampled monthly from a wheat field at the Warwick Crop Centre, Wellesbourne
- The BSC (upper 2mm) and bulk soil (5cm) were separated and sieved (2mm)
- From pooled BSC and bulk samples, DNA was extracted and stored for sequencing. Chlorophyll α concentrations were taken for use as a phototroph biomass proxy [3]

Aim 2

- [^{14}C]-labelled benzovindiflupyr was applied to the surface of intact soil cores
- Cores were inserted into soil and covered under either clear (transmission of all wavelengths), UV-limited (transmission >400 nm) or photosynthetically active radiation (PAR) filters (transmission between 450-600 nm, required for phototroph development)
- Cores were destructively sampled over 120 days, and the top 5 mm, 5-30 mm and 30-55 mm layers were separated
- Degradation of benzovindiflupyr was measured using HPLC

RESULTS – AIM 1

- There was no BSC present 2 weeks post-cultivation (tillage to 6 inches and glyphosate application)
- BSCs develop by day 60 (figures 2 and 3) and peak by 275 days
- Glyphosate application in April reset the developmental stage of BSCs, but rapid growth in phototroph communities was seen in the following months

Figure 2. *Pictures of a random core taken from each sampling month*

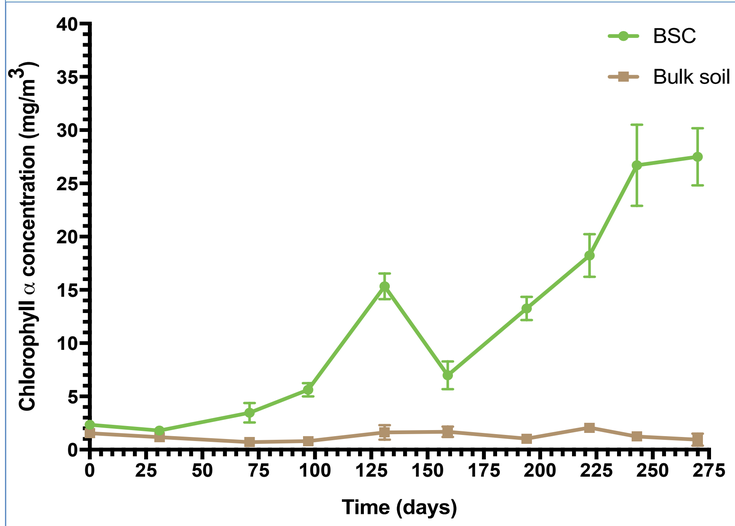

Figure 3. *Average chlorophyll α concentrations in monthly BSC (green) and bulk soil (brown) samples. Initial sampling date was on the 31st October 2016.*

RESULTS – AIM 2

- There was no significant difference in degradation under clear and UV-limited filters, suggesting there was no photolysis
- Degradation of benzovindiflupyr occurred quicker with light filters (combined UV-limited and clear filters), relative to PAR-limited filters (figure 4)
- There was increased movement of benzovindiflupyr through the soil profile in soil with light filters relative to PAR filters

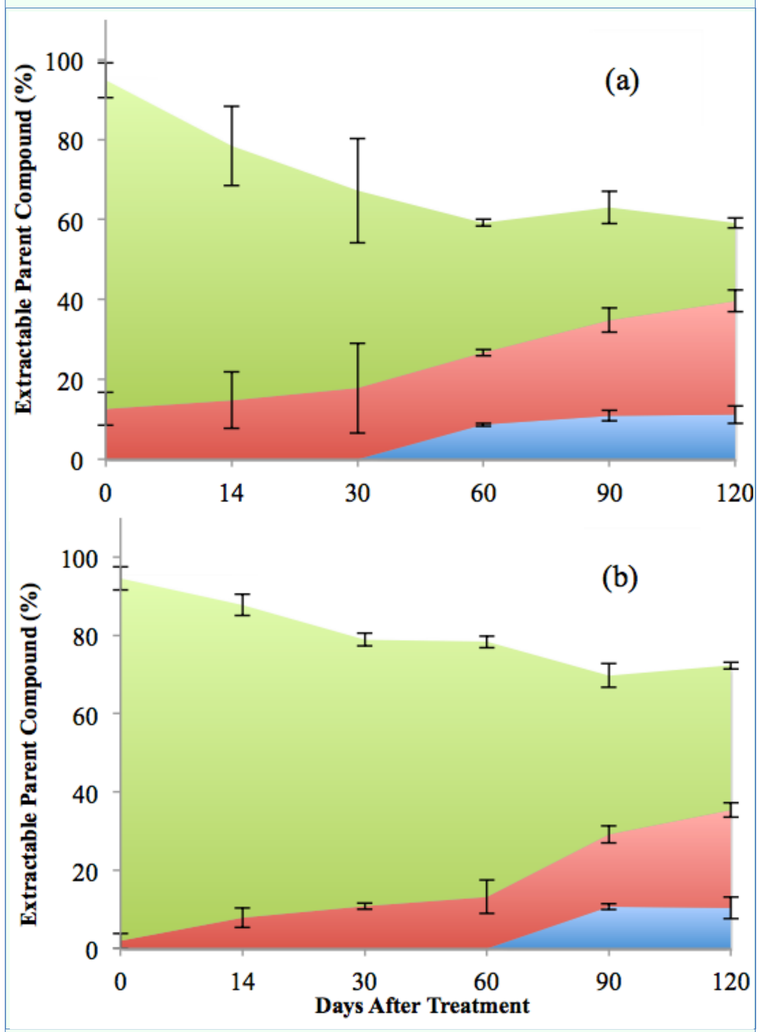

Figure 4. *Position of extractable benzovindiflupyr under (a) LIGHT and (b) PAR-limited conditions at each time point. The percentage of the parent compound in the soil surface (green), top bulk (red) and lower bulk (blue) are displayed. Error bars represent standard error.*

CONCLUSIONS

Aim 1

- The BSC is highly dynamic and develops rapidly from March onwards
- Development of BSCs is hindered by the application of herbicides

Aim 2

- Phototrophic communities increased the degradation rate of benzovindiflupyr
- Increased movement of the CPP through the soil profile could be due to increased water infiltration rates due to the presence of a BSC

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