Influence of drying-rewetting events on the response of soil microbial functions to biochar

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1. Background

There is currently considerable interest in soil management practices that may reduce greenhouse gas (GHG) emissions from soils whilst increasing crop productivity necessary for global food security and ecological sustainability. Biochar application has been shown to positively affect microbial functions such as reduced GHG emissions; and increase organic matter and nutrients via the activities of extracellular enzymes[1].

The aims of this study were to (1) examine the effect of two types of biochar on soil physicochemistry, GHG production, soil enzyme activities and microbial biomass in two typical agricultural soils, and (2) examine whether the responses were altered by drying, rewetting and flooding events.

2. Materials & Methods

Two soil types (**sandy loam** and **clay loam**) were mixed with either 0 (control), low (2% v/v) or high (10% v/v) biochar (***Miscanthus*** or **Dairyfibre** – dried cattle manure - pyrolyzed at 450 ºC [Fig. 1; Table 1]) and maintained at 15 ºC in temperature controlled incubators. Soil was maintained at field moisture content (FMC) from 0 to 44 days**; air dried** from 44 to 80 days; **rewetted** to FMC from 80 to 101 days; and **flooded** (saturated) from 101 to 114 days. 1 g pooled sub-samples (*n* = 4) were collected for determination of **pH** and **DOC** (SUVA @ 254 nm); **microbial biomass** by Substrate Induced Respiration (CO_2 and N_2O production)[2] ; and the maximum rate of reaction of the enzymes alkaline **phosphatase**[3] and **phenol oxidase**[4]. Treatment effects (biochar and soil type, biochar level, change in moisture) were compared using one-way ANOVA with Bonferroni comparisons .

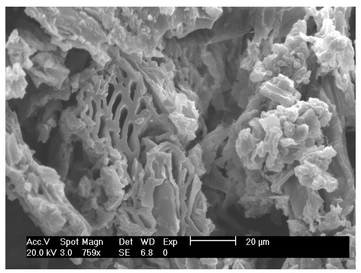

Figure 1 SEM image of *Miscanthus* biochar

Table 1 Biochar ultimate and proximate analyses

Feedstock	Unit	Miscanthus	Dairy fibre
[a]*Ultimate analysis*			
Carbon	wt.%	41.34	25.02
Hydrogen	wt.%	5.27	3.18
Oxygen[b]	wt.%	51.81	62.82
Nitrogen	wt.%	0.57	1.62
Sulphur	wt.%	0.35	0.36
Phosphorous	wt.%	0.045	0.25
Potassium	wt.%	0.23	0.98
C/O ratio		0.81	0.40
[c]*Proximate analysis*			
Moisture	wt.%	10.44	10.84
Ash content	wt.%	2.98	24.61
Density @20°C	kg/m^3	640	633
Higher Heating Value (HHV)	MJ/kg	17.28	11.34
Lower Heating Value (LHV)	MJ/kg	16.16	10.67

Physicochemistry

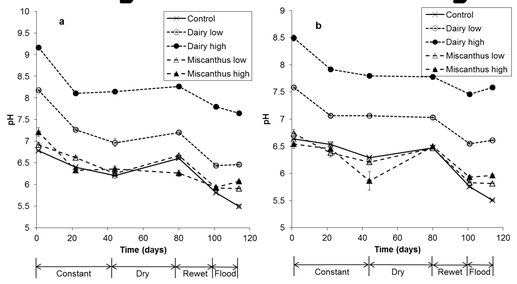

Figure 2 Response of **pH** to biochars in (a) sandy loam and (b) clay loam with temporal moisture variation (mean ± s.e.)

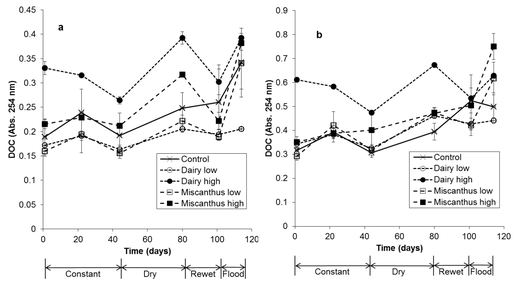

Figure 3 Response of **DOC** by SUVA to biochars in (a) sandy loam and (b) clay loam with temporal moisture variation (mean ± s.e.)

Microbial biomass

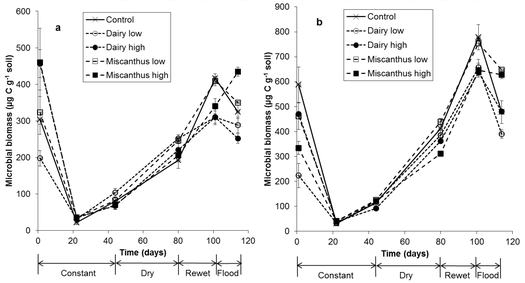

Figure 6 Response of **microbial biomass** to biochars in (a) sandy loam and (b) clay loam with temporal moisture variation (mean ± s.e.)

Enzyme activities

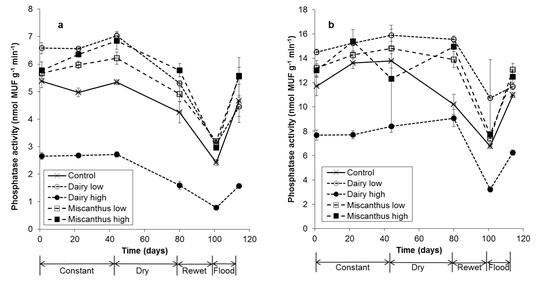

Figure 4 Response of **phosphatase** activity to biochars in (a) sandy loam and (b) clay loam with temporal moisture variation (mean ± s.e.)

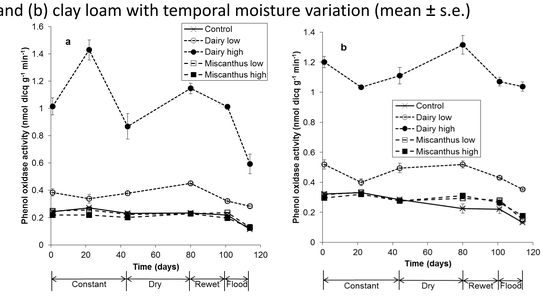

Figure 5 Response of **phenol oxidase** activity to biochars in (a) sandy loam and (b) clay loam with temporal moisture variation (mean ± s.e.)

Substrate-induced N_2O

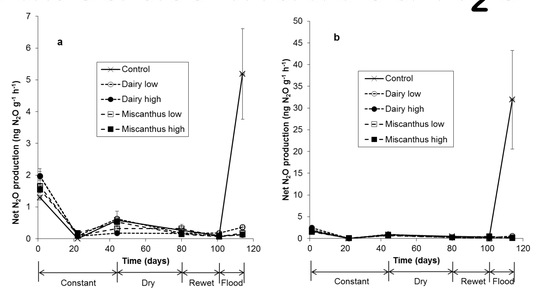

Figure 7 Response of **SI N_2O** to biochars in (a) sandy loam and (b) clay loam with temporal moisture variation (mean ± s.e.)

3. Results and Discussion

- **Physicochemistry:** Dairyfibre biochar increased alkalinity (Fig. 2; *P*<0.001) due to dissolution of alkaline minerals, high ash content (Table 1) and possibly increased DOC solubility (Fig. 3; *P*<0.05). The effect of changing moisture on DOC was only significant within the high biochar treatments *(P*<0.001).
- **Enzyme activities:** Low levels of biochar stimulated phosphatase activity (Fig. 4; *P*<0.05), but high dairyfibre biochar surprisingly decreased activity (*P*<0.001) despite the significant increase in alkalinity. Thus deprotonation of soil phenols (Fig. 3) at higher pH (Fig. 2) may have inhibited activity as occurs in peatlands by the enzyme-latch mechanism[5] that was supported by higher phenol oxidase activity (Fig. 5; *P*<0.05) within the dairyfibre biochar treatments in response to available substrate and/or alkalinity.
- **Biomass and N_2O:** The effect of biochar on microbial biomass depended on moisture conditions. *Miscanthus* biochar may have stimulated growth due to structural properties such as porespace[1] (Fig. 1), whilst dairyfibre inhibited growth probably due to the alkalinity (Fig. 6). Initial changes in biomass were related to the production of N_2O (Fig. 7). Under flooded conditions, all biochar treatments inhibited the production of N_2O (*P*<0.001) suggesting biochar decreased glucose availability to denitrifiers through adsorption and stabilisation at its surface.[6]

4. Conclusion

Drying-rewetting events generally had expected impacts on microbial functions in all treatments with a few exceptions. However, the results highlight that specific feedstocks for biochars may be used to control microbial functions in soil such as inhibiting hydrolase enzymes for carbon sequestration as occurs naturally in peatlands or suppressing the production of the potent greenhouse gas N_2O. Further research is needed to mechanistically link these microbial functions.

References

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