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Progressing from Terra Preta de Índios to the Whole World

Development of a Biochar Classification System Based on Plant Growth Effects

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Introduction

Our investigations focus on the characterisation and classification of biochars based on their compositions and influences on plant growth. Biochars from Miscanthus x *giganteus* chips, pine and willow were pyrolysed in a lab-scale pyrolyser (1 dm^3). The more extensive studies have focused on miscanthus. Biochar products from pyrolysis at: (a) 400°C for 10 min; (b) 500°C for 30 min; and (c) 600 °C for 60 min have been used as amendments (1% and 5% w/w) to a shallow calcareous Irish brown earth loam soil (20% clay, pH 7.5), and maize (*Zea mays* L) seeds were planted in pots for plant growth experiments variously carried out in a growth chamber and in a greenhouse. At the end of the growing periods (21 and 28 days), plants were cut at the soil level, weighed, and oven dried at 60°C. Surface area measurements, heating values, and C, H, and N contents were determined for each biochar sample. Biochar morphologies were observed using Scanning Electron Microscopy (SEM). Volatile materials associated with the biochars were determined according to the standard procedure CEN/TS 15148:2005. Solid state CPMAS ^{13}C NMR was a major procedure for the characterisation of the biochars produced.

Results and Discussions

After 15 days, maize seedlings had not emerged in the control pots in the greenhouse experiment whereas stems were 10 cm in height and with three leaves per stem in pots amended with the 5 wt.% miscanthus biochar. Seedling emergence was observed after 20 days for the control. The best growth was observed for the miscanthus biochar-amended pots (Figure 1 and Table 1), and in these cases the results for the 1% amendments matched those for 5%.

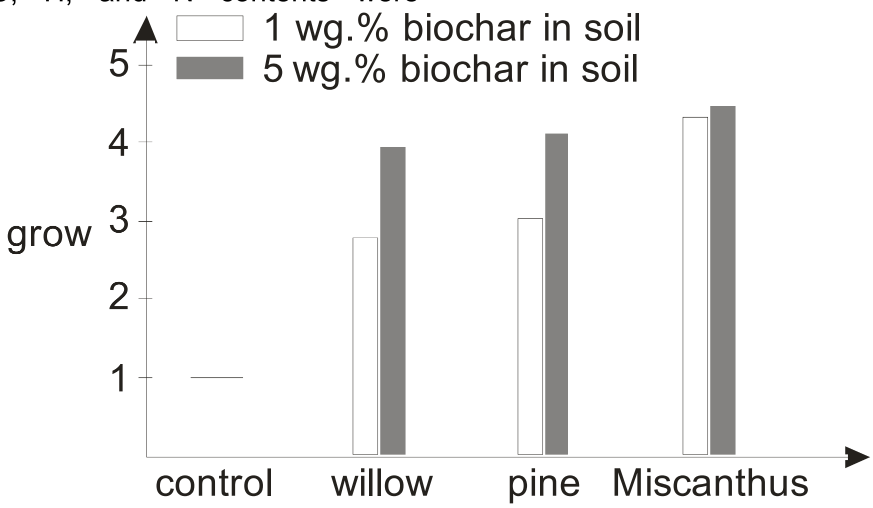

Figure 1. Growth of plants (relative to the control) after 21 days in soil amended with 1 and 5 wt.% biochar from miscanthus, willow, and pine prepared under the same conditions.

Table 1. Yields and properties of biochars from different substrates and reaction conditions

Biochar source	Control (no biochar)	Willow	Pine	Miscanthus
Yield after 21 days (as growth % of control)	100	393	402	437
Yield after 28 days (as growth % of control)	100	128	135	153

Biochars from willow and pine also gave similar growth response at the 5% level, though the response to these was less at the 1% amendment level (Figure 1). The difference in growth in the control and char-amended soils became less with time, as can be inferred from the data in Table 1. The greenhouse experiments have shown that biochar has the best effects during germination and in the first stages of growth. The experimentation has shown that biochar prepared at 600 °C for 60 min gave the best growth results, and that prepared at 400 °C for 10 min suppressed plant growth. The latter had a significantly lower surface area. The NMR spectra (Figure 2) for the biochar samples differed greatly from that for the parent miscanthus The distinctive evidence for lignin and carbohydrate components in miscanthus was absent from the spectra for the biochars formed at 600 °C.

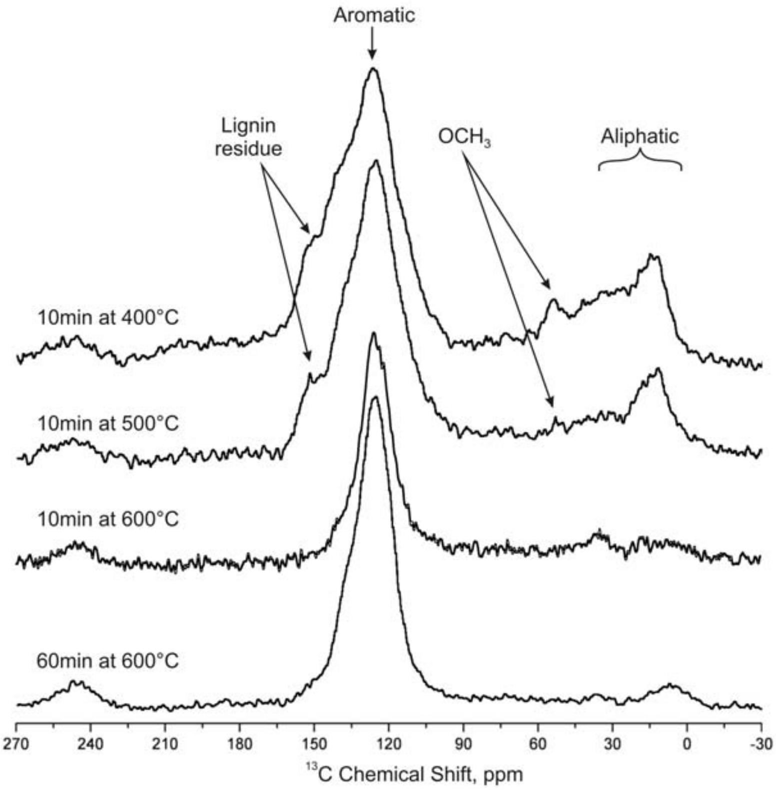

Figure 2. DPMAS ^{13}C NMR spectra of different miscanthus biochars.

However, there is evidence for some lignin-derived residuals in the products formed at 400 °C and at 500 °C. The product formed at 600 °C for 60 min clearly shows a resonance at 127 ppm that is characteristic of fused aromatic structures characteristic of chars.

Conclusions

Our results have shown that the temperature and time of pyrolysis have major influences on the extents to which biochar amendments to soil influence seed germination, and plant growth, at least in the early stages. It would seem that the stimulation of seed germination is hormonal/chemical from sorbates on the biochar surfaces. Further research by our team members has shown prolific fungal associations (possibly VAM fungi), with the plant roots associated with the biochar, and also extensive bacterial proliferations in the biochar enriched areas in the soil. Symbiotic relationships between fungi and plants may give rise to long term stimulation of the plant growth. It is clear that, depending on the procedures used for the preparations of biochars, the products can stimulate or inhibit plant growth. It is therefore very important to develop a biochar preparation and testing protocol that that will allow classification of biochar products in terms of their properties for uses in agriculture. Surface area is an important criterion, and that property, combined with NMR data provide the best evidence we have at this time to indicate that a particular biochar can benefit plant growth.

It is very important also to develop criteria that will indicate that marketable biochars do not pose a threat to human health.

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