

Establishing release dynamics for plant nutrients from biochar

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Introduction

To understand the value of biochar products to direct supply of crop nutrients, and to distinguish these from indirect effects on plant nutrition, the dynamics and mechanisms of nutrient release need to be described.

In this study the magnitude and dynamics of phosphorus, magnesium and potassium released in water were studied for a hardwood charcoal, with different levels of prior physical disruption (crushing).

The charcoal was created at 500°C from sycamore wood in a traditional charcoal kiln¹. Total elemental composition of both sycamore and charcoal was determined by ICP-OES analysis.

The sample was manually ground and sieved into a size range of 150–600 µm. Three sub-samples (approx. 10.0g) were weighed into 500mL LDPE bottles. Deionized water was added to give a solid-to-liquid ratio of 1:20 by mass. The bottles were then shaken using an orbital shaker at 160 min⁻¹ for 4 h along with one LDPE bottle containing only deionized water as a control.

The contents of each bottle were subsequently filtered to recover charcoal, including loosened particles >11 µm (pre-weighed Whatman No. 1). The filtrate was filtered again at 0.45 µm and analyzed for total P, K and Mg by ICP-OES.

Solid residues >11 µm were dried on the filters overnight at 105°C, cooled to room temperature in a desiccator and weighed. The samples were then subjected to the same water extraction procedure five more times.

The volume of water added in each cycle was adjusted accordingly to maintain the same solid-to-liquid ratio. After the sixth extraction, the samples were dried overnight and sieved using a 150 µm mesh, and for each sample the weight of the particles <150 µm was recorded to establish the extent of physical breakdown during the treatments.

Results and Discussions

Phosphorus concentration in charcoal was low (119 mg kg⁻¹), but approx. four times greater than in sycamore wood, reflecting the ratio of feedstock mass to charcoal yield in charcoal manufacture. In contrast, the magnesium and potassium contents of charcoal were 1889 mg kg⁻¹ and 3309 mg kg⁻¹ respectively. The latter were only twice the feedstock concentrations of 856 mg kg⁻¹ and 1651 mg kg⁻¹ which may suggest a decrease in chemical extractability.

Phosphorus released in water did not change greatly between extraction cycles, the first few extractions yielding only slightly greater amounts than the last extractions. However, one-fifth of total extractable-P was released in the first cycle, suggesting that P is conserved and rendered more water-available by pyrolysis. Phosphorus released from the first extraction was 0.027 mg g⁻¹, which at a charcoal application rate of 20 t ha⁻¹ would equate to only 0.54 kg ha⁻¹ P. However, it would appear that this could be sustained over time.

The washing, shaking and/or handling of the charcoal samples both created fine particles and led to some losses through the filter paper. In addition, some charcoal was unable to be retrieved from the interior of the bottle following each extraction. An average of 16 % mass was lost from each sample, and an average of 3% of each sample was recovered as particle sizes <150 µm. The concentration of P in later extractions could be explained by the generation of smaller particles with a higher release potential. The P concentrations could also reflect P that was sorbed to the <11 µm particles that passed through the filter.

The release of Mg decreased linearly from one extraction to the next. This, and the fact that the proportion released in the first cycle was smaller than P, 5–10 %, indicates that the availability of this element is low in pyrolysed material compared to P. Mg released from the first extraction was 0.176 mg g⁻¹ charcoal,

which at a charcoal application rate of 20 t ha^{-1} would equate to $3.52 \text{ kg ha}^{-1} \text{ Mg}$.

The proportion of K released in the first extraction was higher than for Mg, but declined exponentially in subsequent cycles. This indicates that although the water-available portion of K is small it is released very quickly, suggesting a different location within the char structure from P and Mg. The release of

potassium does not appear to have been affected by the erosion of the particles since the correlation between the particle size and the release of potassium remained almost the same throughout the extractions (data not shown). K released from the first extraction was $2.47 \text{ mg g}^{-1} \text{ charcoal}$, which at a charcoal application rate of 20 t ha^{-1} would equate to $49 \text{ kg ha}^{-1} \text{ K}$.

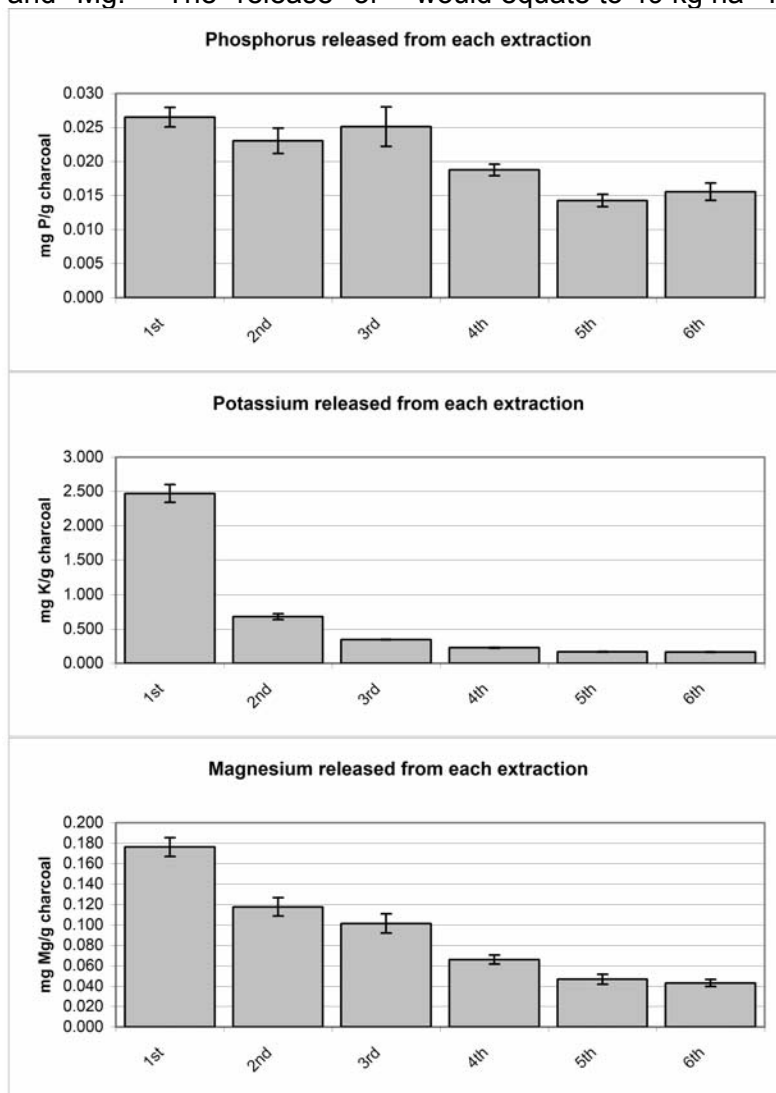


Figure 1. Release of phosphorus, potassium, and magnesium from each extraction

Conclusions

Although sycamore charcoal applied at a rate of 20 t ha^{-1} would be relevant to the K requirement for many crops, in general it is unlikely to meet a great proportion of P or Mg requirement.

Most of the K release from the charcoal occurred during the first extraction, whereas the difference between the earlier extractions of P and the later extractions was less pronounced. In addition, the release of Mg and P did not follow a similar trend. This indicates that these

three elements either adsorb differently to the charcoal, or perhaps one or more of the elements are contained within the charcoal in particulate form.

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[†]Charcoal produced by Dalkeith Char.