Phosphorus bioavailability from ash-rich biochars produced at different pyrolysis temperatures

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Introduction

- Peak phosphorus?
- Animal wastes and high quality biosolids as a source of P?
- The conversion of manure and biosolids into biochars? Added value?
- The effect of pyrolysis on P bioavailability? Types of feedstock and pyrolysis conditions?

Introduction

Aims:

(i) study the bioavailability of P in biochars produced from biosolids (BS) and cattle manure (MA) (P rich organic wastes) at different pyrolysis temperatures;

(ii) develop a robust chemical method for biochar P availability measurements.

Materials and Methods

Materials:

Wet mix then dry

Two different feedstocks

Four different pyrolysis temperatures

250, 350, 450, and 550° C

Methods and Materials

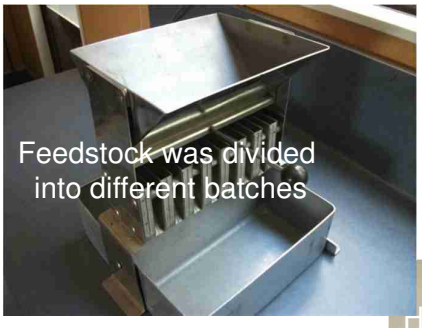
Methods:

(i) chemical analysis – including total P (by 10% HCl:HNO_3 mixture) and extractable P (2% citric acid, 2% formic acid, and neutral ammonium citrate extraction) *(standard methods for inorganic fertilizer P test)*

(ii) a bioassay test using rye-grass grown in a P deficient sandy soil were used to compare the P bioavailability of different biochars

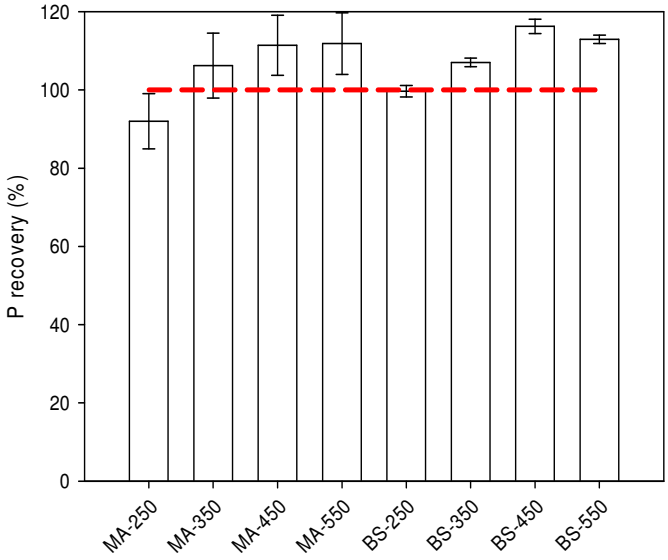
Methods and Materials

some facilities used in this studies



Results and Discussion

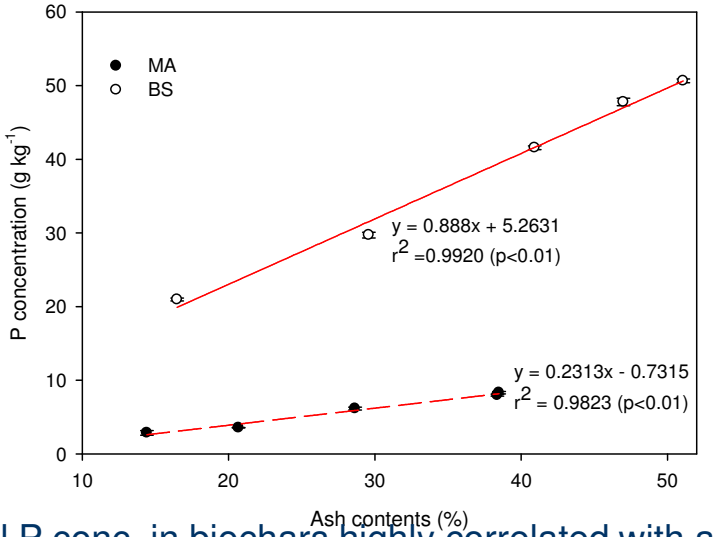
Recovery



- ~93-119% of P from feedstocks could be recovered in biochars
- High temperature biochars showed higher total P recovery than low temperature biochars due to lower recovery of organic P (more abundant in the feedstock) compared to inorganic P using this digestion procedure

Results and Discussion

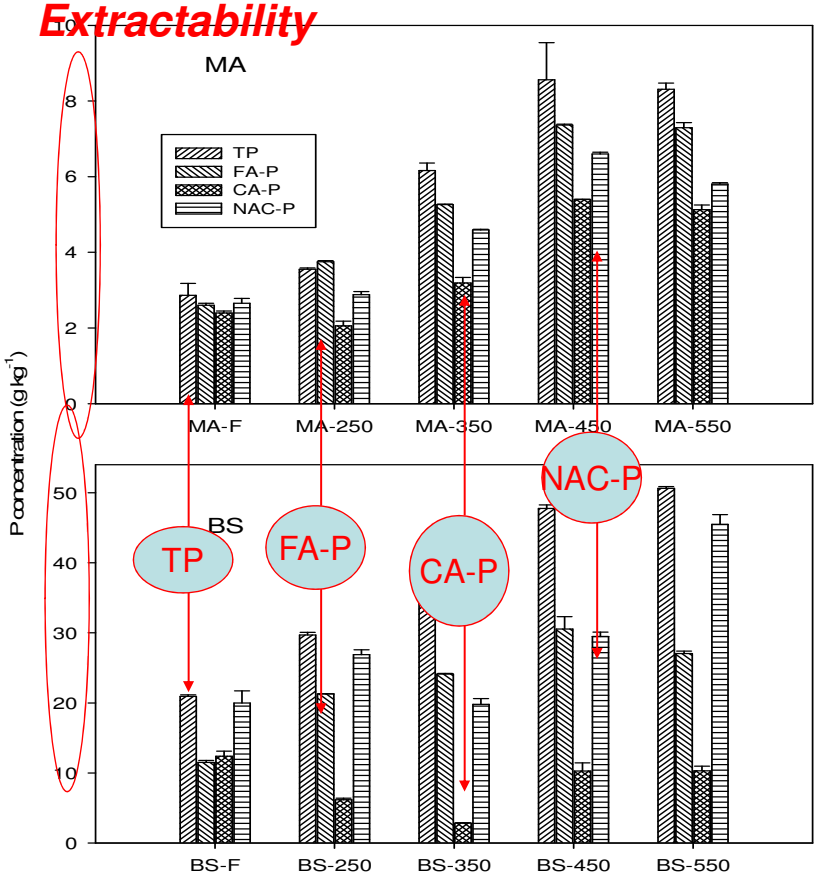
Where is it?



- Total P conc. in biochars highly correlated with ash contents
- P was enriched in ash fractions in biochars ➔the validity of the proposed method (P existed mainly in inorganic forms in biochars)

Results and Discussion

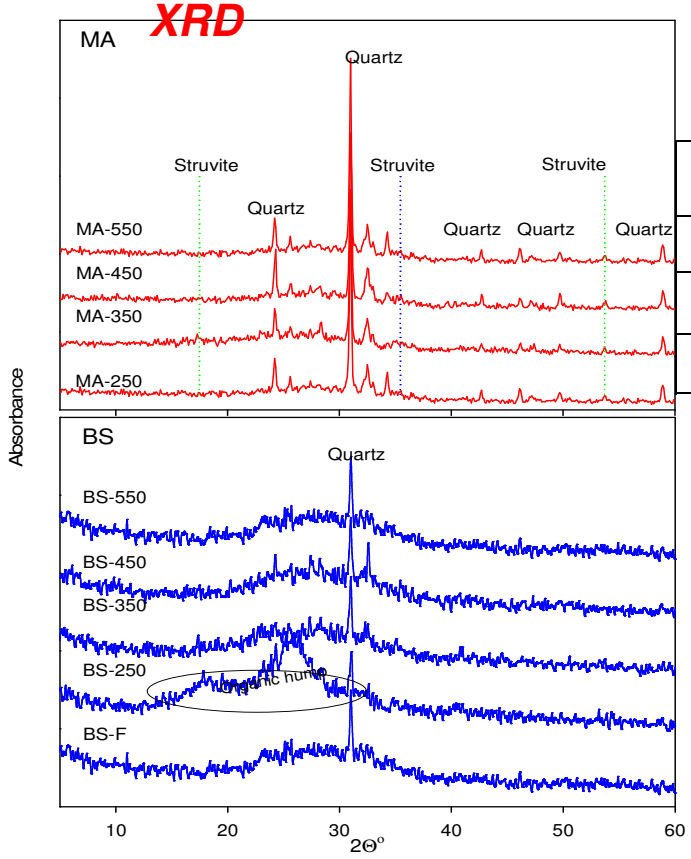
Extractability



- The fraction of extractable P in MA biochar (>69.6%) is higher than in BS biochars (<59.2%), but still more P available in biosolids
- Acidification was the main mechanism for P dissolution in MA biochars, while complexing played a key role in P dissolution in BS biochars

Results and Discussion

XRD



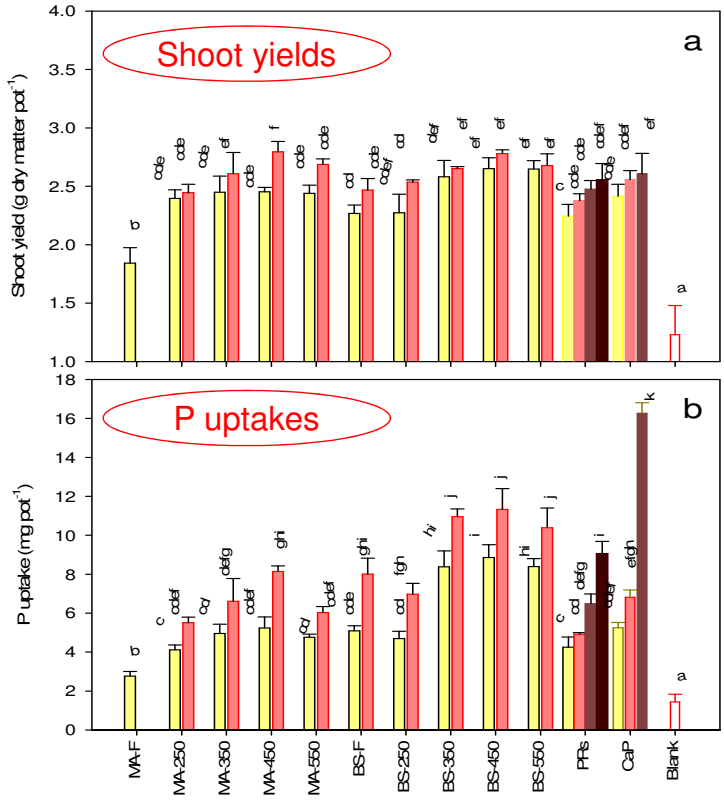
Stepwise regression

Feedstocks	Variables entered	r^2	Probability level p
MA	Mg	0.643	<0.01
BS	Al	0.865	<0.01
	Al, Mg	0.901	<0.01

Mg-P complexes dominated in MA feedstock and biochars, and amorphous Al and/or Mg-P dominated in BS feedstock and biochars.

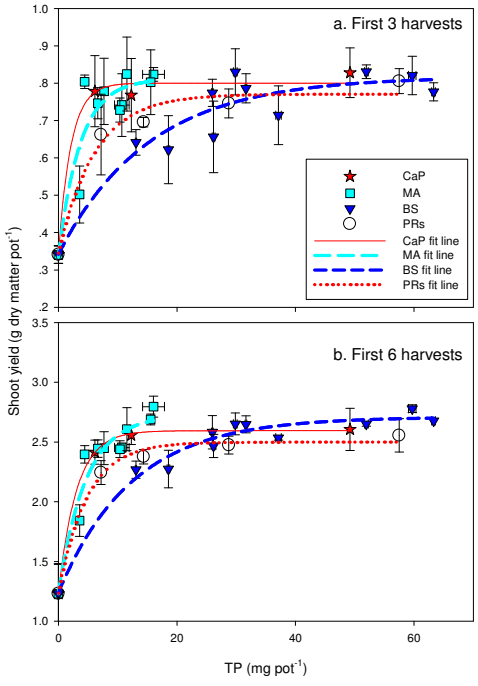
Results and Discussion

Bioassay



- Better than the control treatment and feedstocks
- P uptake was more sensitive to the dose and type of P source than plant yield
- Both dry matter yield and P uptake for both MA-550 and BS-550 decreased, compared with MA-450 and BS-450. Critical point of temperatures?

Results and Discussion



The activity coefficient (ε) followed a descending order as CaP>MA>PRs>BS. Feedstock dependent!

Mitscherlich equation

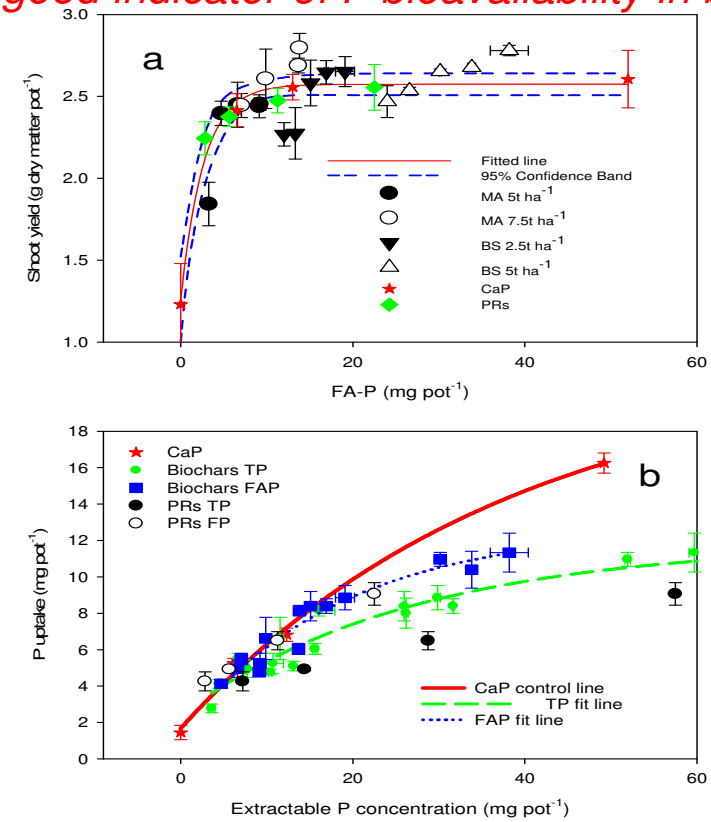
$$Y = Y_0 + {}_{\Delta}Y - {}_{\Delta}Ye^{-\varepsilon N_f}$$

Where Y = The total dry matter yield or P uptake;
Y_0 = The yield or P uptake without biochars or fertilizers application;
ΔY = The difference between the maximum yield or P uptake Y_{max} and Y_0, that is, $Y_{max} = Y_0 + \Delta Y$;
ε = an activity coefficient, which is a measure for the P availability of biochars or fertilizers to the plants; the higher the value, the more readily available of P
N_f = the rate of P applied

6 harvests yields	r^2	ε
CaP	0.997	0.326
MA	0.923	0.217
BS	0.966	0.081
PRs	0.993	0.209

Results and Discussion

FA-P was a good indicator of P bioavailability in biochars



Summary

- P in feedstock was fully recovered in the biochar and was enriched in the ash fraction.
- Amorphous Al phosphate and/or adsorbed P may dominate in BS biochars and Mg phosphate in MA biochars.
- After 6 harvests, the biochars were as effective as the P fertilizers tested [phosphate rocks and $Ca(H_2PO_4)_2$], when comparing them on a formic acid-extractable P basis, in increasing the shoot yield and supplying P to the plants.
- Based on the Mitscherlich equation, 2% formic acid extractable P was the most sensitive indicator of P bioavailability in biochars.

Acknowledgements

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- The Ministry of Agriculture and Forestry New Zealand funded this research
- …….