Effect of rice husk biochar and nitrification inhibitor treated urea on N and other macronutrient uptake by maize.

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Abstract
Biochar is reputed to improve the water holding capacity and the availability of nutrients in soil as well as the biomass of crops. Biochar combined with nitrogen fertiliser has been reported to have positive effects for the soil and the plant.

A glasshouse pot experiment was undertaken to investigate the effect of rice husk biochar on the growth and macronutrient content of corn. The experiment was a factorial arranged in randomised blocks with three replicates. The factors included were; with and without biochar (10t/ha); with and without leaching, and single and split applications of either urea or a urea containing a nitrification inhibiter (Entec). There were zero N controls for each biochar and leaching combination.

The application of 10t/ha rice husk biochar increased the tops dry matter yield in the single urea and Entec treatments both in the presence and absence of leaching. Biochar also increased the tops content of K and P and decreased the tops content of Ca and Mg in both the presence and absence of leaching. There was no significant effect of biochar on tops S and N content.

Key words

Nutrients, phosphorus, potassium, calcium, magnesium

Introduction
Biochar is a high carbon material produced from the slow pyrolysis of biomass. Interest in biochars has recently been driven by two major global issues: climate change and the realisation of the need for sustainable soil management. Biochar can potentially be used as a soil amendment for improving the quality of agricultural soils. Numerous beneficial effects of biochar in terms of increased crop yield and improved soil quality have been reported but little research has been published elucidating the mechanism responsible for the reported benefits of the biochars on crop growth, production, and soil quality (Chan et al. 2007).

If the addition of biochar could result in improved N use efficiency (NUE) this would potentially change the economics of its use. Some improvements in NUE have been reported in various agricultural and horticultural crops resulting from the addition of a new nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) (Entec™) to urea.

This objective of this study was to assess the effect of rice husk biochar and nitrification inhibitor treated urea on crop yield and N and other macronutrient uptake by corn.

Materials and methods
A glasshouse experiment was set up to study the effect of rice husk biochar on corn growth. Soil was collected from the Kirby Experimental Station of the University of New England, Armidale, Australia. Soil samples were collected from the 0-30 cm horizon, dried, ground, and passed through a 2.0 mm sieve.

The treatments included a factorial combination of the following:
Leaching, biochar (10 t/ha), urea single and urea split (110 kg N/ha), Entec™ single and Entec™ split (110kg N/ha). A zero N control was included for each factor. The 20 treatments were arranged in a randomized block design with 3 replications. Entec™ is urea containing DMPP which acts as an ammonium stabiliser by reducing the activity of nitrifying bacteria.

The biochar used was produced in the Philippines from rice husks and provided by Mr Slamet Supriyadi. It had a $pH_{(H2O)}$ of 9.85, 0.43 %N, 33.2 %C and Colwell P of 241 mg/kg.

For each unleached pot, 1.5 kg of soil was placed in a plastic bag and a solution of KH_2PO_4 was added to supply the equivalent of 38 kg K/ha and 30 kg P/ha on a surface area basis. A second solution of $MgSO_4.7H_2O$ was added to supply the equivalent of 10 kg/ha Mg and 13 kg/ha S, These, and the initial applications of solid urea and solid Entec were mixed throughout the entire soil volume. Leached pots were treated the same except that tissue paper was placed in the bottom of the pot rather than a plastic bag. Two seeds of corn (*Zea mays*) were planted in each pot and soil moisture was adjusted to field capacity and maintained near this for 45 days.

Split applications of solid urea and Entec™ were applied to the soil surface on 3 occasions and leaching by watering to 30% above field capacity was conducted at fortnightly intervals. Corn was harvested at the end of the sixth week by cutting 1.5 cm above the soil surface. The tops were dried and ground to pass a 1mm screen and analysed for N by combustion in a LECO combustion furnace and macro and micronutrients by ICP following acid digestion.

Results

All three main effects were significant as was the nitrogen*biochar interaction. Data from all treatments is presented in Table 1 for clarity. Tops yields were an average of 11% (P<0.05) lower following leaching (Table 1)and were lower with split N applications compared to a single application in the presence and absence of both biochar and leaching. The yields were lower in the Entec single compared to the urea single treatment in the absence of leaching, both with and without biochar. Biochar addition increased the dry matter yield of tops irrespective of leaching with single N applications in this infertile soil.

Table 1. Dry matter yield of tops.

N treatment	Unleached		Leached	
	- Biochar	+ Biochar	- Biochar	+ Biochar
		g/pot		
Control	2.4	1.7	1.2	1.4
Urea single	12.4	13.5	10.4	12.0
Urea split	10.2	11.0	9.0	9.3
Entec single	11.6	12.5	10.0	11.6
Entec split	9.9	10.2	8.7	8.7
lsd (p=0.05) for N*B*L interaction		1.0		

Table 2. Apparent N recovery in tops.

N treatment	Unleached		Leached	
	-Biochar	+ Biochar	-Biochar	+ Biochar
			%	
Urea single	64.1	71.1	52.6	54.5
Urea split	58.0	60.8	55.3	55.3
Entec single	60.7	66.4	58.7	55.2
Entec split	52.6	62.2	55.0	54.7
lsd (p=0.05)			7.4	

Although not always significant there was a trend to lower apparent N recovery in the unleached compared to the leached treatments and this difference was greater with single than with split applications (Table 2). These reductions in %N recovery were significant in the urea single treatment both in the presence and absence of biochar and in the absence of biochar in the single Entec treatment. There were no differences in %N recovery between Urea treatments in any leaching/biochar combination

Both yield and K concentration was improved with the addition of biochar compared to without biochar resulting in substantially higher tops K content when biochar was applied (Table 3). In contrast, tops Mg and Ca contents were reduced where biochar was applied. There was a significantly higher P content in the + biochar than in the – biochar treatment and there were no significant differences in tops S and N content between the + and - biochar treatments (Table 3).

Table 3. Other macronutrient content of tops. (mg/pot)

Treatment	Yield (g)	Nutrient content (mg)					
		N	K	Mg	Ca	P	S
- Biochar	8.6	101.5	120.3	33.2	25.3	21.4	14.6
+ Biochar	9.2	103.2	179.0	25.5	22.4	23.9	14.0
lsd (p=0.05)	0.3	4.1	11.0	1.8	1.3	1.2	1.0

Yield was significantly higher in the unleached treatment compared to the leached treatment (Table 4). Similarly the macronutrient nutrient content was greater in the unleached treatments (Table 4).

Table 4. Other macronutrient content of tops. (mg)

Treatment	Yield (g)	Nutrient content (mg)					
		N	K	Mg	Ca	P	S
Unleached	9.6	110.7	155.0	31.6	25.8	24.1	16.7
Leached	8.2	94.0	144.3	27.1	21.9	21.2	11.9
lsd (p=0.05)	0.3	4.0	11.0	1.8	1.3	1.2	1.0

Tops K content increased with biochar application in all N treatments. It was not different between single and split applications of urea but it was between single and split applications of Entec in the + biochar treatment (Table 5).Tops P content was enhanced with biochar and it was higher with split N applications in the presence of biochar. The highest tops P content was in the split application treatments. Tops S increased with biochar in the split Entec treatments. Tops Mg and Ca content was reduced with biochar. Tops Mg and Ca content was higher in the single applications than split applications. Tops S content was reduced with biochar when N application was split and was lowest with split urea.

Table 5. Effect of biochar and N applications on the macronutrient content of tops. (mg)

		N Treatment					
		Control	Urea single	Urea split	Entec single	Entec split	lsd (p=0.05)
K	- Biochar	65	127	132	143	134	24
	+ Biochar	65	201	205	196	228	
Mg	- Biochar	4	49	36	45	32	4
	+ Biochar	2	40	26	35	25	
Ca	- Biochar	5	35	29	33	25	3
	+ Biochar	4	32	23	29	25	
P	- Biochar	8	25	25	25	26	3
	+ Biochar	7	28	29	26	29	
S	- Biochar	4	17	17	19	16	2
	+ Biochar	2	18	15	16	18	

Discussion

Biochar addition increased the dry weight of corn tops both in the presence and absence of leaching. Several factors could have influenced this result but Streubel et al. (2011) found that the application of biochar increased the water retention capacity, as well as increasing nutrient availability, reducing N loss via emission and reducing the loss of nitrate by leaching. Yeboah et al. (2011) observed improved N recovery of 11% from an addition of 120 kg N/ha with biochar application in a sandy loam soil but no effect on a silt loam soil.

The significant reductions in %N recovery foundin the urea single treatment both in the presence and absence of biochar and in the absence of biochar in the single Entec treatment indicate a flushing of the applied N with the first watering. The lower apparent N recovery in the split fertiliser application than in the single application treatment without leaching resulted from slow early growth in the split treatments which reduced the final yield.

Tops K and P content was higher in the + biochar than in the – biochar treatments due both to higher concentrations in the tops and higher dry matter yield. The high K uptake in the presence of biochar reduced the uptake of Ca and Mg, most likely due to cation competition. There was no influence of biochar on the S and N content of the tops despite the extra 43 kg N/ha supplied in the biochar.

When the corn was grown under leaching conditions it developed slowly because of the loss of essential nutrients such as N, K, Ca, Mg and S and hence the final yield was reduced.

It is not possible to separate the nutrient effects from those of water relations in this study and in most studies of a similar nature. The biochar application rate of 10 t/ha used in this study is at the lower end of rates used in similar studies and such high application rates are likely to prove impractical, both logistically and economically. In addition, the variable chemical composition of biochar made from the same generic feedstock and from different feedstocks means that it is not possible to generalize the effects of biochar additions.

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