Geophysical Research Abstracts
Vol. 19, EGU2017-15274, 2017
EGU General Assembly 2017

Biochar may physically entrap nitrate during field aging or co-composting which become plant available under controlled conditions

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Conversion of organic biomass (agriculture/forestry residues) to biochar (BC) for carbon sequestration in soil to abate global warming has received much attention in recent years. However, apart from carbon sequestration, the incorporation of freshly produced biochars in agricultural soils have shown varying effects on soil-plant-moisture and nutrient interactions. It has been frequently reported that BC amendment may accelerate soil N transformations, reduce nitrate leaching, increase nutrient availability and soil fertility thereby increase crop yields by 10-15%. In addition, recent meta-studies suggested that BC-nitrogen (N) interactions in agricultural soils have the potential to reduce nitrous oxide (N2O) emissions by 50% with the underlying mechanisms not well understood. Also, mechanisms of BC-N sorption and desorption or plant availability of captured N in BC remain poorly understood. In this study we conducted two different experiments aiming (a) to understand the mechanism of nitrate capture by field aged (>3 years) BC (wood chip, pruning, bark and leaves (550-600°C)) and (b) to test the availability of captured nitrate by field-aged and composted BC to plants (quinoa, ryegrass) in a pot study under controlled conditions. Experiment (A): We hypothesized that N captured in the pores of BC may remain inaccessible to extraction solutions due to clogging of BC pores by the development of hydrophobic layer on BC surface following oxidation under field conditions. Therefore (i) physically breaking the structure or (ii) exerting under-pressure to water-immersed aged BC particles may allow extracting greater nitrate with the standard 2 M KCl method compared to intact particles. Study (A) encompassed 1) extraction from intact field-aged BC particles, 2) extraction after immersion in water and evacuation in vacutainers, 3) extraction after grinding of BC to powder and 4) prolonged shaking (48 hours at 80°C) of intact field aged BC particles and then extraction. Surprisingly, the ground BC particles released more than two times the amount of nitrate than standard-extracted intact BC particles (2 M KCl 1 hour shaking). Evacuation of intact BC particles did not result in a significant difference from the control either, while the prolonged shaking in hot water resulted in the maximum extracted amount of nitrate. Experiment (B): The availability of N from three different sources (nitrate supplied via field-aged BC, composted BC or $Ca(NO_3)$) applied at increasing rate of addition (control, 44, 88, 177 and 355 kg N ha-1) was tested by growing Quinoa (Chenopodium quinoa) and ryegrass (Lolium perenne L.). Interestingly, the captured N by field aged and composted BC was largely plant available and supported plant biomass production comparable to the synthetic N fertilizer. In conclusion, we argue that the BC N capture is more likely due to physical entrapment (in pores) rather than to chemical bonding. Moreover, N loading of BC may provide an option to use biochar for crop production and climate change mitigation.

Acknowledgements: CK acknowledges funding by DFG-grant KA3442/1-1 and GH was funded by DAAD and the higher education commission of Pakistan.