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# Organically treated biochar increases plant production and reduces N2O emissions: mechanistic insights by 15N tracing

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Pyrogenic carbon (biochar) offers considerable potential for carbon capture and soil storage (CCSS) compared to other, less recalcitrant soil-C additives. Recent meta-analysis demonstrated that it can significantly reduce agricultural N2O emissions. Freshly produced biochars, however, do not always have yield-improving effects, i.e. there is no immediate economic incentive for using it. Hence, combining biochar with organic nutrient-rich amendments may be a promising agricultural strategy to accelerate CCSS, but it is unclear if biochar still reduces N2O emissions, in particular when it may act as nutrient carrier.

We explored the potential of biochar to improve the GHG-cost/yield ratio and thereby its socio-economic value as soil amendment in two subsequent studies under controlled conditions: (1) A proof-of-concept study where the effects of untreated biochar were compared to those of co-composted biochar combined with stepwise improved nutritional regimes (+/- compost; +/- mineral-N application), and (2) a 15N-labeling-tracing study to unravel N exchange on biochar particles and N2O production and reduction mechanisms. Both studies were carried out in nutrient-poor sandy soils, the most likely initial target soils for biochar-CCSS strategies.

While the untreated biochar reduced plant growth under N-limiting conditions, or at best did not reduce it, the co-composted biochar always significantly stimulated plant growth. The relative stimulation was largest with the lowest nutrient additions (305% versus 61% of control with untreated biochar). Electro-ultra-filtration analyses revealed that the co-composted but not the untreated biochar carried considerable amounts of easily extractable as well as more strongly sorbed plant nutrients, in particular nitrate and phosphorus.

The subsequent 15N labelling-tracing study revealed that the co-composted biochar still (i) acted as a mineral-N exchange site for nitrate and ammonium despite its N-preloading, (ii) reduced N2O emissions significantly, although it carried dissolved organic carbon and nitrate as prerequisites for denitrification; and that it thus (iii) significantly improved the GHG-cost/yield ratio of plant production.

Our results therefore encourage further investigations on strategies where nutrient-rich agricultural waste streams are combined with biochar post-treatment. Cascading use of biochar in agriculture may have the potential to evolve into a key CCSS technology to turn agriculture from being part of the problem into being part of the solution.