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Mechanisms of nitrate capture in biochar: Are they related to biochar properties, post-treatment and soil environment?

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Biochar use in soils is assumed to increase soil fertility and the efficiency of nutrient use, particularly nitrogen. It was demonstrated recently that biochar is able to capture considerable amounts of the mobile anion nitrate which was observed in co-composted as well as field aged biochar1,2. Moreover the nitrate was not sufficiently extractable with standard methods from biochar particles; extractions had to be repeated to effectively remove the nitrate1. Subsequently the co-composted nitrate-enriched biochar stimulated plant growth due to N supply to the plants2. However, in a field study in sandy soil in Germany, a different biochar also captured nitrate, increasing the topsoil nitrate concentration and likely reducing nitrate leaching to subsoils1. This was particularly seen after a dry year in the re-picked and analysed particles. However, in the field experiment this aged, nitrate-enriched biochar did not improve crop yields3. To better understand the way biochar interacts with nitrate we undertook several laboratory experiments with 13 well characterized biochars produced from cypress, pine and grapewood at 350, 500, 700 and 900 °C including one Kon-Tiki produced grapewood biochar (600-700°C). Our results showed that (1) pure, pristine (not post-treated) biochar captured more nitrate when they were air-moist and not totally dry; that (2) letting biochar particles dry in nitrate solution forces more nitrate into biochar particles than incubating them in the solution, but (3) that shaking during drying nevertheless caused a higher nitrate uptake into biochar particles; that(4) the counter ion K+ in nitrate solution was more effective than Na+ for N-loading of biochar; (5)that drying a soil-biochar mix in nitrate solution produced a higher nitrate loading of the mixture (i.e. the biochar) than drying both components separately in the same solution; (6)that a higher biochar production temperature caused higher nitrate capture up to 700-900°C. Furthermore we found (7)that this captured nitrate was well protected against leaching, (8)that repeated drying-wetting cycles increased nitrate capture, with the amount protected against leaching remaining more or less constant; and (9) that an organic “coating” (or application of the nitrate in an organic solution, here: black tea) increased biochars’ capability of nitrate capture. Our results thus underline that the phenomenon of nitrate capture is not purely due to ionic mechanisms but may partly rely on physical interactions and the pore structure of the biochar.

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