Can combined application of biochar and nitrogen promote microbial functions and root plasticity for plant growth in low-fertile soils?

Xiaona Song1,2, Bahar Razavi3, Bernard Ludwig2, Kazem Zamanian1,5, Huadong Zang4, Yakov Kuzyakov5,6, Michaela Dippold1, and Anna Gunina2

1Biogeochemistry of Agroecosystems, University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany
2Department of Environmental Chemistry, University of Kassel, Nordbahnhofstraße 1a, 37213 Witzenhausen, Germany
3Institute of Plant Nutrition and Soil Science, University of Kiel, Kiel, Germany
4College of Agronomy and Biotechnology, China Agricultural University, Beijing 100193, China
5Agricultural Soil Science, University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany
6Agro-Technology Institute, RUDN University, Moscow, Russia

Biochar and nitrogen (N) fertilizers are frequently applied to improve soil properties and increase crop productivity. However, it remains unclear how root plasticity, soil enzyme activities, N and (phosphorus) P cycling in plant-soil system are changed after application of biochar, N or their combination. To address these questions, left and right parts of rhizoboxes were filled with silty-clay loam subsoil amended with biochar (15 g kg\(^{-1}\) soil, wheat straw, 300 °C), N (0.05 g KNO\(_3\)-N kg\(^{-1}\) soil) or a control (no amendments), resulting the following combinations (Cm): biochar/control (Cm1), N/control (Cm2) and biochar/N (Cm3). One seed of maize (Zea mays L.) was planted in the middle of each rhizobox, thus allowing roots to choose freely the growth direction. Root growth was quantified by a photographic approach constantly during the experiment (30 d), and soil enzyme activities, available N and P, root morphology and plant biomass were analyzed after plant harvest.

Maximum plant biomass was found for biochar/N application (0.91 g), whereas minimal values was for biochar/control (0.56 g). At the same time, decreased soil bulk density and increased availability of P in the biochar compartment (Cm1 and Cm3) stimulated root length by 1.4-1.8 times – an effect which was independent from the presence of N in the same rhizobox. Together with stimulated activities of β-glucosidase and leucine aminopeptidase (by 33%-39%) in presence of biochar (Cm3) compared to N, this shows the coupling of C, N and P cycles in biochar/N treated soils. Application of N (Cm2) also increased β-glucosidase activity compared to control soil, whereas root elongation stayed unaffected. Thus, combined application of biochar/N over-win benefits of biochar or N alone for plant growth, which is linked with i) the stimulation of microbial enzyme activity at the biochar locations to reduce C and N limitation for both plant and microorganisms, and ii) increasing of fine root proportion to improve N utilization efficiency in the N-treated compartment. Thus, strategy of combined biochar/N application can not only improve the above-ground biomass production, but also increase root-microorganism
interactions to overcome nutrient limitation in low fertile agricultural soils.