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Effects of organic fertilizers and biochar/organic fertilizer combinations on fertility and organic matter dynamics of a sandy soil in north-west Germany

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Biochar and biochar/organic fertilizer combinations have been recommended as soil amendments to improve plant productivity and soil properties, as well as to increase soil organic C (OC) storage. However, these claims have been largely unverified by field experiments lasting several years. To address these issues, a field experiment was established in 2012 to analyze the effects of organic fertilizers and biochar/organic fertilizer combinations (five field replicates, fully randomized block design) on the fertility and organic matter dynamics of a sandy Cambisol. In 2016, samples were taken from the 0-10 cm and 10-30 cm soil depths of the following treatments: mineral fertilizer and maize digestate that were applied both individually and in combination with 1 t/ha or 40 t/ha biochar. Further treatments were compost and 10 t/ha composted biochar. The treatments were analyzed for the plant yield and the bulk soil samples were analyzed for the pH, cation exchange capacity (CEC), OC content, microbial biomass C and the distribution of aggregate-size fractions (i.e. >2 mm, 2 mm - 250 μm, 250 - 53 μm, <53 μm). The latter were also analyzed for OC content and by FTIR. In 2012, the combination of 40 t/ha biochar+digestate accounted for about 42% higher maize (Zea mays) yields (7.9 t/ha) than the mineral fertilization treatment. For winter rye (Secale cereale) in 2013, we detected the highest yield (10.4 t/ha) for the 10 t/ha composted biochar treatment. In 2014, the highest yield for blue lupine (Lupinus angustifolius) (1.84 t/ha) was detected for the 40 t/ha biochar+digestate treatment. The first data for the soil samples indicate that the 10 t/ha composted biochar and the compost treatment are most effective in increasing the CEC, and the microbial biomass C content of the soil, while pH was not significantly affected by any of the treatments. The bulk soil OC content of the treatments receiving 40 t/ha biochar+fertilizer (digestate or mineral), 10 t/ha composted biochar, and compost has been significantly increased by 43 to 88% in the 10-30 cm depth compared to the individual application of mineral fertilizer. The OC content of the water-stable macro- (2 mm - 250 μm) and micro-aggregates (250 - 53 μm) of the treatments receiving 40 t/ha biochar+fertilizer (digestate or mineral), 10 t/ha composted biochar, and compost was increased by 12 to 120% compared to the mineral fertilizer treatment. The magnitude of the demonstrated positive effect of biochar application on crop yield depends on the type and amount of the biochar+organic fertilizer mixture and the cultivated plant species. Besides benefiting biomass production, applications of 10 to 40 t/ha of biochar+fertilizer mixtures seem to result in increased bulk soil and aggregate protected OC contents, indicating a longer lasting positive effect on the OC storage and the structural stability of this sandy soil. Cost/benefit wise, the 10 t/ha composted biochar treatment seems to be most promising for improving soil properties and crop yield, while the compost treatment seems to be the best alternative for sandy soils where biochar is either unavailable or prohibitively expensive.