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Biochar increased photosynthetic performance and biomass yield of maize by improving the plant eco-physiological water status

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Mechanistic understanding of biochar implementation in agricultural systems is mandatory to successfully employ the biochar toolbox to secure sustainable agricultural land use. We hypothesized that biochar (BC) will have positive effects by improving the plants' water status, either directly by enlarging the soil water reservoir (water holding capacity, WHC) or indirectly by impacting the plants' eco-physiological water status and water use efficiency. Furthermore we hypothesized that the combination of biochar and humic acids, which are also known to help alleviate drought stress, may create the "better biochar". In a completely randomized set-up BC (0, 1.5 and 3%; w/w), HA (0 or 8 kg ha-1) or HA-loaded biochar were thoroughly mixed with a sandy-poor soil. Maize (Zea mays var. 'Amadeo' DKC-3399) was grown in pots (6 kg pot-1) for 66 days under greenhouse conditions. Initially plants were grown at 60% WHC of the respective soil/soil-BC mixture; WHC was significantly increased by biochar addition. At day 29th, the six experimental replicates were separated into two sub-sets: one continuing with daily water replacement to 60% WHC and a second subjected to limited water supply until appearance of wilting symptoms. In the latter daily water replacement was equal to all treatments ('same rain for all'), and was kept at the verge of wilting. BC, at any rate of application (but not HA, added alone or loaded on BC) significantly improved plant water relations as indicated by increased leaf relative water content, osmotic potential, decreased stomatal resistance and increased transpiration, resulting in higher water use efficiency of productivity (WUEp). BC amendments decreased the leaf chlorophyll concentration while more nitrate remained in the soil under both water regimes. Still photosynthetic electron transport rate (ETR) of photosystem II (PSII) was improved as well as the ratio of effective photochemical yield to non-photochemical quenching (Y(II)/Y(NPQ)), indicating reduced heat dissipation. The significant BC effects on plant eco-physiological performance resulted in higher WUEp and finally higher dry biomass yield over that of the control. Although the drought treatment clearly reduced maize biomass, the relative magnitude of BC effects at both watering regimes indicated that positive effects of BC on the plant water status cannot simply be explained by larger soil water stocks alone. However, although HA addition alone improved photosynthesis performance, the effects were not large enough to result in larger maize yields. In combination with BC, any potential HA effects were dominated by BC, refuting our initial hypothesis. In conclusion, BC addition in poor sandy soils can improve eco-physiological performance and biomass yield of maize, mainly working along the plant water status pathway. However HA added alone did not improve biomass yield, nor did HA-loading produce a 'better biochar'.
Keywords: Biochar, Humic acids, Maize, Sandy soil, drought, Water holding capacity and Plant eco-physiology.