Biochar to conserve carbon and nitrogen in an arid region soil of low native organic matter

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Abstract
We investigate the effects of corncob-derived biochar on decomposition of native and fresh organic matter in an organic carbon (C) deficient Aridisol. A laboratory incubation study was conducted by using biochar produced from corncobs by pyrolysing the biomass at 400 °C. The incubation study consisted of four treatments: unamended control soil, 45 tons ha^{-1} biochar, 45 tons ha^{-1} corncob residue and 22.5 tons ha^{-1} each of biochar and residue. Soil C mineralization was quantified by measuring soil respiration periodically throughout the experiment over 54 d incubation period. The results revealed that only a very little fraction of biochar was respired, whereas a high proportion of corncob was decomposed. Biochar addition suppressed decomposition of native and fresh organic matter through negative priming effect. Compared to the raw corncob, addition of biochar with corncob residue significantly increased microbial biomass C (MBC) but decreased water extractable organic matter (WEOM) and net CO_2 efflux. Soil mineral N contents were the highest in the biochar and biochar + residue treatments. The results of this study conclude that biochar could decrease C mineralization but enhanced microbial C use efficiency and, therefore, offer an important management strategy to improve C sequestration in nutrient and organic C deficient Aridisol.

Keywords: Biochar; Carbon sequestration; Nitrogen mineralization; Microbial biomass; Aridisol

Introduction, scope and main objectives
Biochar is a carbon rich product derived from the pyrolysis of organic material at relatively low temperatures which is known to improve soil biogeochemical properties for sustainable soil management and crop production (Lehmann and Joseph, 2008). Biochar is a potentially effective strategy to increase the carbon (C) status in the soil-plant systems (Novak et al., 2009; Lal, 2016). A variety of feedstocks could be used for biochar production. Biochar stability and its effects on native and fresh organic matter are not widely known yet, especially for the soils under arid and semi-arid conditions. In this context, a microcosm study was designed to investigate the impact of corncob-derived biochar on the decomposition of indigenous and fresh organic matter.

Methodology
Surface soil (0-15 cm), used in the study, was sampled from an agricultural field under corn cultivation and had typical soil organic matter content of less than 1%. The treatments, replicated five times, included un-amended control, 45 tons ha^{-1} corncob residues, 45 tons ha^{-1} biochar and 22.5 tons ha^{-1} each of corncob residues and biochar. The microcosms, containing 40 g oven-dry equivalent soil, were incubated at 60-70% water holding capacity for 54 days and soil C mineralization was quantified by measuring soil respiration at regular intervals. After 54 days of incubation, soil samples were destructively analyzed for pH, EC, WEOM, MBC and extractable ammonium-N, nitrate-N and mineral-N contents. One way analysis of variance test was performed to test the effect of treatments on soil C and N mineralization.

Results

The results demonstrated that application of biochar had significant effects on soil chemical and biological properties. Biochar significantly ($p<0.05$) reduced decomposition of fresh organic matter and resulted in lower cumulative basal respiration by inducing negative priming effect. Cumulative soil respiration for the biochar treated soil were also less than that from the unamended control treatment, however, it was not statistically significant (Fig 1).

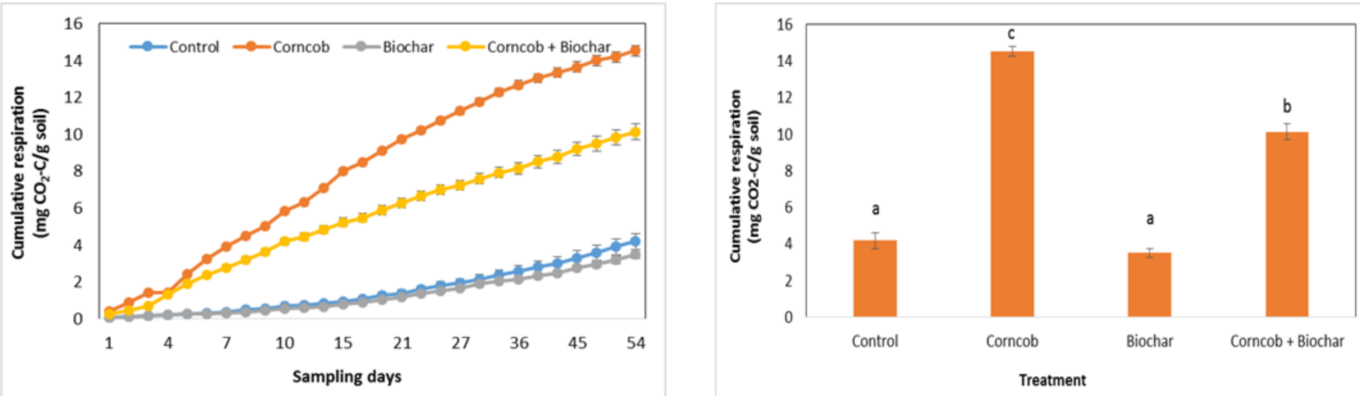

Fig. 1: Effect of biochar alone and/or in combination with fresh corncob on soil cumulative respiration (mg CO2-C/g soil). Values are means of five replicates and contains standard errors of means (n=5). Bars with different letters indicate significant differences at $p<0.05$. Source: Riaz et al. (2017). Geoderma (In revision).

Discussion

The decrease in C mineralization in biochar amended soil could be due to the strong adsorption of soluble soil C, nutrients and microbes on the surface of biochar resulting in enhanced C use efficiency and reduction in activity of C mineralization enzymes (Lehmann et al., 2011). Another mechanism for the reduced rate of C mineralization could be CO_2 adsorption on biochar surface as carbonate (Joseph et al. 2010). Low decomposition rates of biochar have also been reported in many studies (e.g. Kuzyakov et al., 2009; Zavalloni et al., 2011; Dempster et al., 2012). The decrease in mineral N in the presence of biochar could indicate that organic N was assimilated into microbial biomass rather than being mineralized (Prayogo et al., 2014). Therefore, biochar could reduce the rates of N_2O emissions, NH_3 volatilization and N leaching by immobilization and, concurrently, increasing the rate of N fixation by biological organisms (Clough et al., 2013).

Conclusions

The understanding of C and N mineralization is pre-requisite to mitigate negative effects of the climate change on soil quality and agricultural sustainability. The results of this study conclude that biochar could decrease C mineralization but enhanced microbial C use efficiency and, therefore, offer an important management strategy to improve C sequestration in nutrient and organic C deficient alkaline soil. The results also imply that the amendment of corncob residue with biochar had a potential to conserve soil N by decreasing the rate of the soil nitrogen leaching and N_2O emission by N immobilization and sorption to biochar.

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