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Combined biochar and nitrogen fertilizer change soil enzyme and microbial activities in a 2-year field trial

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ABSTRACT

Treating soil with a combination of nitrogen (N) and biochar (BC) has often been suggested as an approach to enhancing soil quality. In the present study, we therefore conducted a two -year randomized two-factorial field experiment in order to explore optimal N fertilizer management strategies in the context of BC application to calcareous soil, with a focus on both microbial activities and soil nutrient levels. Maize straw BC (0 or 22.5 t ha^{-1}) was applied to the soil once prior to the planting of wheat, with four different N fertilizer concentrations (0, 150, 225, and 300 kg ha^{-1}) being applied to experimental plots. We found that N fertilizer addition resulted in significant reductions in soil pH and available phosphorus (AP) levels, whereas soil phosphatase activity was increased by such treatment. Relative to treatment with only BC or N in isolation, the combined application of both N and BC led to significant increases in soil organic carbon (SOC), total nitrogen (TN), dissolved organic carbon (DOC), total dissolved nitrogen (TDN), and available potassium (AK) levels, while also enhancing the activity of C- and N-cycling enzymes. In contrast, this combination treatment did not impact soil pH or phosphatase activity. The application of BC did not significantly affect microbial biomass, but it was associated with changes in overall microbial community structure, including a decrease in the fungi/bacteria ratio and the Gram-negative/Gram-positive bacteria ratio. These changes were also linked to increases in relative actinomycetes abundance and an elevated cy19:0/18:1ω7c ratio. These results suggested that combined N and BC application is thus not conducive to rapid fungal growth, with soil AK, pH, TN, and TDN being the primary factors that affected soil microbial community structure. While BC did significantly increase the βG:(NAG LAM) ratio, this was not associated with any N-mediated microbial restriction. Overall, our findings conclusively demonstrate that combined BC and N fertilizer application can enhance soil quality while supporting a more stable microbial community structure and more active soil biological activity.

1. Introduction

Biochar (BC) is a term used to refer to carbon-rich organic residues that are generated via the pyrolysis of organic compounds under low-oxygen conditions. Owing to the C-rich nature of BC and the fact that it can persist for extended periods of time, there has been substantial research interest in the application of BC as a means of enhancing soil structure and quality [1,2]. BC application has been shown to both directly affect soil properties owing to its mineral contents and adsorptive properties, while also indirectly altering soil pH and biological activity [3,4]. BC is generally rich in minerals including calcium, potassium, and phosphorus that are readily released into the soil during soil amendment [5]. When applied to low-pH soil, BC can also increase local soil pH, thereby altering the binding characteristics of important cationic and anionic nutrients and enhancing the availability of macronutrients including N and P [4,6]. BC application can further bolster soil anion and cation exchange capacity while reducing N leaching [7], and BC-modified soil has been additionally proposed to exhibit increased water-holding capacity that bolsters N retention [8]. However, some studies have provided contrasting evidence suggesting that BC application can adversely impact soil nutrient availability, potentially resulting in microbial N immobilization and thereby decreasing soil

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