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Responses of soil nutrients and microbial activities to additions of maize straw biochar and chemical fertilization in a calcareous soil

Dali Song[a,1], Jiwei Tang[a,1], Xiangyin Xi[b], Shuiqing Zhang[c], Guoqing Liang[a], Wei Zhou[a], Xiubin Wang[a,*]

[a] Institute of Agricultural Resource and Regional Planning, Chinese Academy of Agricultural Sciences, Key Lab of Plant Nutrition and Nutrient Cycling, Ministry of Agriculture, Beijing 100081, China
[b] Southwest University, Chong Qing 400715, China
[c] Institute of Plant Nutrient and Environmental Resources, Henan Academy of Agricultural Sciences, Zhengzhou 450002, China

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ABSTRACT

Biochar addition to soil has been proposed as a strategy to enhance soil quality and crop productivity. However, little is known about responses of soil nutrients and microbial activities to additions of chemical fertilizer and biochar with different pyrolysis temperatures. To investigate the effects of control (CK), chemical fertilizer (NPK), and NPK with maize straw biochar (MC) produced at 300, 450, and 600 °C (NPK + MC300, NPK + MC450, and NPK + MC600) on crop yield, soil nutrients, soil enzyme activities, and microbial attributes in a calcareous soil, we conducted a pot experiment. The results showed that the NPK + MC450 treatment obtained the highest wheat yield and N, P, and K uptakes. The NPK + MC300 and NPK + MC450 treatments decreased significantly the soil available K content and increased the C/N ratio, contents of soil organic carbon (SOC) and available P compared to the NPK + MC600 treatment. The NPK + MC450 treatment promoted the increases in soil C- and N-cycling enzyme activities. The total N content, soil MBC and MBN were the main driving factors affecting soil enzyme activities. All the NPK plus MC soils significantly reduced the relative abundance of soil fungi and enhanced soil nutrient contents (excluding soil inorganic nitrogen) and total phospholipid fatty acid concentrations. A redundancy analysis revealed that the changes in soil microbial community depended mainly on the contents of MBC, MBN and available K as well as the C/N ratio. This study provides clear evidence that the co-application of NPK fertilizers and MC produced at 450 °C was more efficient for improving soil quality and potential crop productivity.

1. Introduction

Biochar (BC) is produced by the pyrolysis of organic biomass under relatively low temperature (< 700 °C) and oxygen-limited conditions. Biochar contains large amounts of carbon and macro or micro-nutrients depending on the feedstock and pyrolysis temperature [1]. Some studies have reported that BC as a soil amendment has considerable potential for enhancing soil fertility and crop productivity [2]. The enhancement of soil fertility as a result of BC addition has been attributed to increased soil electrical conductivity (EC), soil organic carbon (SOC), and the soil holding capacity of nitrogen (N), phosphorus (P), and potassium (K), changes to soil pH, or direct nutrient contributions from the BC [1,3,4]. However, other studies have shown either negative effects or no effect of BC on soil fertility parameters and C storage potential, such as short-term reductions in soil mineral N availability [5,6] and decreased performance of crops on calcareous soils [7]. Therefore, the effects of BC on soil quality and nutrient cycling are uncertain.

Soil microbes play very important roles in soil organic matter (SOM) decomposition, nutrient cycling, and other relevant functions [8]. Soil microbial biomass C and N (MBC and MBN) and enzyme activities are related to soil fertility and agricultural productivity [9,10]. Nevertheless, microbial responses to BC addition are uncertain about both the nature of BC and experimental conditions. The meta-analysis of Zhou et al. [11] showed that BC amendments to soil increased MBC by 26% and MBN by 21% for the 413 and 106 pairs of data reported, respectively. Interestingly, the laboratory incubation, pot and field experiments showed that BC addition could increase soil MBC content. Soil MBN increased significantly only in incubation studies (mean: 42%), but did not differ significantly from controls in pot or field studies. Whereas, the divergent change in MBN across the experimental types

* Corresponding author.
E-mail address: wangxiubin@caas.cn (X. Wang).
[1] Dali Song and Jiwei Tang are the co-first authors.

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