Advances in
Biotechnology & Microbiology
ISSN 2474-7637

Juniper Publishers
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Mini Review
Volume 9 Issue 4 - June 2018
DOI: 10.19080/AIBM.2018.09.555770

Adv Biotech & Micro

The Role of Biochar in Sustainable Agriculture and Environment: Promising but Inconsistent

Wenqiao Yuan[1*], Xiangang Meng[2*] and Arthur James[3]

[1]*Department of Biological and Agricultural Engineering, North Carolina State University, USA*

[2]*School of Chemical and Biological Engineering of Lanzhou Jiaotong University, PR China*

[3]*Department of Mechanical Engineering, Universidad Tecnológica de Panamá, Panama*

Submission: January 30, 2018**; Published:** June 08, 2018

***Corresponding author:** Wenqiao Yuan, Department of Biological and Agricultural Engineering, North Carolina State University, 265 Weaver Labs, 3110 Faucette Drive, Raleigh, NC27695, USA, Tel: 919-515-6742; Fax: 919-515-9476; Email: wyuan2@ncsu.edu

Xiangang Meng, School of Chemical and Biological Engineering of Lanzhou Jiaotong University, Lanzhou, Gansu Province, PR China, 730070, Tel: +86-931-4956524; Email: mengxg@mail.lzjtu.cn

Introduction

Biochar, an end- or co-product of biomass thermochemical conversion processes, has been identified as a key strategy to sequester carbon, produce energy, increase soil and crop productivity, and improve environmental quality [1-4]. The application of biochar to soil contributes to the sequestration of carbon because carbon captured from the atmosphere by the biomass is eventually retained in the soil. In addition, the utilization of biochar may improves oil quality because of its sorption capabilities that help to retain nutrients and promote the growth of microorganisms in the soil. Due to its high surface area, biochar can promote the retention of nutrients within its micro-pores. As result, the needed rate of fertilizers can be reduced, which impacts the environment and agro-economy in a positive way. Biochar may also increase water retention, reduce leaching of nutrients and lower the acidity of the soil [5,6].

Biochar Effects on Soil Properties and Crop Production

However, field studies have shown mixed effects of biochar on crop production. Crop yields may [7] or may not [8] increase with the application of biochar. This can depend on soil type and fertilizer management. Studies have also shown mixed effects of biochar applications on soil physical and biological quality. Busscher et al. [9] found that addition of pecan shell biochar to loamy sand reduced soil penetration resistance, but had no effects on soil aggregate stability and water infiltration. Chan et al. [10] reported that tensile strength of soil cores decreased, suggesting that biochar application can reduce risks of soil compaction.

Biochar Effects on Greenhouse Gas (GHG) Emissions

The effect of biochar addition on GHG emissions, including CO_2, CH_4 and N_2O, has also been broadly reported with some varied results. Studies have generally shown a consistent reduction in N_2O emission [11]. In contrast to the decrease in N_2O emission, in most cases, a wide variation in the rates of CO_2 emissions from soils treated with biochar has been reported in the literature. A 100-day incubation study conducted by Spokas & Reicosky [12] demonstrated that when three different soil types were amended with 16 types of biochars, three kinds of effects were observed. This included repression, no change, and stimulation of CO_2 respiration due to biochar addition. The emissions of CH_4 in soils are considered to be repressed due to biochar amendment in most cases. Liu et al. [13] observed that CH_4 emission from the paddy soil amended with biochar was reduced by 91.2%, compared with those without biochar. In contrast to these findings showing methane emission reduction, Castaldi et al. [14] investigated the impact of biochar application to a Mediterranean wheat crop on greenhouse gas fluxes, and concluded no significant differences of CH_4 fluxes among different biochar treatments and the control.

What are Missing?

As previously described, biochar has the potential to improve the sustainability of agriculture and environment. However, inconsistent results are often found in literature. One important reason is that biochars are not all the same. Biochars produced from different feedstocks (e.g., woody biomass vs. crop residues), different processes (e.g., slow pyrolysis vs. fast pyrolysis vs. gasification), or different operating conditions (e.g., airflow rate, biomass particle size, moisture content) may have significantly different properties [15]. Once applied to soils, such vastly different biochars may result in inconsistent conclusions about GHG emissions and crop performance. The authors suggest that standards regarding biochar properties should be established. Another reason is that the way biochar is applied can vary significantly based on the type of soil and the application rate of biochar. Opposite effects of biochar can be observed on clay and sand. It is apparent to expect that the water retention capability of clay may not be improved by biochar application, however, sand will benefit significantly by adding biochar to keep moisture in the micropores. On the other hand, biochar can help clay to reduce soil compaction, but the benefit may be negligible in sand. The results are also dependent on the application rate of biochar. A previous study demonstrated that 2% biochar added to sand helped sand retain moisture and supported algal growth, however, more than 2% biochar did not show any positive effects [16]. Thus, biochar application procedures should be considered for comparable results.

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How to cite this article: Wenqiao Y, Xiangang M, Arthur J. The Role of Biochar in Sustainable Agriculture and Environment: Promising but Inconsistent. Adv Biotech & Micro. 2018; 9(4): 555770. DOI: 10.19080/AIBM.2018.09.555770.