Pedosphere **25**(5): 631–638, 2015
ISSN 1002-0160/CN 32-1315/P

Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Editorial

Application of Biochars for Soil Constraints: Challenges and Solutions

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(Received June 8, 2015; revised July 22, 2015)

ABSTRACT

Biochar addition to soil is currently being considered as a means to sequester carbon while simultaneously improving soil health, soil fertility and agronomic benefits. The focus of this special issue is on current research on the effects of biochar application to soil for overcoming diverse soil constraints and recommending further research relating to biochar application to soil. The biochar research has progressed considerably with important key findings on agronomic benefits, carbon sequestration, greenhouse gas emissions, soil acidity, soil fertility, soil health, soil salinity, *etc.*, but more research is required before definitive recommendations can be made to end-users regarding the effects of biochar application across a range of soils, climates and land management practices.

Key Words: agronomic benefits, carbon sequestration, greenhouse gas emissions, pH, soil fertility, soil health, soil salinity

Citation: Solaiman Z M, Anawar H M. 2015. Application of biochars for soil constraints: Challenges and solutions. *Pedosphere*. **25**(5): 631–638.

INTRODUCTION

In recent years, research on biochars has focused on enhancing soil fertility, carbon sequestration, activities of microorganisms, agricultural production, mitigating climate change, soil contamination and many other aspects (Chan *et al.*, 2007; Solaiman *et al.*, 2010; Biederman and Harpole, 2013) (Table I). Given the rapidly growing interest in biochar, this special issue includes original research as well as review articles exploring different aspects of the applications of biochar for alleviation of soil constraints and for improving microbial activities, soil fertility and crop production. Furthermore, characterization of biochar properties and functions associated with biochars, including improvement in soil biology and fertility, are elucidated.

FEATURES OF THIS BIOCHAR SPECIAL ISSUE AND FUTURE RECOMMENDATIONS

Jaafar *et al.* and Lanza *et al.* studied responses in soil microbial activities, mineralization of native soil organic carbon and soil respiration to biochar and soil amendment with biochar, while another article by Jaafar *et al.* studied the interactions of biochars with four different agricultural soils. Mete *et al.*, Hall and Bell, Joseph *et al.*, Blackwell *et al.* and Kongthod *et al.* studied the effects of 1) biochar and NPK fertilizer, 2) biochar and compost, 3) enriched biochars containing nanophase magnetic iron particles, 4) mineral fertiliser and biochar mineral complex, 5) biochar and organic soil amendments and 6) nutrients in biochar on plant growth, nutrient uptake, mycorrhizal colonisation and soil quality improvement in different soil types. Jun *et al.* and Mia *et al.* investigated the influence of pyrolysis temperature on the properties of rice straw-derived biochars and the characteristics of three biochar production kilns. Hossain *et al.* and Yao *et al.* developed wastewater sludge biochar and biochar NPK fertilisers, respectively, and tested their effects on plant growth, yield and bioaccumulation of metals. Anawar *et al.* reviewed and Fan *et al.* studied the effects of biochar and super absorbent polymer amendment on soil development, plant growth and remediation of contaminants on the mining, industrial and sewage wastes and substrate. Finally, Joseph *et al.* studied how feeding biochar to cows can provide an innovative solution for

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TABLE I

Biochar impacts on soil, plant and environmental factors

Statement	Description	Reference(s)
Increasing crop production	Several studies observed crop yield increases generally for a limited time period (1–2 years), but in some cases the negative effects have also been reported	Loveland and Webb, 2003; Chan *et al.*, 2007
Increasing arbuscular mycorrhizal colonisation linked to increases in crop production	This effect is possibly due to alteration of soil properties, indirect effects on mycorrhizae through effects on other soil microbes, plant-fungus signalling interference and detoxification of allelochemicals on biochar, and provision of refugia from fungal grazers	Warnock *et al.*, 2007; Solaiman *et al.*, 2010
Acting as microbial habitats	Biochar increases soil microbial biomass and microbial activity and the degree of the response appears to be dependent on nutrient availability in soils	Steiner *et al.*, 2008; Jaafar *et al.*, 2014
Increasing earthworm abundance and activity	Earthworms have been shown to prefer some soils amended with biochar than those soils with no biochar addition	Topoliantz and Ponge, 2005; Van *et al.*, 2006
Liming effect	Biochars have neutral to basic pH and several field experiments show an increase in soil pH after biochar application when the initial pH is low, but there may be different pictures on alkaline soils.	Cheng *et al.*, 2006; 2008
Increasing soil cation exchange capacity (CEC)	Biochar increases CEC of soil and the efficiency and duration of this CEC increase after addition to soil need to be explored	Cheng *et al.*, 2006; 2008
Influencing N cycle	Emissions of N_2O depend on effects of biochar addition on soil hydrology and associated microbial processes, of which the mechanisms largely remain to be explored	Yanai *et al.*, 2007
Decreasing soil microbial biomass and N mineralisation	The activity of the microbial community decreases with the addition of biochar through decreased soil organic matter decomposition and N mineralisation which may have been caused by the decreased microbial biomass C	Dempster *et al.*, 2012
Influencing seed germination and early growth of seedlings	Biochar types and application rates influence wheat seed germination and seedling growth and germination and early root growth of mung bean and subterranean clover differ from those of wheat	Solaiman *et al.*, 2012
Influencing soil salinity	Biochars sorb salts and mitigate salt stress to plants, demonstrating that biochars can ameliorate salt stress effects on plants, suggesting uses of biochar to mitigate salinity in agricultural soils	Thomas *et al.*, 2013; Lashari *et al.*, 2015
Influencing soil pH dynamics	The pH of biochar is influenced by the type of feedstock, production temperature and production duration; biochar types, application rates, and their interactions have significant effects on soil pH both in acidic and alkaline soils	Liu and Zhang, 2012; Chintala *et al.*, 2014
Mobility and loss of biochar in soil profile	Biochar mobility and loss through the soil profile and into the water resources have been scarcely quantified and transport mechanisms remain poorly understood	Sohi *et al.*, 2009
Biochar loss with soil by erosion	Top-dressing biochar to soil is likely to increase erosion of the biochar particles with soil both by wind and water	Jones *et al.*, 2008
Influencing soil organic matter dynamics	Various relevant processes are acknowledged, but the ways these processes are influenced by combinations of soil, climate and management factors remain largely unknown	Marschner *et al.*, 2008
Influencing soil-water holding capacity	Adding biochar to soil can have direct and indirect effects on soil water retention, which can be short or long lived, and can be negative or positive depending on soil type	Sohi *et al.*, 2009
Priming effect	Inconclusive evidence of a possible priming effect exists and covers only the short term and very restricted samples of biochar and soil types	Kuzyakov *et al.*, 2000
Role of biochar pore size and connectivity	Although pore size distribution in biochar may significantly alter key soil physical properties and processes (*e.g.*, water retention, aeration and habitat), experimental evidence on this is scarce	Cheng *et al.*, 2006
Influencing soil hydrophobicity	The influences of biochar on soil water repellency and hydrophobicity remains largely untested	Doerr *et al.*, 2000
Decomposition of biochar enhanced by agricultural management practices	Agricultural management practices (ploughing, sowing, planting, *etc.*) with biochar may influence (accelerate) the breakdown of biochar in the soil, thereby potentially reducing its C storage potential	Lehmann *et al.*, 2003

(to be continued)