Final Project Report

(April 2013 to March 2017)

Production of biochar from various biowastes and its soil application for sustainable soil management and mitigation of GHG emission

Funded by

University Grants Commission
New Delhi

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Annexure I

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1. Introduction:

In order to achieve food security various drastic steps were taken in the past few decades which had very adverse effect on the environment such as clearing of forest cover and indiscriminate use of harmful chemicals (pesticides, insecticides, etc.,). Also, many researchers have reported the emission of Green House Gases (GHGs) from the agricultural field, though the soils contain a relatively small proportion of the global soil carbon pool, but this quantity is significant, relative to the annual atmospheric flux [1]. Thus, in order to tackle these problems use of a single technology cannot help to attained a solution but require different approaches along with the implementation of adequate regulations and use of biochar (charcoal-like material) for agriculture and environmental management is one such approach. Apart from mitigation of climate change and sustainable option for management of waste; it is believed that use of biochar in agriculture will help us to achieve food security.

Biochar is an organic material produced via the pyrolysis of C-based feed stocks (biomass) and is best described as a "soil conditioner". Biochar is produced from biomass and is predominantly composed of recalcitrant organic C with contents of plant micro- and macro-nutrients retained from the original feedstock. Research has shown that applying biochar to soil may be more desirable as it can increase soil organic carbon (SOC) and improve the supply of nutrients to plants, therefore enhancing plant growth and soil physical, chemical, and biological properties [1-3]. Biochar incorporation can alter soil physical properties such as structure, pore size distribution, and density, and has implications for soil aeration, water holding capacity, plant growth, and soil work ability [4]. Biochar as a bulking agent can increase microbial activity and reduce nutrient losses during composting which is attributed to the high adsorption capacity during composting. [5] Carbonization/Pyrolysis reduces the original biomass to a size dependent on the thermal condition undergone by the biomass raw material and the characteristics of biomass. Biochar contains 50% of the original carbon which is highly recalcitrant in nature. This biochar is retained in the soil as much as the way the rich, fertile soils called *terra preta* (dark earth) soils were created through a process similar to pyrolysis in the Amazon Basin thousands of years ago.The long residence time of biochar in soil makes it an important C sequestration tool. During the conversion of biomass to biochar, about 50% of the original C is retained in the biochar, which offers considerable opportunity for creating a C sinks [6].

Developing country like India is under tremendous pressure to strike a balance between both development and conservation or protection of environment. In this regard, production of biochar from waste and its subsequent soil application for sustainable soil management can emerge as a solution. Since agriculture is the major source of occupation, it becomes very important to incorporate new technologies to improve crop productivity having least adverse effect on environment. According to Ministry of New and Renewable Energy (MNRE), Govt. of India's report about 500 million tons of agro-residue is generated each year and about 120–150 million tons surplus biomass is available [2]. Thus, production of biochar from waste seems to be a viable option as India has a vast source of feedstock.

Objectives:

1. To assess the physic-chemical properties of biochar and the effects of different feed stocks and variations in the pyrolysis process on the final composition and properties of biochar.

2. To assess the impact of biochar application on soil, plant growth and its role in the reduction of emission of GHGs from soil as well as carbon sequestration.

Reference:

1. Glaser, B.; Lehmann, J.; Zech, W. 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal—A review. Biology and Fertility of Soils 35:219-230.

2. Lehmann, J.; da Silva, J.P., Jr.; Rondon, M.; Cravo, M.S.; Greenwood, J.; Nehls, T.; Steiner, C.; Glaser, B. 2002. Slash-and-char—A feasible alternative for soil fertility management in the central Amazon? In: Proceedings of the 17th World Congress of Soil Science; Bangkok, Thailand, 449:1-12.

3. Rondon, M.A.; Lehmann, J.; Ramirez, J.; Hurtado, M. 2007. Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. Biology and Fertility of Soils 43:699-708.

4. Downie, A.; Crosky, A.; Munroe, P. 2009. Physical properties of biochar. In: Biochar for environmental management: Science and technology. Eds. J. Lehmann and S. Joseph. Earthscan, London; Sterling, VA: 13-32.

5. Dias, B.O., C.A. Silva, F.S. Higashikawa, A. Roig, and M.A. Sanchez-Monedero. 2010. Use of biochar as bulking agent for the composting of poultry manure;effect on organic matter degradation and humification.

6. Lehmann, J. 2007. Bio-energy in the black, Frontiers in Ecology and the Environment, vol 5, pp381–387.

Annexure II

SUMMARY

Important highlights

- The twin objective of sustainable management and utilization of waste biomass was achieved via thermo-chemical conversion of biowaste. The target product of the present study i.e. biochar holds enormous importance from sustainable agricultural production point of view.
- The recalcitrance index and carbon sequestration potential of the various biochar produced were assessed during the study period.
- Biochar application in soil has reportedly improved the soil physical, chemical and biological properties on a long term basis. Higher fertilizer use efficiency of plants grown in biochar applied soils is also reported and is an indication of its all-round implications on sustainable soil management for agricultural production.
- Further, reduction of CO_2 gas emission (GHG) from agricultural soils applied with biochar was observed during the incubation study.

Observations and findings of the research work

In the current study four different biowastes were taken i.e., *Parthenium hysterophorus* (PAR), *Jatropha curcus* deoiled cake (JCDC), *Jatropha curcus* seed cover (JCSC) and *Pongamia glabra* deoiled cake (PGDC) for production of biochar through pyrolysis. The biochar were produced at a temperature range of 350-650 ^{o}C at a constant heating rate of 40 ^{o}C/min. The study suggest that the biochar produced at higher temperature showed higher degree of stability against degradation through microbes hence greater carbon sequestration potential. This finding was supported by both crystalinity index and recalcitrance index obtained from XRD and TGA analysis of the biochar. Both pH and electrical conductivity (EC) increased with the increase in the production temperature. Though increase in pH is beneficial for acidic soil but high EC have negative impact on plant nutrition and growth. Biochar produced from all the feedstocks showed an increase in Cation exchange capacity (CEC) at 450 °C which decreases with the increase in production temperature. CEC is also one of the important measures to assess the suitability of biochar for soil application as higher CEC means low nutrient leaching, thus biochar produced at 450 ^{o}C is a strong candidate for soil amendment for agronomic purposes.

The soil was amended with biochar with two different fertiliser regimes i.e., full dose of recommended and half dose of the recommended dose of fertiliser for Toria TS 67 and Ranjit cultivation. The soil physicochemical analysis both before and after biochar application were studied to assess the effect of biochar on soil. Biochar addition to the soil resulted in significant changes in soil chemical and physical properties, including increases in C, N, pH, and available P. From the two way ANOVA analysis done at 5% confidence level, it was revealed that there was no significant difference observed in toria and Ranjit yield between half dose of fertilizer and full dose of fertilizer, while a significant difference was observed among the different levels of biochar amended soil. The interaction effect was also not significant. The highest average yield was observed in soil amended with 5 t/ha biochar in both half and full dose of recommended fertilizer treatment. The average yield in case of toria during the three year for 5t/ha treatment ranged between 332.23-521.6 kg/ha and 243.31-442.78 kg/ha for full dose and half dose of recommended dose of fertilizer, respectively. The average yield in case of Ranjit for 5t/ha treatment ranged between 2918.09-3626.86 kg/ha and 2788.89-31.86.58 kg/ha for full dose and half dose of recommended dose of fertilizer, respectively. Thus, it can be concluded that the suitable rate of biochar application for this region is 5 t/ha.

PUBLICATIONS

1. Bordoloi, N., Narzary, R., Chutia, R.S., Bhaskar, T., Kataki, R. (2015). Pyrolysis of *Mesua ferrea* and *Pongamia glabra* seed cover: Characterization of bio-oil and its sub-fractions. ***Bioresource Technology***, 178: 83-89.
2. Narzari, R., Bordoloi, Neon J., Sarma, B., Gogoi, L., Gogoi, N., Borkotoki, B., Kataki, R. (2017). Fabrication of bio-carbons obtained from valorization of biowaste and evaluation of its physicochemical properties. ***Bioresource Technology***, 242: 324-328.
3. Narzari, R., Bordoloi, N., Chutia, R.S., Borkotoki, B., Gogoi, N., Bora, A. and Kataki, R. Biochar-an overview on its production, properties and potential benefits. In: Biology, Biotechnology and Sustainable Development, (Ed. Choudhury, H.), Research India Publications, Delhi, 2015, pp. 13-40 (ISBN: 978-93-84443-19-1).