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Biochar – an Effective Tool to Abate Climate Change and Ensure Sustainable Agriculture

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ABSTRACT *An excess emission of green house gases exerted a negative impact on global climate and carbon dioxide (CO_2) is one among the gases responsible for global warming. Sequestration of atmospheric carbon to the soil is a challenging task for the scientific community to mitigate the rising concentration of atmospheric CO_2. Sustainable agriculture is also the need to the hour to feed the growing population with safe and nutritious feed but the large dependency of agriculture on fossil fuel based fertilizers again led to environmental degradation. In this paper, the beneficial effects of use of pyrolysis derived biochar are discussed by considering the research conducted world wide. An attempt has been made to recommend the relevant measures to policy makers and research systems in order to avail the multiple benefits of biochar interms of carbon sequestration, soil productivity enhancement, waste management, global climate change mitigation and so on.*

Introduction

The two major aspects viz., global climate change and sustainable agriculture are the hot topics across the globe for discussion in recent years in order to save the mother earth and to provide safe, secured nutritious food to the mankind. In order to offset the challenges of climate change, the emission of global warming gases viz., CO_2, CH_4, N_2O from different sources needs to be reduced. Currently biomass burning accounts for 10% of global CH_4 emission and 1% of N_2O. Application of biochar can significantly decrease CO_2 emission from soil by considerably lowering its rate of decomposition as suggested by the high stability of biochar. Development and implementation of productivity-increasing farming technologies that are truly sustainable in the sense that they do not themselves inflict damage on the soil, water and ecological resources as well as on the atmospheric conditions on which future food output depends is essential to maintaining food security and productivity (FAO 2009). Hence a review on practical aspects of biochar production, characteristics, utility in agriculture and its effect on mitigating global climate change by carbon sequestration has been undertaken to find out the research lacuna and also to suggest the measures to be undertaken by policy makers and scientists before going for large scale application of biochar in global context and in particular in developing countries like India.

The processing of Biochar making – Pyrolysis

Biochar is commonly produced through the process known as pyrolysis in which the organic materials like crop stubbles, wood chips, poultry litter waste, municipal wastes are subjected to heat with much reduced oxygen levels. Pyrolysis converts easily broken down organic matter into a highly stable form of carbon. Worldwide 41 million tonnes of Biochar is produced annually (McHenry, 2009). Though many of the crop residues well utilized as livestock feed and some quantity used in generation of thermal energy, a sizable quantum of farm waste are dumped as waste and it poses serious environmental issues like occupying space and create environmental pollution as it takes more time to decay under natural conditions. Most of the times, the burning of plant derived biomass by natural fires or man induced accounts for major green house gas emission hence a reduction of biomass dumping and prevention of fire is necessary.

In these circumstances making biochar by pyrolysis process would be the reliable option to minimize the level of green house gases in the environment; and also biochar could be potentially used in agriculture as soil amendment. Pyrolysis can occur on many different scales; from simple, low input traditional kilns to large, highly efficient industrial plants. Humans have used temporary pits and kilns constructed from earth, stones and wood for char production for thousands of years (Pratt and Moran, 2010). These kinds of kilns are low cost method of producing char recommended for use in developing countries. However the International Biochar Initiatives, UK after series of trails and modifications designed several models of char producing machines in the name of 'Carbon Catchers' with the production capacity of high, medium and low quantities.

Characteristic and composition of Biochar

The physical characteristics and chemical composition of biochar and its potential application to agricultural soils or carbon sequestration were highly dependent on the type of feedstock and temperature during pyrolysis. The elemental composition of biochar includes carbon (more than 60%), nitrogen, hydrogen and other nutrient elements such as Ca, Mg, Na, Si. In general with increasing pyrolysis temperature from 300 to 800°C, the carbon content of biochar will increase with the reduction on nitrogen and hydrogen content. The bulk composition of biochar is dominated by condensed aromatic rings and a few functional groups making it resistant to decay. Due to its aromatic structure, biochar carbon is also chemically and biologically more stable than carbon in the original biomass. This has important implications for carbon sequestration and is the reason there is so much interest in Biochar as a climate mitigation tool. The ash content of biochar varies from 1 to 24 per cent depending on the feedstock used. The woody feedstocks generally produce char with less ash content while some straws and grasses are high in silica and produce char with more ash (Joseph *et al*., 2009). If the Biochar is intended for agricultural use the high ash content of biochar would be the ideal trait as it is the rich source of potash to the plants.

The structure of biochar can influence some of its quality characteristics. The porosity and surface area of biochar are particularly important and have a large role in deter-

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mining its end use. This has potentially significant effects on water holding capacity, adsorption and retention of nutrients (Downie *et al.*, 2009 and Sohi *et al.*, 2010). But the mechanisms of increased water holding capacity of soils amended with biochar are not well understood. It is also reported that low temperature pyrolysis condition may produce biochar suitable for use as nitrogen fertilizer substitute (Day *et al.*, 2005) while biochar produced at high temperatures showed adsorption of heavy metals, herbicides and pesticide particles in soil.

The nutrient retention capacities of biochar depend on their cation exchange capacity and anion exchange capacity. Biochar has an appreciable anion exchange capacity and therefore it can absorb anion nutrients such as nitrate and phosphate. Research also revealed that biochar produced at low temperatures have a high cation exchange capacity, while those produced at a high temperature of more than 600°C have limited or no cation exchange capacity (Chan *et al.*, 2007). Hence the biochar intended for use as soil amendment should not be produced at high temperatures. The biochar with high cation exchange capacity have the ability to adsorb heavy metals and other contaminants such as pesticide and herbicide particles from the soil ecosystem (Navia and Crowley, 2010). Though the use of biochar for environmental remediation is evidenced, the other school of thought is that, it could adversely affect the efficacy of agrochemicals such as herbicides and pesticides (Kookana, 2010). Hence, the research on these areas must be focused before recommending for wide spread application of biochar where the agriculture is being practiced intensively involving hybrids, synthetic fertilizers and plant protection chemicals.

Generally biochar is alkaline in nature and may have the effete of raising the soil p^H to which they are added. The p^H of biochars may range from 4 to 12 depending on the feedstock used and pyrolysis condition.

Application of Biochar in Agriculture

The addition of biochar can dramatically enhance organic matter content of soils and thereby improved soil fertility. There are number of studies show that the incorporation of biochar in soils influences soil structure, texture, porosity, water holding capacity, congenial condition for soil microflora and so on. Based on these favourable situations available for plant growth and development, it could be hypothesized that application of biochar will enhance cop yield and quality. But this hypothesis has to be proved by conducting location specific, crop specific field trials using biochar. The quantum of biochar to be applied per unit area has to be optimized. Field trials using biochars in the different parts of the world starts since 1980 and mostly focused on tropical and semi-tropical regions of South America and South East Asia (Blackwell *et al.*, 2009). Owing to the differences in Biochar its characteristics and potential applications, limited information is available to farmers on how best to apply it. The options available for applying biochar to the agricultural fields or crops are deep banding with manures or compost, applying through slurry and spreading by hand or machine; however most of the methods have not been extensively studied. Besides strategies on timing and location of biochar application need to be developed.

It is well corroborate that Biochar application favours microbial consortia in soil ecosystem. Both biochar and mycorrhizal association contributing to sustainable plant production, ecosystem restoration, soil carbon sequestration and hence mitigation of global climate changes (Suman *et al.*, 1997).

Very few researches on effect of biochar on improving livestock productivity have been reported in goat, ducks and broiler chickens. In addition to potential productivity gains, adding biochar to livestock diets has the potential to minimize nitrogen excretion and improve the carbon sequestration potential of manure. Currently it is identified that upto 0.6% of feed requirement could be replaced with biochar (Van *et al.*, 2006) and further research is needed to optimize it.

Biochar and environmental implications

Burning of fossil fuels releases excessive CO_2 into the atmosphere. Decomposition or open burning of biomass releases CO_2 back into the atmosphere. The potential advantage of pyrolysis derived biochar in terms of greenhouse gas emission results not only solely from the retention of upto 50 % of the feedstock carbon in stable biochar, but from direct savings that may result from the use of biochar in agriculture, specifically the soil (Sohi et al., 2009). A potential abatement to increasing levels of CO_2 in the atmosphere is the use of pyrolysis to convert vegetative biomass into a more stable form of carbon ie., biochar that could then be applied to the soil. Conversion of biomass carbon to biochar carbon leads to sequestration of about 50% of the initial carbon compared to the low amounts retained after burning (3%) and biological decomposition (10-20% after 10 years), therefore more stable soil carbon than burning or direct land application of biomass. The effect of biochar application as biological nitrogen in leguminous crops is quite evidenced and thereby the application rate of fossil fuel based nitrogenous fertilizers could be largely avoided to the extent of 20 to 25%. However the studies on phosphorous solubilisation and potash mobilization are nil and hence researches to be focused on these areas too.

Conclusion and recommendations

From the preceding discussion, it could be concluded that production of biochar by pyrolysis process stands as the viable option to combat the illeffects of green house gases such as CO_2, N_2O, CH_4 in long term besides serving as soil amendment for sustainable production of crops. Further research is needed to identify the optimal application rates, biochar quality and its effect on soil, crop and environment. Once the knowledge gaps are abridged by strengthening research, biochar may play a pivotal role in improving productivity and environmental sustainability issues in world agriculture. With this conclusion, it is the need of this hour to suggest some measures for policy makers and researchers for the better utilization of biochar in sustainable agricultural production and also to minimize the consequences of global climate change.

Submission to policy makers or Governments

1. Setting up of national and regional level research institute with laboratories exclusively biochar research
2. Discouraging slash-and-burn system of cultivation and promoting slash-and-char system of cultivation to prevent further degradation of land and release of greenhouse gases
3. Inclusion of biochar related extension activities in the mandates of existing agricultural extension systems like Krishi Vigyan Kendras (Agricultural Science Centres) in India
4. Providing subsidies for purchase or fabrication of carbon catchers by the farmers themselves for their own use at his farm

5. Promotion of biochar producing industries through public private partnership mode
6. Encouraging the scientists involved in biochar research to participate in the global forum
7. Instituting Awards in recognition of best work carried out in the field of biochar

Recommendations to research system

1. The joint institutional or joint experts effort from the field of agriculture, engineering, microbiology, environmental science, climatology, economics etc must be initiated for biochar research
2. Long term trails must be conducted rather than short term trails of few months or year
3. The researchable issues includes assessment of suitability of feedstock, fabrication of suitable pyrolysis units, rate of application & time of application to each crops, enrichment of biochar with beneficial microbes, slurry etc., and effect of biochar on problematic soils
4. The behaviour of soil microbes under the presence of a non-degrading carbon source should be assessed
5. Researches to find out the long term effect of biochar in soil to assess is there any negative impact of biochar on soil health run
6. Publication of periodicals to share the significant research results in the world arena
7. Organizing periodical national level conferences to share the findings and exploring the newer areas for research
8. Various risks associated with biochar production and use has to be assessed with its overcoming strategies

It is further strongly suggested that, the research on biochar and its effects are scanty in India and hence an immediate attention may be paid to initiate the research on biochar to cope up with the world.

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