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Biochar – The Future of Agriculture

(*Vinay, Mudit Tripathi and Vivek Sehra)
Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, 211007, Uttar Pradesh, India
*Corresponding Author's email: doodwalvinay@gmail.com

The amount of carbon in the soil is a direct indication of good quality of soil. Higher carbon stocks have a direct correlation with increased agricultural yields through improved soil health.

In the current scenario of climate change and global warming, much of carbon in atmosphere must be sequestrated into soil carbon pool so that increasing CO_2 in the atmosphere and resulting warming could be reduced.

The use of biochar can be a simple yet powerful tool to combat climate change by sequestering much of atmospheric carbon into soil as well as providing an opportunity for the processing of agricultural and other waste into useful clean energy. (Brady, N.C. and Weil, R.R., 2008)

What is Biochar?

Biochar is a solid material obtained from the carbonisation of biomass. Biochar is produced through a process known as pyrolysis, means thermal decomposition of organic material (i.e., wood chips etc, crop waste and manure) under limited supply of oxygen (O_2), and at relatively low temperatures (<700°C). (Al-Wabel *et al*., 2013)

This process often mirrors the production of charcoal, which is perhaps the most ancient industrial technology developed by humankind. However, it distinguishes itself from charcoal and similar materials by the fact that biochar is produced with the intent to be applied to soil as a means to improve soil health, to filter and retain nutrients from percolating soil water, and to provide carbon storage. (Ameloot *et al*., 2013b)

Due to the molecular structure of biochar, it is in a more stable form than the original carbon (i.e., plant biomass, manure, etc.) both chemically and biologically. As a result, it is more difficult to breakdown biochar in the soil, resulting in a product that can remain stable in the soil for hundreds to thousands of years.

One of the great things about producing biochar through the process of pyrolysis is the fact that the main by-product is a gas, known as syngas which is a form of bio energy waiting to be used. (Preston, C.M. and Schmidt, M.W.I., 2006)

It is easily captured and can be used to produce heat and power, to generate electricity as well as power the pyrolysis machine in the process, making the machine largely self-sufficient.

Application in Agriculture

The potential benefits that biochar offers for farming includes:

1. Improved soil fertility and crop yields
2. Increased fertilizer use efficiency

3. Improved water retention, aeration and soil tilth
4. Higher cation exchange capacity and less nutrient runoff
5. Clean and efficient biomass energy production from crop residues and forest debris
6. Combined heat, power, and refrigeration opportunities from pyrolysis
7. Leads to net sequestration of carbon from the atmosphere to the soil thereby increasing soil organic carbon (SOC)
8. Greater on-farm profitability
9. Can be financed through carbon markets and carbon offsets
10. Decreased nitrous oxide and methane emissions from soils
11. Provides powerful tool for reversing desertification
12. Provides alternative for slash-and burn agriculture
13. Can work as component of reforestation and afforestation efforts
14. Can produce electricity, bio-oils, and/or hydrogen fuels
15. Can use wide variety of feedstock including crop residues such as wheat and corn straw, poultry litter, cow manure, forest debris, and other farm-based biomass resources
16. Acts as a liming agent to reduce acidity of soils
17. Carbon sequestration by the natural process of photosynthesis
18. Net production of energy in form of bio energy. (Singh, B.P. and Cowie, A.L., 2010)

Environmental Impact of Biochar

Biochar can be a simple yet powerful tool to combat climate change. Biochar sequestration is considered carbon negative as it results in a net decrease in atmospheric carbon dioxide over centuries or millennia time scales.

It can make a big difference in the fossil fuel emissions worldwide and act as a major player in the global carbon market with its robust, clean and simple production technology. As organic materials decay, greenhouse gases, such as carbon dioxide and methane (which is 21 times more potent as a greenhouse gas than CO_2), are released into the atmosphere. (Brewer, C.E. and Brown, R.C., 2012)

Instead of allowing the organic matter to decompose and emit CO_2, pyrolysis can be used to sequester the carbon and remove circulating CO_2 from the atmosphere and store it in virtually permanent soil carbon pools, making it a carbon-negative process. By charring the organic material, much of the carbon becomes "fixed" into a more stable form, and when the resulting biochar is applied to soils, the carbon is effectively sequestered.

It is estimated that use of this method to "tie up" carbon has the potential to reduce current global carbon emissions by as much as 10 percent.

The use of pyrolysis also provides an opportunity for the processing of agricultural residues, wood wastes and municipal solid waste into useful clean energy. Although some organic matter is necessary for agricultural soil to maintain its productivity, much of the agricultural waste can be turned directly into biochar, bio-oil, and syngas. (Ducey, T.M. *et al*., 2012)

Biochar can also provide an extremely powerful means of reversing desertification. In most semi-arid and desert climates the soil is nearly void of soil organic carbon (SOC), and thus has the potential to absorb massive quantities of carbon. Generally, the amount of carbon in the soil is a direct indication of soil quality: the greater the amount of SOC, the higher quality the soil.

Higher carbon stocks have a direct correlation with increased agricultural yields, higher plant moisture absorption, improved soil tilth, and higher levels of soil biological activity. (Ennis, C.J. *et al*., 2012)

Best Management Practices for Biochar Soil Application

The particle size distribution of biochar materials will vary widely depending on the feedstock and the pyrolysis technique used to produce the biochar. With small particles, it is important to apply biochar in ways that minimize loss due to wind or water erosion. Some best management practices are enlisted below to avoid these losses:

1. Apply biochar under the right weather conditions when winds are mild. It varies according to general weather conditions and time of day. It may also be helpful to apply biochar during mild rain conditions where light rain will dampen biochar dust and hold it on the soil surface until it can be tilled in.
2. Apply moisture to biochar. Water can be applied directly to the biochar, or it can be mixed with moist manure.
3. Produce a biochar formulation by pelleting, prilling, and mixing biochar with other types of amendments such as manures or composts. Different biochar formulations will be best suited to different application methods, and very fine biochar may be desirable in certain cases, for example when applying as slurry, by itself or mixed with manure. (Ippolito, J. A. *et al*., 2012)

Size of Biochar Particles

Ideal particle sizes to improve soil moisture retention have not yet been determined. Handling and applying the biochar will also impact the decision of what particle size is best. Biochar can be finely divided and can be applied to soil as it is, provided care is taken to minimize wind losses. If particle size must be reduced (for example from biochar made from old pallets or larger pieces of wood), it can be hand crushed inside bags using a large pestle.

Small amounts can also be crushed by driving over the material with a roller pulled by a tractor. For crushing larger amounts of biochar materials, hammer mills can be used, as well as compost shredders.

Best management practices include moistening the material before crushing it to reduce dust created during the process, and/or crushing the biochar inside closed bags. (Schnell *et al*., 2012)

Application Rate of Biochar

Recommended application rates for any soil amendment must be based on extensive field testing, soil types and crops. Also, biochar materials can differ widely in their characteristics, thus the nature of a specific biochar material (e.g., pH, ash content) also influences application rate.

Application rates of 5-50 tonnes of biochar per hectare (0.5 – 5 kg/m^2), with appropriate nutrient management results in better yield of crops. Most biochar materials are not substitutes for fertilizer, so adding biochar without necessary amounts of nitrogen (N) and other nutrients cannot be expected to provide Improvements to crop yield. (Glaser, B. *et al*., 2002)

Frequency of Application

Due to its recalcitrance to decomposition in soil, single applications of biochar can provide beneficial effects over several growing seasons in the field. Therefore, biochar does not need to be applied with each crop, as is usually the case for manures, compost, and synthetic fertilizers.

Depending on the target application rate, the availability of the biochar supply, and the soil management system, biochar amendments can be applied in increments. However, it is believed that beneficial effects of applying biochar to soil improve with time, and this may need to be taken into consideration when splitting applications over time. (Zhao *et al*., 2015)

Methods of Biochar Application under Conventional Field Crop Systems

a) **Broadcast and incorporate:** Broadcasting can be done by hand on small scales or on larger scales by using lime/solid manure spreaders or broadcast seeders. Moistened biochar materials may be better suited to application with manure spreaders than lime spreaders. Incorporation can be achieved using any ploughing method at any scale, including hand hoes, animal draft ploughs, disc harrows, chisels, rotary hoes, etc.

Mould board ploughing is not recommended as it is unlikely to mix the biochar into the soil and may result in deep biochar layers.

b) **Traditional banding:** Banding of seeds and fertilizers is a routine operation in mechanized agriculture, and involves applying an amendment in a narrow band, usually using equipment that cuts the soil open, without disturbing the entire soil surface. Banding allows biochar to be placed inside the soil while minimizing soil disturbance, making it possible to apply biochar after crop establishment.

However, the amounts of biochar that can be applied in this way are lower than those which can be achieved by broadcast applications. When working by hand, biochar can be applied in furrows opened using a hoe and closed after applying biochar.

c) **Mixing biochar with other solid amendments:** Mixing biochar with other soil amendments such as manure, compost or lime before soi application can improve efficiency by reducing the number of field operations required.

Since biochar has been shown to sorb nutrients and protect them against leaching, mixing with biochar may improve the efficiency of manure or other amendment application.

d) **Mixing biochar with liquid manures:** Biochar can also be mixed with liquid manures and applied as Fine biochars will likely be best suited to this type of application using existing application equipment, and dust problems associated with these would be addressed.

Biochar could also be mixed with manure in holding ponds and could potentially reduce gaseous nitrogen losses as it does when apply to soil. (Liang, B. *et al*., 2006)

Formulated Biochar Products

Since biochar itself cannot be considered a source of nutrients (unless it has a high ash content), there is interest in blending it with other materials such as synthetic fertilizers, compost and manures to enhance its value as a soil amendment.

Adding biochar to sewage sludge or poultry manure during composting has been shown to reduce N losses and the mobility of some heavy metals was also reduced in sewage sludge compost with biochar. It is also believed that adding biochar to composts and manures can reduce odors.

Another organic fertilizer made by Japan as bokashi, that is a fertilizer combining "effective" microbes, molasses, biochar, bran, and animal manure with water, and incubating under anaerobic or partially anaerobic conditions. Rice hull biochar is often used due to the availability of rice hulls in many regions. However, great care must be exercised while carbonizing rice hulls, as high process temperatures can lead to the production of carcinogenic compounds. (Rajapaksha *et al*., 2014)

Potential Health Issues of Biochar Application

Health risks from biochar relate to possible soil and thus food contamination, and to the effects of breathing in small biochar particles. Contamination can come either from contaminated biomass or from the pyrolysis process. For example, trees absorb heavy metals and other air pollutants and when wood is burnt or pyrolyzed, those become concentrated in the ash, which forms part of the biochar.

The ash retained after burning wood from forests well away from any sources of pollution contained so many heavy metals that some of it should have qualified as toxic waste. Depending on the pyrolysis temperature and the original biomass, there is a risk of particles called Polycyclic.

Aromatic Hydrocarbons (PAHs) forming, some of which are known to cause cancer and birth defects. All of this can be avoided by testing different batches of biochar before they are used. Breathing in small charcoal particles can cause "black lung disease' or pneumoconiosis. (Verheijen *et al*., 2010)

Furthermore, breathing in ash residues from charred rice husks is linked to a risk of the lung disease silicosis. Both are potentially fatal lung diseases. These risks can be significantly reduced if people who handle and apply biochar wear adequate masks.

Conclusion

Biochar has a both positive as well as negative impact on crop growth, yield and human health. This technology involves a large biomass demand for production as well as fine biochar particles are causing severe health hazards thus, it is critical that we address this issue with caution.

However, application of biochar to damaged soils of low fertility seems promising and has a high potential for mitigating climate change and helping to raise soil fertility but not a silver bullet to improve nutrient economy in farming, or to increase crop yields. We need to investigate and utilise it to reduce our emissions and sustain soils, but we cannot rely on it for solving our emerging problems.

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