AGRIALLIS
Science for Agriculture and Allied Sector: A Monthly e Newsletter
Volume 1 – Issue 3
www.agriallis.com

BIOCHAR: A BENEFICIAL SOIL AMENDMENT

Article Id: AL201917

Snigdha Chatterjee[1*], Debomita Dey[1] and Satarupa Ghosh[2]

[1] Ph.D. Scholar, Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal-741252, India

[2] Ph.D. Scholar, Aquatic Environment Management Department, West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal-700037, India

Email: snigdhachat160@gmail.com

Continuous application of inorganic fertilizers in agricultural land to increase productivity deteriorates soil health. Depletion in soil nutrients and faster decomposition of soil organic matter are posing great threats to the sustainability of agricultural production in the tropical regions. Moreover, burning of crop biomass is a serious problem in North India. Apart from loss of almost entire C, it leads to loss of about 80-90% N, 75% S and 20-25% P and K present in the straw. In recent years, processing of surplus crop biomass to produce biochar and applying to soil is being considered as a sustainable way of agricultural waste management. To restore the contaminated sites, biochar is considered as a potential soil amendment. It is a carbonaceous product obtained through the thermal decomposition of biomass in the absence of oxygen or small amount of oxygen at very high temperature. It is difficult to decompose due to its aromatic structure and crystalline graphing sheet present within it.Soil nutrient availability from biochar is a function of various factors like type of feedstock, pyrolysis temperature, residence time, heating rate. In general, application of biochar helps to improve the soil nutrients status by raising soil pH, attracting more microbes, improving cation exchange capacity (CEC) and retaining nutrients.

Properties of Biochar

The properties of biochar depend upon the type of feed stocks (viz. crop residue, organic manure, vermicompost, woodchips, municipal solid waste) and pyrolysis conditions. Biochar mainly produced by slow pyrolysis process due to its moderate operational conditions and relatively high yield. A number of studies have investigated that the proportion of elemental carbon in the biochars increases with increasing pyrolysis temperature that indicates the increase in the degree of carbonation by the thermochemical conversion of more labile form of organic residue in the feedstock to highly stable form of

carbon. The stability of biochar in soil is a critical factor to be tested before these are applied to the soil as an amendment. If biochar is produced at high temperature will have high micro pore and contain few nutrients. Biochar produced through woody feed stock is coarser and more recalcitrant as compared to that produced from agronomic wastes. The properties of Biochar such as pH, nutrients, C content, porosity and surface area affect the mechanisms of interaction between soil inhabitants, thus influence aboveground and belowground ecosystem response. The amount of volatile matter content decreased continuously with increasing pyrolysis temperature rendering higher decomposition rate and making these unsuitable for long-term C sequestration. Rapid loss of elements like O and H was found between 300 to 500°C temperatures.

Benefits of Biochar

Addition of biochar in the soils resulted in the better physical condition of soil in terms of soil texture, more porosity, good structure, and particle size distribution. Application of biochar can be extremely useful for the improvement of soil organic carbon, water holding capacity, stimulating soil microbial activity and their biomass, increasing availability and retention of nutrients, bettering crop yield as well as reducing greenhouse gases emission and increase carbon sequestration. Effects of biochar as soil amendment are evaluated by measuring the improvement in pH and organic carbon content in soil. However, the efficiency of biochar application practices is site specific in nature varied with different climatic conditions. Hardwood Biochar produced by traditional methods processed the most consistent increase in soil fertilization when added to soils. The greatest effects with regard to soil analyses were usually seen in coarse soils with biochar from feedstock containing sufficient nutrients itself.

Improvement of nutrient availability in soils

Better soil texture, more porosity, good structure, and density and particle size distribution were observed by incorporating biochar in the soils. Biochar is applied on the soil resulted in oxidation of the surface of particles. With higher porosity and more surface area it can help in the providing space for microorganisms which are beneficial for the soil. Biochar application especially for long-term leads to the increase in pH of the soil and that leads to improved availability of essential nutrient elements like P, K, Mg, Ca, Mo and B. The increase in pH in acidic soils had the effect of alleviating the Al toxicity in ultisols which increase CEC that increases bio available phosphorus. The reason behind the high CEC is the

oxidation of aromatic carbon that leads to the formation of functional groups like carboxyl. The increase in CEC aids in increasing the fertility of soil, as the nutrients will remain on surface soil opposing the leaching process because of CEC. When highly oxidized organic matter attached with the surface it will create negative charge on the surface. This results in the decrease of positive charge on the sites. Additionally, the porous structure of biochar that retained water and improved water balance leads to better nutrient availability. Biochar amendments also increase the soil organic carbon (SOC) content and total N. High levels of SOC accumulation in soil enhanced N efficiency, thus offer an opportunity to save N fertilizer. A substantial amount of K (10%) and S (20-28%) were recovered with the amendment of biochar from sewage sludge. The increase in plant-available water with biochar suggests that the application of biochar to croplands could contribute to the reduction of the frequency of irrigation which is particularly important in water-limited or semiarid regions. The positive effect of biochar on increasing water retention can be larger in sandy soils with lower micro porosity and a smaller specific surface area than in clayey soils.

Increases crop yield

As biochar incorporation improve soil fertility that significantly increase in the crop production as growth of seed is also better with biochar application. Increase in radish dry matter was observed from a study due to the presence of N fertilizer along with biochar but there was no increase in the yield even with highest rate of fertilizer without biochar. Another study claimed the increase in the yield of maize grain by almost 98% with the application of biochar. Cow manure biochar applied at a rate between 10 and 20 t ha^{-1} and poultry manure biochar showed the strongest positive effect among all different kind of feedstock. Similar results were found in the soil of China cultivating paddy, the yield of rice increased by 12 to 14% in the soils where no fertilizer was added by the addition of 10 and 40 t $ha^{-1}$of biochar while 8.8 to 12.1% increase in the yield was observed with the addition of N fertilizers.

Reduction of environmental pollution

Biochar application on the soil helps in the reduction of environmental pollution. It increases the retention of nutrients like N and P in the soils, thereby decreases the leaching of nutrients to the groundwater and saves the nutrients from erosion due to the surface water flow. By the pyrolysis of animal manures, a significant amount of reduction in the mobility of phosphorous of animal manures can be achieved. This technique will help in disposing the bulk amount of the organic wastes easily. It also has the ability to convert the soluble

inorganic phosphate resent in the manure into the adsorbed phosphate in biochar. Biochar pyrolysed at 700°C from poultry litter and pine chips resulted in reduction in *Escherichia coli* transport.

Reduction of hazardous materials from environment

Biochar is highly efficient to adsorb major environmental contaminants from the soil. Many organic pollutants are being sequestered by using biochar to alter their effects on the environment. Biochar acts as a critical binding material for different organic pollutants in the environment due to its resisting nature towards microorganisms and its extraordinary sorption affinity. There are carbonized and non-carbonized type of organic matter in the biochar which plays the great role in sorption depending on their bulk and surfaces. It is reported that biochar made up of incompletely burned wheat and rice residues adsorbed 400 to 2500 times more pesticides than that of normal soil. Another report revealed that charcoals derived from red gum have the efficiency to sorb diuron pesticide from the polluted soil. Biochar made up manure derived from dairy have the sorption capacity for heavy metals like lead and other organic contaminants. Biochar derived from *Pinus radiata* have the higher efficiency for the sorption and desorption of a pollutant named phenanthrene from the soil. The sorption capacity of soil for hydrophobic organic compounds is higher when treated with biochar depending upon the content of that soil, the properties of biochar and the contact time between the soil and biochar. Biochar is more likely to adsorb organic contamination like persistent organic pollutants (POPs), poly aromatic hydrocarbons (PAHs) as they have high affinity for biochar because it is naturally occurring.

Mitigates climate change

Excessive amount of carbon dioxide is being released in the atmosphere due to the burning of fossil fuels and decomposition of biomass that increases the CO_2 levels in the atmosphere. Application of biochar on these soils can help decrease the CO_2 emission as it can store 50% of the carbon from feedstock. Biochar is highly stable so that it significantly restrains the emission of CO_2 from organic matter decomposition and plays a vital role in controlling the release of methane (CH_4) and nitrogen dioxide (NO_2) from the soil which are the potential greenhouse gases. This reduction in the release of NO_2 is because of the ability of biochar to adsorb and retain the ammonium in soils and then reduce the availability of N

for denitrification process. Studies showed that the agricultural soils contribute 12% in the total CH_4 emissions globally, mostly from paddy field. The emissions of CH_4 from the soil treated with biochar mainly depend on the type of soil, the properties of biochar and environmental condition. In the fields, CH_4 emissions from the fields get lowered when treated with biochar. However, the emissions of NO_2 were found 40-51% less in soils than that of those soils which are not treated with biochar. These facts show that global warming gases from soils decreases by amending soils with biochar. Studies showed that pyrolysis seems to propose added opportunities as by the application of biochar into the soil leads to scrubbing of greenhouse gases.

Factors affecting benefits of Biochar application in soil

1. Placement method

Biochar benefits can depend on the biochar placement method. It is commonly incorporated into the soil to reduce losses from wind and water erosion as well as to improve biochar-soil contact. Mixing of biochar with soil reduced soil water repellence and bulk density when compared with surface application. Surface application of biochar has positive effects on reducing soil surface albedo than biochar incorporated deep into the soil. Application of biochar to no-till systems without incorporation could reduce surface albedo.

2. Age of biochar

The effect of biochar on soil properties may change with the time after application. Fresh wooden biochar are found to be higher water repellent than older biochar. Oxidation and drying of biochar with time reduces hydrophobic properties due to reduction of organic compounds on the surface of biochar particles. Physical, chemical, and biological reactions on the surface of biochar particles alter with time which, in turn, influence soil physical properties.

3. Biochar particle size

Biochar particle size can directly affect biochar–soil interactions, influencing changes in soil physical, chemical and biological properties. Small Biochar particles could more easily mix or interact with soil particles to form aggregates than large biochar particles. In addition, the smaller the biochar particles, the greater the specific surface area per unit of mass.

4. Feedstock type

Biochar could have different impacts within herbaceous or wood feedstock groups. Herbaceous feedstock can have more beneficial effects on soil physical properties than woody feedstock. It is found that wheat straw reduced bulk density and increased the amount of water-stable aggregates and available water more than wood feedstock.

5. Pyrolysis temperature

The temperature used during the thermochemical conversion of biochar can influence the extent to which biochar affect soil properties. Biochar produced at high temperatures (>500°C) retain more water and have lower water repellency than those produced at low temperatures due to removal of the hydrophobic organic materials that coat the surface of biochar particles at elevated temperature. Biochar when produced at 500°C 13-fold decrease its water repellent property compared with when it was produced at300°C. Some have found that differences in the pyrolysis temperature of biochar may have small effects on soil physical properties.

Conclusions

Biochar application generally improves structural quality of the soil. Biochar appears to have the most consistent effect on water retention among all the soil physical properties of the soil. It improves soil fertility, soil texture, sorption for nutrients which then helps in lowering the unjudicious use of fertilizer which leads to the decrease in pollution through fertilizer run off. Biochar is highly efficient in increasing the crop yield. It helps in combating the climate change by sequestering the CO_2 from the atmosphere and reducing the release of GHGs (NO_2 and CH_4). It can also be used for the rehabilitation of degraded lands. Combined application of biochar with other amendments has been proposed as an option for improving fertilizer use efficiency of soil. Further, more inter-disciplinary and location-specific research has to be taken up for facilitating the long-term effects of biochar in combination with other amendments to study soil nutrient dynamics. Biochar is posing benefits to the agricultural environment and economy in the longer run, so it is highly recommended to incorporate it in agriculture practices.

References

Abdelhafez, A.A., J. Li, and M.H. Abbas. (2014). Feasibility of biochar manufactured from organic wastes on the stabilization of heavy metals in a metal smelter contaminated soil. *Chemosphere*, **117**:66–71.

Bekele, A., J.L. Roy, and M.A. Young. (2015). Use of biochar and oxidized lignite for reconstructing functioning agronomic topsoil: Effects on soil properties in a greenhouse study. *Canadian Journal of Soil Science*, **95**:269–285.

Liu, E., Changrong, Y., Xurong, M., Wenqing, H. and So H.B. (2010). Long term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*,**150**:173-180.

Rehman, H.A. and Razzaq, R. (2017) Benefits of Biochar on the Agriculture and Environment - A Review. *Journal of Environmental Analytical Chemitry*,**4**:207.

Steiner, C., Teixeira, W.G., Lehmann, J. and Zech, W. (2007) Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and Soil*,**291**:275-290.

Woolf, D., Amonette, J.E., Street-Perrott, F.A. and Lehmann, J. (2010). Sustainable Biochar to Mitigate Global Climate Change. *Nature*,**1**:1-9.