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# Effect of biochar on soil fertility and carbon sequestration

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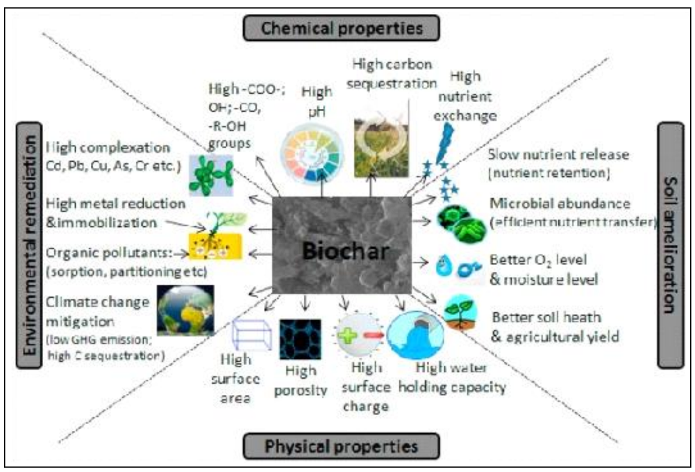
Every year worldwide anthropogenic $CO_2$ emissions from energy generation is increasing. By 2020, 33.8 billionmetric tons per year could be emitted, up from 29.7 billion metric tons per year in 2007.Added to anthropogenic $CO_2$ emissions,the natural carbon cycle and deforestation. Research to mitigate $CO_2$ emissions, reduce the $CO_2$ atmospheric concentration, and enhance soil fertility, crop production and bio-derived energy production would be welcome. Efforts to reduce $CO_2$ emissions through carbon sequestration include both reforestation and $CO_2$ injection into underground saline and other geological formations or into the deep ocean. Sequestering C in soils as biochar can improve soil fertility, supplementing adding biosolids, organic waste fertilizers and improving crop rotation. However, organic wastes and biosolids will decompose in the soil emitting $CO_2$.Conversely, the carbon in biochars, originally removed from the atmosphere as $CO_2$ during plant growth, persist in soils from decades to millennia. Thus, if biochar application proves widely applicable at low cost in improving soil fertility in agriculture, its widespread use could lead to enhanced carbon sequestration. Biochar can be made either as a byproduct of fast pyrolysis to generate biooil (a liquid fuel precursor) or slow pyrolysis. Biochar production technologies 26 and $CO_2$ capture, storage and utilization.

Soil mineral depletion is a major issue due mainly to soil erosion and nutrient leaching. The addition of biochar is a solution because biochar has been shown to improve soil fertility, to promote plant growth, to increase crop yield, and to reduce contaminations. Biochar is one of a series of materials referred to as black carbon because it is produced by thermochemical transformation of the original biomass material under a variety of conditions.Biochar is a stable, recalcitrant organic carbon (C) compound that is produced by thermochemical alteration of biomass (feedstock) for the purpose of soil amendment and carbon sequestration (Jeffery *et al.*, 2011). Biochar has the potential to be used for a wide range of applications. In agronomy, biochar appears to increase soil fertility and reduce nutrient leaching, thereby improving crop production in coarse-textured soils. Moreover, biochar is considered to be relatively stable in soil with mineralization rates that are slower than that found in the original biomass. This makes biochar attractive as a carbon sequestration option in addition to its potential for enhancing soil quality and minimizing the release of environmental pollutants (Clough and Condron, 2010).

The needs to develop more sustainable agriculture systems and improve weak rural economies necessitate major changes in agriculture management. Soil degradation, including decreased fertility and increased erosion, is a major concern in global agriculture. Long-term cultivation of soils could result in degradation, containing soil acidification, soil organic matter depletion, and severe soil erosion. Furthermore, the decrease in soil organic matter decreases the aggregate stability of soil. Therefore, it is crucial to remediate the degradation soils by simple and sustainable methods. Manures and composts contain pathogens, heavy metals and pharmaceuticals, which may cause long-term contamination of farmland. Moreover, manures and composts have the potential to lead to ammonia and methane releases, which can aggravate global warming and serious groundwater and stream nutrient pollution. Being a renewable resource and due to its economic and environmental benefits, biochar is a promising resource for soil's fertility management. Furthermore, biochar loaded with ammonium, nitrate, and phosphate could be also proposed to be a slow-release fertilizer to enhance soil fertility. Biochar is the by-product of biomass pyrolysis in an oxygen depleted atmosphere. It contains porous carbonaceous structure and an array of functional groups. Biochar's highly porous structure can contain amounts of extractable humic-like and fulvic-like substances. Moreover, its molecular structure shows a high degree of chemical and microbial stability. The physical and chemical properties of biochar are highly dependent on pyrolysis temperature and process parameters, such as residence time and furnace temperature, as well as on the feedstock type.

Biochar was reported to improve not only soil chemical and physical properties but also soil microbial properties. Many studies indicated that the combination of biochar with soils could improve soil structure, increase porosity, decrease bulk density, and enhance aggregation and water retention. In addition, biochar can increase soil electrical conductivity by 124.6 per cent and cation exchange capacity by 20 per cent, while reduce soil acidity by 31.9 per cent. Moreover, biochar has also been tested to increase soil biological community composition and microbial biomass by 125 per cent. Steiner *et al.* (2008) indicated that, after biochar application, basal respiration increased about by 30.1 per cent $CO_2$ in the following 35 h after substrate addition. In recent years, an increasing interest in applying biochar is focused on the amendment of nutrient-poor soil for soil ecological restoration including sequestering carbon.




Various mechanisms have been suggested for the increase of plant nutrient availability in nutrient limited agro - ecosystems such as:

– The initial addition of soluble nutrients contained in the biochar and the mineralization of the labile fraction of biochar containing organically bound nutrients.

– Reduction of nutrient leaching due to biochar's physico-chemical properties.

– Lower escapable N losses by ammonia volatilization and $N_2$ and $N_2O$ from denitrification.

– A retention of N, P and S associated with the increase in biological activities or community shifts.

In the field trials, many researchers reported that biochar application improved soil quality, increased crop production and promoted plant growth. Uzoma *et al.* (2011) found that, compared to the control, maize grain yield significantly increased by 150 and 98 per cent after the application of biochar at 15 and 20 t $ha^{-1}$, respectively. However, grain yield decreased by 23.3, 10 and 26.7 per cent while the application rate of biochar was and 16 t $ha^{-1}$, respectively. The decreased crop yield may be attributed to the high volatile matter, as well as toxic and harmful substance in biochar, which can reduce nutrient uptake and inhibit plant growth. Thereby, the improvements of crop production and plant growth may be dependent on the properties of biochar and soil. It is significant to understand the mechanisms which may induce changes on soil fertilizer after biochar application into soil.

**The influence of biochar on properties of soils:** Currently, some studies have focused on the amendment of biochar on physical and chemical properties of various soils. Biochar could possibly be part of a long-term adaptation strategy, as it could improve soil physical properties including the increase of porosity and water storage capacity, as well as the decrease of bulk density. Biochar may also be used as a sustainable amendment to enhance soil chemical properties. For example, the content of ash in biochars ranged from 0.35 to 59.05 per cent, which were rich in available nutrients, especially cationic elements, such as K (0–560 mmol $kg^{-1}$), Ca (3–1210 mmol $kg^{-1}$), Mg (0–325 mmol $kg^{-1}$) and Na (0–413 mmol $kg^{-1}$).

**The effect of biochar on physical and chemical properties of soils :** The physical and chemical properties of biochar are keys to understand performances and mechanisms of biochar in the improvement of soil's fertility. A possible main mechanism for yield improvement may be the increase of soil water holding capacity after biochar treatment. Biochar has high total porosity and it could both retain water in small pores and thus, increase water holding capacity and assist water to infiltrate from the ground surface to the topsoil through the larger pores after heavy rain.

**The retention of soil nutrients by biochar:** Some researches indicated that incorporation of biochar into soil effectively reduced $N_2O$ emission from different soils.It has been reported that 50 per cent reduction of $N_2O$ emissions was found under soybean systems while 80 per cent decrease of $N_2O$ emissions was found for grass systems. Similarly, biochars treatment could decrease $N_2O$ emissions and suppress $N_2O$ emissions between 21.3 and 91.6 per cent. However, there were several studies reported that no effect or even increase was detected on $N_2O$ emissions after the application of biochar. The retention of nutrients by biochar could be dependent on biochar pyrolysis temperature, soil types, fertilizer doses, and soil water contents.


The application of biochar into soils has great potential for improving soils fertility and promoting plant growth. Soil quality improvement and carbon sequestration are two of the commonly reported benefits of biochar amendment of soils. The choice of biochar managing various soils is flexible, because diverse biomass materials could be used as feedstocks of biochars and the feedstocks could be pyrolyzed at different temperatures. Moreover, biochar has huge surface area, well developed pore structure, amounts of exchangeable cations and nutrient elements, and plenty of liming. Because of these properties, soil properties could be improved after biochar treatment. For instance, the huge surface area and well developed pore structure may increase the water holding capacity and microbial abundance. The cation exchange capacity and availability of nutrients could be increased due to the amounts of exchangeable cations and nutrient elements. The increased pH of soils should be attributed to the plenty of liming contained in biochar. Therefore, improvements of soil physical, chemical, and biological properties promote the productivity of plant through increasing the amount of nutrient elements, enhancing availability of nutrient elements, reducing nutrient leaching and mitigating gaseous nutrients losses.

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