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Research Review

Potential Impact of Biochar in Agriculture: A Review

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ABSTRACT

Biochar is a solid product obtained from pyrolysis of biomass. Biochar is a stable, carbon rich form of charcoal that is applied to soil. This carbon enriched porous material which can be used for a broad spectrum of applications, among which crop enhancement, soil improvement, soil remediation, carbon sequestration and pollution control were take the most important roles. Pesticide pollution and soil degradation are two major problems in the agricultural ecosystem. In addition to that, every year Indian farmers are adversely affected by various constraints in relevant to changes in monsoon, crop quality, declining crop production and soil fertility. Since they have no viable option to dispose the residual crop wastes in each season, they often resort to crop burning in North India and this causes a spike in air pollution every year. Application of biochar is the efficient and economical way to potentially manage these problems. Recently biochar gained interest and importance as a way to deal with agricultural ecosystem. Many studies have demonstrated the positive influence of biochar on soil quality, fertilizers efficiency, plant growth as well as soil microbiota. In worldwide research on biochar has increased drastically over the past decade. In India many numbers of studies in biochar have gone up in the past few years. The main objective of this review paper is to discuss the biochar features and its applicability in various agricultural practices in related to improve soil productivity, plant growth and development. From this review it could be concluded that, use of biochar in agricultural and environmental ecosystems is one of the viable options to improve soil productivity, plant growth and development. Available research evidences strongly justify that continuous research and development efforts need for understanding more about the benefits, potentiality as well as limitations of biochar and expanding its uses for agriculture in economical way.

***Key words*:** Biochar, Biochar in agriculture, Black carbon, Pyrolysis, Soil amendment, Soil fertility

Biochar is a solid heterogeneous substance rich in aromatic carbon and minerals obtained in pyrolysis of biomass. The term 'biochar' is defined by scientists in many ways. According to Tilman [1] defines, biochar is a carbon enriched matrix obtained from organic materials under limited supply of oxygen (O_2) and temperatures below 700°C. A similar definition is given by The International Biochar Initiative (IBI). Biochar is used to enhance the plant growth by improving physical and chemical characteristics of the soil, as well as enhancing the carbon dioxide sequestration that would release into the atmosphere through the organic residue decomposition. Biochar contains high concentration of recalcitrant carbons thereby it sequestering carbon for a long period of time [2]. Biochar is a carbon enriched porous material which can be used for a broad spectrum of applications, among which crop enhancement, soil improvement, soil remediation and pollution control were take the most important roles. Biochar has potential to enhance the plant growth by improving soil physical properties (Temperature, aeration, density, infiltration, hydraulic conductivity and water retention), soil chemical properties (pH, cation exchange capacity, exchangeable acidity, nutrient availability, nutrient uptake and sorption) and soil biological properties (Microbial population, microbial biomass, enzymatic activity and root nodulation), all these factors are offering for an enhanced crop production. Biochar is also used to improve the nutrient use efficiency, soil pH, soil structure, reduce the leaching loss of nutrients, acts as a liming agent, reduces the toxicity of Al and Fe to plant roots as well as enhance the beneficial soil microorganisms and decreases greenhouse gas (N_2O and CH_4) emissions from agricultural field.

The use of biochar in agriculture is not a new practice. Farmers have been using the biochar unknowingly for enhancing the crop production since long ago. One such example is the slash and burn cultivation, which is still being practiced in some part of north-eastern India. In the natural carbon cycle, plant matter decomposes rapidly after completion of life cycle and emits carbon dioxide back to the atmosphere. About 85-95% of plant bio mass of carbon returned back to the

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atmosphere after decomposition. Whereas, if we produce biochar from the same amount of biomass at least 50% of the total carbon is captured permanently [3]. The highly aromatic structure of biochar and its specific surface characteristics, along with its high porosity have been considered as the main reasons for its long-lasting stability in soils, its ability to increase nutrient bioavailability and increasing crop productivity under specific climatic conditions.

As a product, biochar is different from the charcoal, which is produced under lower temperatures and considered as solid fuel containing high quantity of volatile matter. Biochar is also known as black carbon, it can persist in the soil for long periods at various depths, typically more than thousand years. The most popular example is charcoal that derived from wood. Similarly, *Terra Preta* soils in Amazon basin are the most commonly known examples of biochar. In recent days, considerable researches have focused on biochar, its nature, production technology, properties to explore its potential benefits and negative impacts particularly for applying to agricultural fields as amendments. In India many numbers of studies in biochar have gone up in the past few years. The main objective of this review paper is to discuss the biochar features and its applicability in various agricultural practices in related to improve soil productivity, plant growth and development.

Production methodologies

Biochar is the charred biomass produced by slow pyrolysis in which organic material is heated under controlled temperatures of 300-500°C with absence of oxygen. Biochar should have high carbon content (> 60 %) and C:H:C molar ratio of final product should not exceed (0.7). Different pyrolysis methods are commonly available for producing biochar depending upon residues used under different working condition. In India, Protocols for production of biochar are not yet standardized. A low-cost portable biochar kiln with proper design and operational process can be considered as an economically viable option in rainfed areas of developing countries for efficient recycling of unused and excess crop residues [4].

There are various ways available for producing biochar. The carbonization process undergoes three steps viz., removal of moisture and some volatiles compounds which followed by conversion of unreacted residues to volatiles, gasses, biochar and finally formation of recalcitrant material called biochar through slow chemical rearrangement. In India low-cost technologies have been developed by some institutions having minimal control over temperature and time parameters. Few commonly used methods in India are described as under.

(i) *Heaping and charring*

Heap method is mostly practiced in Tamil Nadu. In this method biomass such as wood lopping, small wood logs, twigs, woody crop residues were heaped up to a height of about three to four feet and is covered with mud paste. Holes are opened at starting from the top and working downwards on drying of mud paste. The heap is set at fire from one end and let to smoke for a considerable time period usually in few days to week. Biochar is formed under oxygen stress conditions but there is no perfect control over temperature and air.

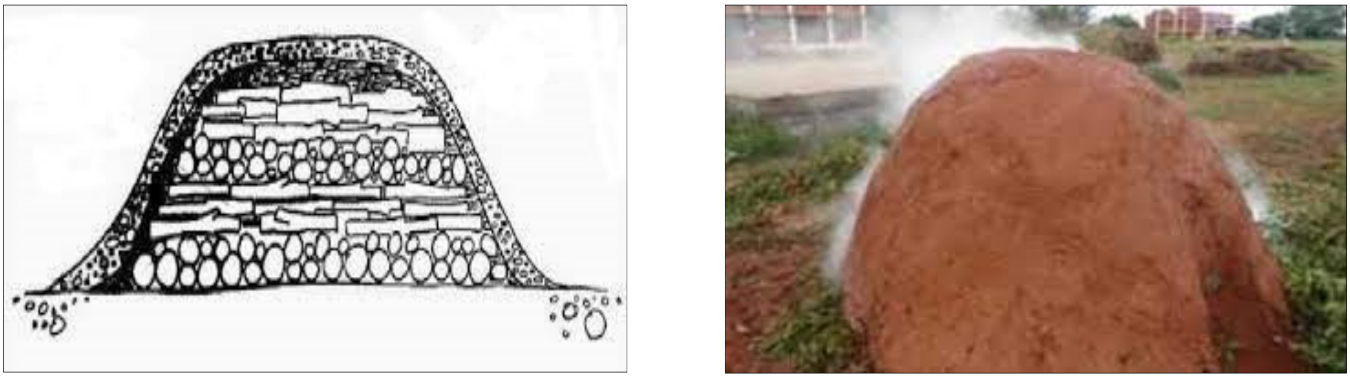

Fig 1 Heap method of biochar production

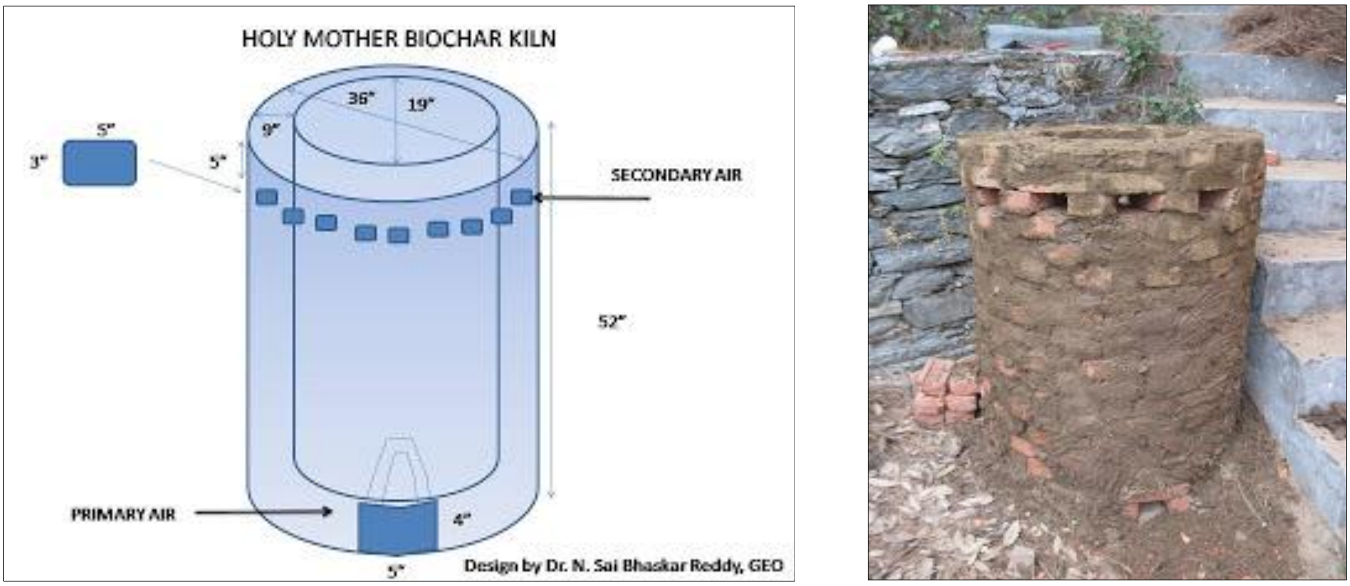

Fig 2 Biochar kiln

(ii) *Biochar kiln*

Holy Mother Biochar Kiln (HMBK) was developed by Sarada Matt in Almora town, Uttarakhand, India. Bricks and clay are mostly used for construction of this biochar kiln. Here, Air is allowed to flow from bottom and biomass is added continuously as the fire continues. Once the biomass reaches level just below the secondary air vents, further adding of biomass is stopped and then the bottom vent is also closed. After some time, water is sprayed to extinguish the fire. The biochar is collected after some time. In this case also biochar is formed under oxygen stress conditions but there is no perfect control over temperature. ICAR-Central Institute of Agricultural Engineering, Bhopal has also developed various biochar kiln with different designs to produce biochar. The yield of these designs varies with small capacity of about 500 g to high capacity of 5 -10 kg biochar.

(iii) *Drum method*

Various organizations are developed a different type of drums. Few drums are in horizontal dimension and others in vertical dimension. Also, some require external heating, the other may need initial sparking for burning. In this method, there is no control over temperature and air supply. So, pyrolyzed biomass may not be uniform. The ash content in the biochar is also high.

Fig 3 Drum method of biochar production

(iv) *Standard biochar production unit*

Systematic biochar production has been attempted at few locations. In Indian Council of Agricultural Research (ICAR) Research Complex for North East Himalayan (NEH) Region at Barapani, Meghalaya established pyrolysis plant that has a capacity to use 300 kg of feedstock.

Similarly, ICAR-CIAE, Bhopal has designed a biochar plant for a smaller quantity of biochar production. It does not require any initial ignition. Only electric heaters are installed for pyrolysis the biomass. In this kiln there is control over temperature. The smoke is also disposed off safely. Maharana Pratap University of Agriculture and Technology - MPUAT, Udaipur has developed a batch type continuous torrefaction unit (Torrefaction is a thermal process to convert biomass into a coal like material) using a suitable gear motor. It can torrefy about 15-20 kg of crop residues per hour. During this process considerable amount of gases also generated [5]. MPUAT has also developed system of continuous screw type biochar production unit with production of 20 kg per day capacity. Using of groundnut shell it can produce 6 kg biochar per hour, which has calorific value of 5935 k ca1 kg^{-1} which is 58.3% higher than raw material.

Fig 4 Biomass pyrolyser at ICAR research complex for NEH region, Barapani

Best management practices for biochar production (Adapted from IBI)

The biochar manufacturer must follow the relevant local and international regulatory compliance along with following best management practices.

(i) A biochar manufacturer should provide a relevant material safety data sheet (MSDS) for the final output of its biochar production process.
(ii) Biochar should be tested to address the potential for self-heating and flammability during storage and transport. Documentation of the results of this testing should be appended to the material safety data sheet (MSDS).
(iii) To minimize the effects of weathering, which can significantly alter the material properties of biochar after it has been tested.
(iv) Biochar should be stored indoors in a protected location. If stored outdoors, biochar should be covered with a tarpaulin or other material to protect it from precipitation events.

Application of biochar in agriculture

Many studies have proved that biochar have a positive effect on soil quality as well as crop improvement. There are different methods available for biochar application in soil, such as broadcasting, furrow application, band application, deep banding and spot placement. Application of biochar in soil is largely depend on land availability, farming system and machinery availability. Generally, small farmer with small holdings may apply low-cost biochar in their own agricultural land by hand only. But considering the human health, large scale manual application is not possible due to lengthened contact with airborne biochar particulates. More quantity of biochar required for broadcasting a whole field in a levelled field condition. However, only small amount of biochar needs for furrow application and it is very effective method in maize field compared with broadcasting.

Best method for increasing biochar efficiency is application directly into the root rhizosphere zone and it is a viable option for perennial cropping systems [6]. In western Australia, deep banding is mostly practiced in several wheat fields. Mixing of biochar with decomposed manures, composts, crop residues and other organic inputs may increase the nutrient use efficiency and reduce bad odour. Huang *et al.* [7] noted, most of the recent studies described that positive effect of biochar application at 5 - 50 t ha^{-1}. Higher the rate of biochar application may not suit for certain farming condition due to increases the cost of production. Application of biochar at 5 - 10 t ha^{-1} or 0.5 - 1 kg m^{-2} observed beneficial effects on soil properties and crop yield in maize, rice, pea, mustard and soybean [8]. Combined application of organic manures along with biochar will minimized the application rate of manure. This might be due to that biochar also contains some amount of nutrients.

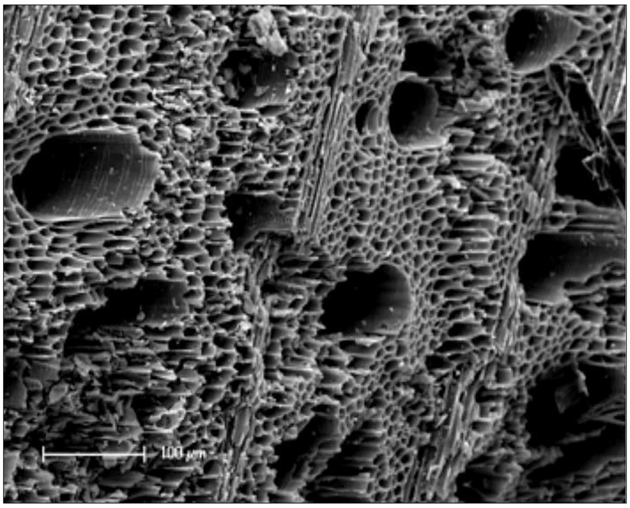

Fig 5 Microscopic view of biochar

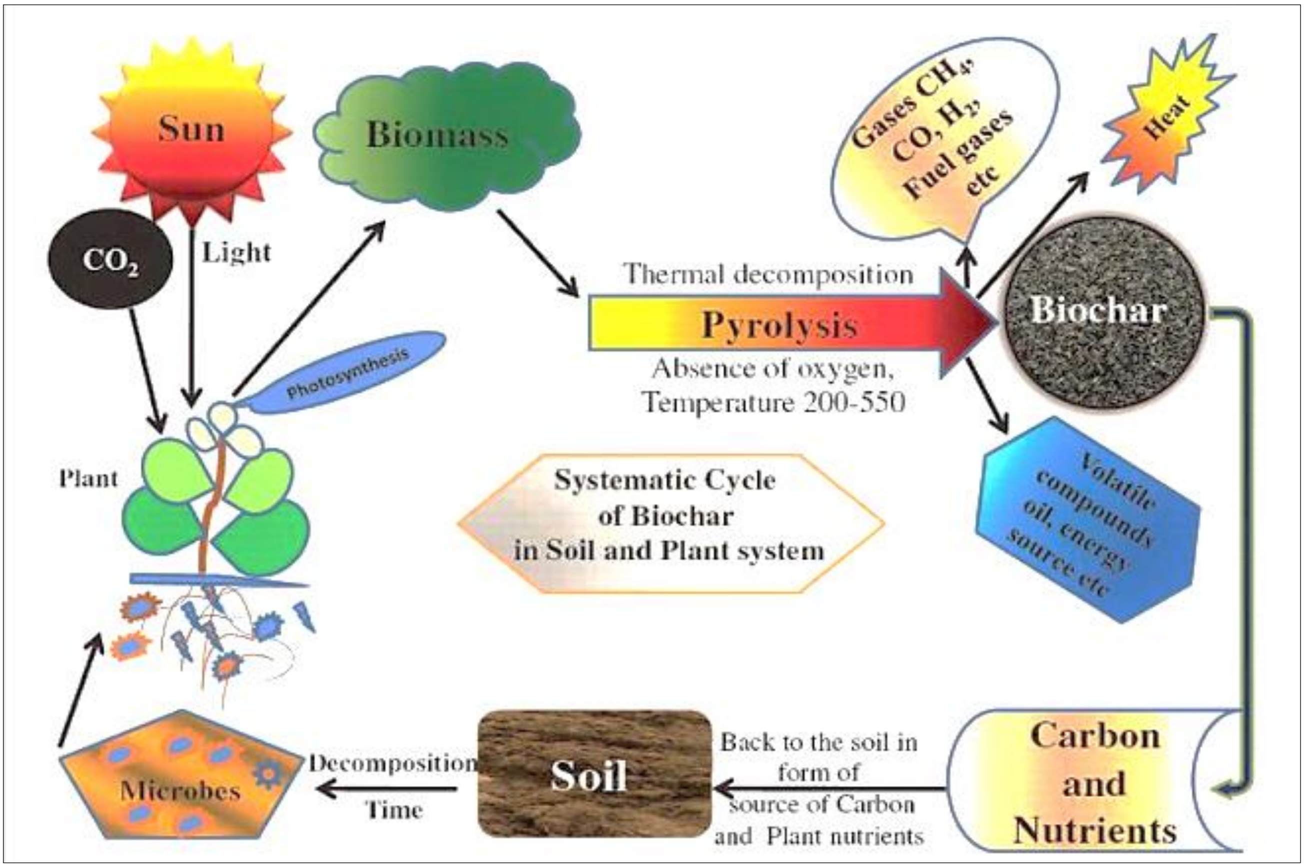

Fig 6 Systemic potential mechanism of biochar in soil and plant system

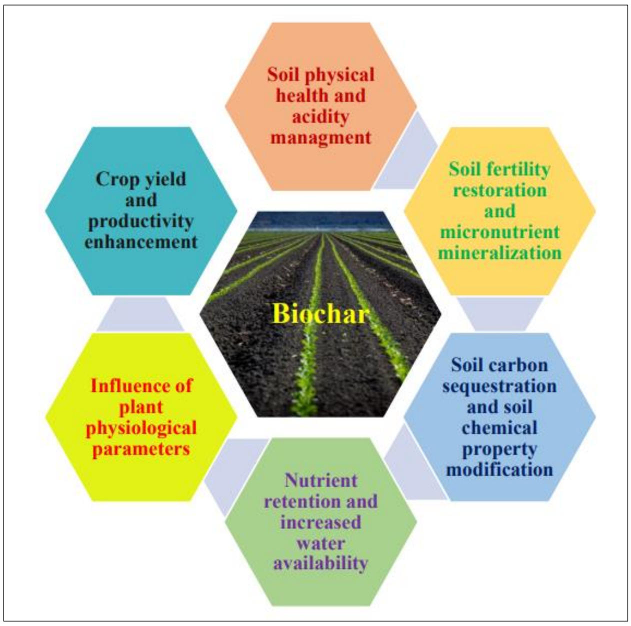

Fig 7 Functions of biochar in agricultural environment

Impact of biochar on soil

1. *Impacts on soil physicochemical properties*

Alterations of the soil chemical properties by application of biochar may enhance the growth performance and yield of crops.

(i) *Soil pH*

Soil pH is the most important physicochemical parameter relating to the soil fertility. Deviations in soil pH can altered the soil environment and enhance soil nutrient availability for plant growth. The soil environment modification also helps to enhance the microbial activity and hastens chemical reactions in the rhizosphere region [9]. Various studies reported that biochar application in soil can change the pH value. Biochar application in acidic soils have more benefits due to the alkaline nature of many biochars and consequently facilitates the alkaline phosphatase activity in soil [10]. Few studies have reported that, pH range of biochar is 5.9 - 12.3 with a mean value of 8.9 [11]. Recent researches evidently proved that pH range of biochar may vary from acidic to alkaline depending upon the feedstock material used. Different rates of biochar application can modify (increase or decrease) the soil pH. Biochar manufactured from pine chips and poultry litter with 1:1 ratio shows the higher soil pH at an application rate of 40 t ha^{-1}. Whereas, biochar derived from rice hull does not show any pH alteration at an application rate of 13.5 t ha^{-1}. Borchard *et al.* [12] found that, application of beech wood biochar significantly increased the temperate soil pH. Application of 9 t ha^{-1} y^{-1} of corncob biochar that produced at 360°C to a winter wheat and summer maize rotation in sandy loam soil increased the alkaline phosphatase activity by 2-3 times [13]. Biochar application enhances the Ca and Mg availability stemming from a decrease of the exchangeable acidity leading to increased maize performance [14].

(ii) *Soil acidity*

Soil acidity is a major constraint in upland agriculture. About 30% of the potential arable lands in the world are reportedly acidic nature [15]. Calcium, Magnesium, Phosphorus deficiencies and Al toxicity are important factors limiting crop production in acidic soil ecosystem [16]. Acidic soil and highly weathered soils gain benefits by application of biochar mainly because of their alkaline nature [17]. Laghari *et al.* [18] reported that, application of pine sawdust biochar in a sandy desert soil is shown contrast effect of decrease the soil pH. Therefore, care must be taken during select the appropriate acidic or alkaline biochar capable of altering the soil rhizosphere accordingly for plant growth and development.

(iii) *Soil electrical conductivity (EC)*

Electrical conductivity of soil is a most important characteristic that governs the growth and quality of upland crops. Especially yield reduction in saline soil is mainly due to the presence of high concentrations of soluble salts in the soil. various studies reported that use of biochar derived from weed, wood sieving and wood waste act as a soil amendment to control soil salinity [19]. He also reported, impaired growth and yield performance of tomato plants grown under saline irrigation conditions improved significantly by application of biochar. This is mainly because of reduction in plant stresses associated with soil salinity through improving soil chemical, physical and biological properties by biochar. Plant growth in saline soil condition may adversely affected by reduction of plant osmotic potential (OP) and increase of specific ion toxicity [20]. Application of Conocarpus biochar enhanced the availability of water, nutrient and organic matter thereby act as an amendment for salt induced stress and enhanced the crop productivity. Application of biochar derived from different feedstock materials increases the soil EC in the range of 2% - 85%. Application of 45 t ha^{-1} pine sawdust biochar reported highest increase in soil EC. Similarly, application of switch grass biochar at 25, 50 and 100 t ha^{-1} increased the soil EC by 20%, 29% and 65%, respectively. In wheat cultivated soil, among the different rate of biochar application, 100 t ha^{-1} is identified as a reasonable rate for enhancing both soil EC and pH [21]. Most of the studies shows EC per cent changes with varying biochar application. Feedstock type, pyrolysis conditions, production method and application rate are the governing factors affecting the EC of soil.

(iv) *Soil cation exchange capacity (CEC)*

Cation exchange capacity is a measure to determine how many cations can be retained on soil particle surfaces. Negative charges on the surfaces of soil particles bind positively charged atoms or molecules, but allow these to exchange with other positively charged particles in the surrounding soil water. Cation exchange capacity (CEC) is a basic key indicator of soil fertility, because it shows the soil ability to supply three important plant nutrients viz., calcium, magnesium and potassium. Cation exchange capacity in related to biochar application defined as the total capacity of a biochar to adsorb and exchange positively charged species. Cation exchange capacity value of biochar varied from negligible to approximately 50 cmol (+) kg^{-1}. Depending upon the feedstock material used and pyrolysis temperature for production of biochar the CEC of the amended soil can be changed accordingly. Biochar produced under low temperature shows relatively high CEC and potentially used for improve soil fertility. However, biochar produced under higher temperature using poplar wood is not suitable for soil with poor nutrient status [22]. Many experiments reported that beneficial effect of biochar on soil CEC. Application of eucalyptus biochar at 10 t ha^{-1} reduces the soil CEC. Whereas, application of the same biochar at 50 t ha^{-1} causes increase a soil CEC by 1.1%. The highest increase in CEC is observed with rice hull derived biochar at 67.5 t ha^{-1} [23]. According to Glaser *et al.* [24], aromatic carbon oxidation and development of carboxyl group in biochar may be a reason for CEC enhancement in biochar applied soil. Biochar in soil act as a source and sink for most of the nutrients affecting plant growth and yield [25]. Hence, application of biochar in soil helps to improving the productivity and nutrient retention capacity especially in poor fertility soils.

(v) *Soil water retention*

Biochar materials possess a lower bulk density and large surface area due to a wide pore size distribution [26]. According to Chan and Xu [27], application of biochar in soil increases the net soil surface area that facilitate soil aeration and soil water retention [28]. Soil physical properties like soil structure, density, water holding capacity, pore size distribution and soil productivity were increased with biochar application. Cely *et al*. [29] reported that, biochar application is the effective method for enhancing the soil water retention in relation to field capacity, wilting point and available water that critical for crop growth. This finding is in agreement with Liu *et al.* [30], who observed plant water holding capacity increased from 0.047 to 0.049 and 0.049 to 0.068 m^{-3} in *Entisol* is attributed primarily to the porosity and high surface area of the biochar. In addition to that, application of low-density biochar, increased the soil total porosity and decreases the bulk density. Higher porosity and surface area lead to a change the tensile strength of the biochar amended soil and ultimately enhance the plant growth [31]. Hence, plants growing under water scarcity condition may gain benefit from application of biochar.

(vi) *Soil erosion*

Biochar has the potentiality to reduce soil erosion significantly [32]. Application of biochar at 33.75 and 67.50 t ha^{-1} to the highly weathered soils reduces soil erosion by 50% and 64%, respectively compared to the control [33]. In addition to that, biochar has the capacity to reducing the runoff ratio, cumulative runoff and nutrient losses in sloping uplands [34]. In biochar applied soil, formation of micro aggregates and coherence of biochar soil particles are possible mechanisms for reduced soil loss [35]. Increment in soil water table aggregates is the potential indicator mechanism for reduce the soil erosion in silt loam soils [36]. Smetanova *et al.* [37] found 10% biochar amended soil reported to reduce 40% runoff and 16% runoff coefficient. Moreover, application of biochar noted to reduce 55% runoff time generated by a rainfall with rainfall intensity of 50 mm h^{-1} [38]. Application of biochar helps to minimizing the effects of soil runoff and erosion by improved water retention and strengthening the soil physical properties [34]. Considering all these beneficial effects, biochar application in sloppy upland areas can be an effective strategy for minimizing crop damages due to soil erosion, especially during rainy seasons.

2. *Impacts on soil nutrient cycling*

Nutrient cycling in soil systems is a complex interacting phenomena and depends on multitude of external (Rainfall patterns, climatic leaching, type and chemical forms of fertilizer) and internal factors (Type of vegetation, vegetative species nutrient efficiency, soil texture, soil structure, soil solution chemistry and soil biology). In addition to that biochar can interact with various phenomena and causes pronounced changes in the soil ecosystem. Nutrient content in the biochar is very much important factor responsible for mediating biochar-plant root interactions and its affecting root growth and overall plant performance by two mechanisms viz., directly as a nutrient source and indirectly by altering the soil nutrient availability [39].

(i) *Nitrogen (N) and Phosphorus (P)*

Application of biochar exert impact on soil pH, nutrients and microbial activity led to altering the N and P cycle. Gul and Whalen [40] reported that, volatilization of ammonia and denitrification are directly affected by the adsorption of gaseous N compounds as well as ionic forms of N by biochar. Nitrogen leaching is reduced by application of biochar [41]. Application of biochar combined with compost reported to reduce the leaching loss of nutrients such as N and P from soil [43]. Moreover, application of 13.5 t ha^{-1} rice straw derived biochar in *Oxisols* noted to restore nitrification and reduce N_2O emission [44]. Willow wood derived biochar is observed to increase the soil NH_4^+ and NO_3^- in maize cultivated soil [45]. According to Palansooriya *et al*. [46] reported that, application of weed biochar at 4 t ha^{-1} and waste willow wood biochar at 10 t ha^{-1} show the highest and lowest increase of available P, respectively. Notably, in *Aridisol* exchangeable phosphorus was enhanced by switch grass derived biochar. Application of switch grass biochar at 25, 50, and 100 t ha^{-1} increases the exchangeable P in the soil by 18%, 29% and 42%, respectively [47].

Leaching of inorganic P in sandy and silty soils are significantly reduced by beech wood biochars [48]. In addition, Agegnehu *et al.* [49] reported that, highest increase (52.9%) in soil available P is found with biochar co-compost treatment. Therefore, the change in soil pH by a single or integrated biochar treatments could be more effective for enhancing available P in the soil.

(ii) *Carbon (C)*

Carbon is another important element in the soil ecosystem. Carbon sequestration is increasingly important due to climate change. Biochar is used for sequestering atmospheric carbon dioxide (CO_2) into the soil. Soil respiration in wheat - maize rotation cropping system reduced by application of maize cob derived biochar [44]. Application of walnut shell biochar at 5 t ha^{-1} to a vegetable crop field is noted to enhance the percentage of total carbon content from 1.60% [50]. This increment might be due to the recalcitrant nature of the walnut shell biochar [51]. The same researcher also observed that, C:N ratio in vegetable crop fields is notably increased by biochar application [52]. Additionally, Lu *et al.* [53] reported that, application of biochar does not affect the total CO_2 emission. It clearly indicates that biochar has some inhibitory effect on the decomposition of native soil organic carbon.

(iii) *Other elements*

According to Akhtar *et al.* [54], biochar can serve as a source or sink for available nutrients such as Na, K, Ca and Mg in soil. In the same study reported that, biochar obtained from pine sawdust and poultry litter shows a higher content of available K. In addition to that retention of base cations in savanna *Oxisol* enhanced by application of wood biochar that modify the soil pH. As a result, the increased availability of Ca, Mg and K enhance the growth of maize and soybean plants [55]. From this above research evidences prove that application of biochar in soil is an effective method for enhancing nutrient cycling in soil ecosystems.

3. *Effects on soil microbial ecology*

Application of biochar facilitate suitable habitat for growth of soil microorganisms and also enhancing the soil microbial activity. Better activity, higher retention and microbial diversity of soil microorganism might be due to high surface area and hydrophobicity of biochar [56]. Domene *et al.* [57] reported, biochar derived from maize enhanced the soil biotic activity and perform well in maize cultivated sandy loam soil. In addition to that, application of biochar at the rate of 30 t ha^{-1} is reported to double the microbial density. However, the same study concludes that addition of biochar does not cause any significant changes in the soil mesofauna activity. Biochar derived from grasses and wood are capable to enhance the soil micropore and soil surface area led to inhibition of soil organic matter mineralization [58]. Application of activated switch grass biochar to arid sub soil shows a significant abundance of microbial genes involved in nitrogen nutrient cycling [59]. However, higher nitrogen fixation and denitrification genes are observed with higher biochar application rate of 135 t ha^{-1}. Hence, biochar has the potential to improve soil biological properties and help to enhance the plant growth.

4. *Changes of biochar within soil*

Changes in biochar within the soil system is mainly depend on its physicochemical properties. For example, C:N ratio of the biochar is the principal factor determining its longevity in soil [60]. Sigua *et al.* [61] found, debarked spruce derived biochar having greater carbon content resulting in a high C:N ratio (88.25:0.35) compared to poultry litter derived biochar (51.10:3.85). Biochar is resistant to degradation and it may undergo small changes after adding into the soil. Depend upon the prolonged residence in the soil, the physical structure and chemical composition of biochar is altered. In addition, factors like wind, rain, penetration of plant roots, fungal hyphae, insect and microbial activity are causing the disintegration of biochar in soils [62]. The functional groups on the outer surface of the biochar may undergo abiotic oxidation leading to carboxylation of carbon in the biochar [63]. Moreover, absorbed organic matter present in the biochar can improve the function of biochar [62]. Applied biochar interact with minerals may form organo-mineral complexes, which lead to decreased the oxidation and degradation of the biochar in the soil. This interaction is the key role for preserving biochar stability in soil systems [64]. The stability and durability of biochar is directly related to the type of feedstock materials used. Verheijen *et al.* [65] found; presence of saprophytic fungi inversely influenced the biochar integrity. Interestingly, a review conducted by Spokas [66] found that, oxygen to carbon molar ratio (O:C) less than 0.2 is indicative of a very stable biochar, often with a half-life longer than 1000 years. For biochar O:C molar ratios in the range of 0.2 - 0.6 denotes intermediate half-lives are in the range of 100-1000 years. However, the persistence and degradation of biochar in soil may vary depending upon several factors including biochar characteristics, soil properties and local environmental conditions [62]. However, the greater stability of biochar within soils, compared to other organic soil amendments confirms its potential for long-term soil productivity.

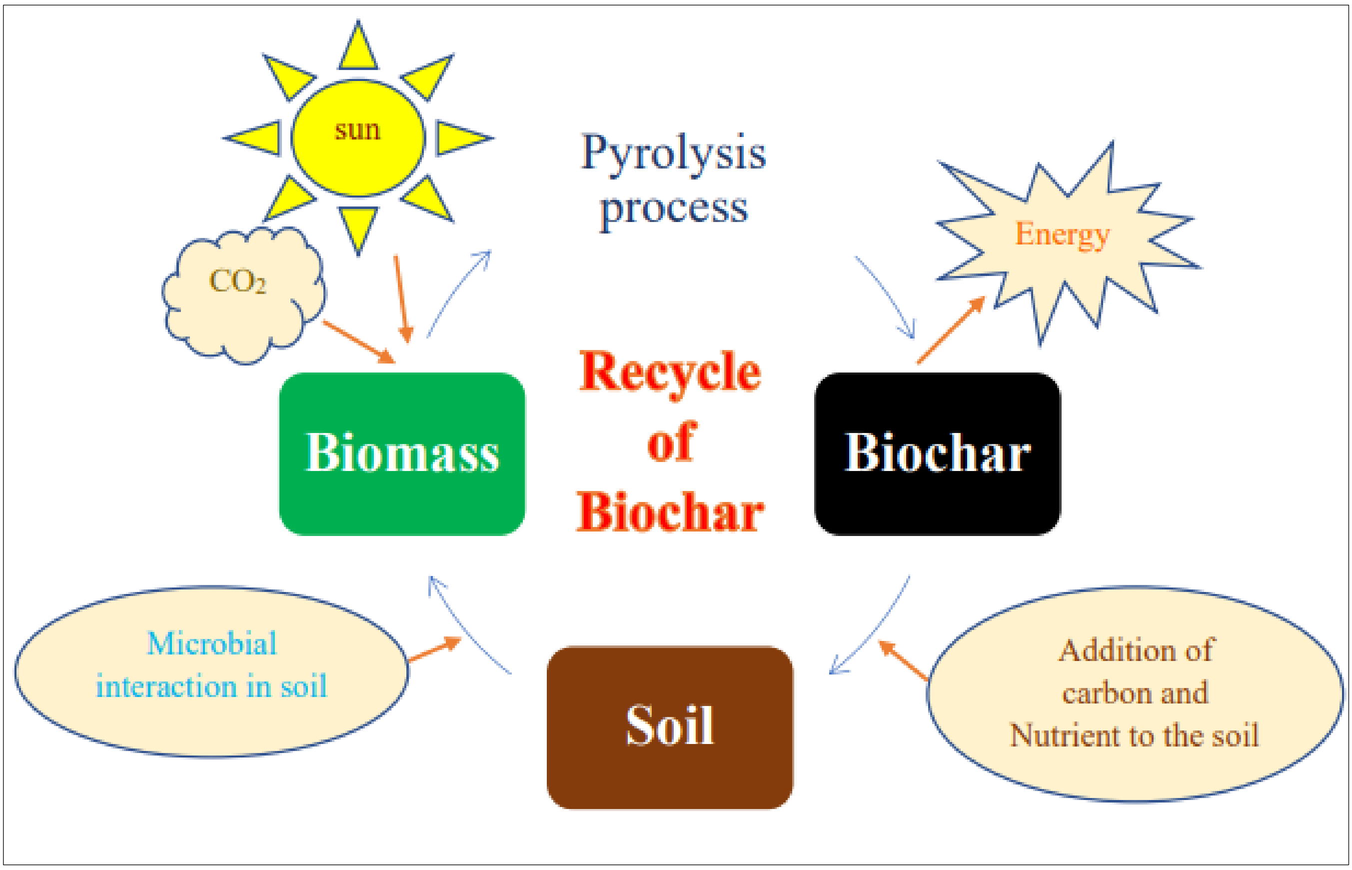

Fig 8 Systematic recycle of biochar in the environment

Future prospects of biochar

Further studies should be focused on the following identified knowledge gaps.

(i) The effects of biochar on soil properties for a long-term period and large-scale field trials should be considered.
(ii) Characteristics of biochar may vary with different feedstock material and pyrolysis process. It's necessary to focus on the production of biochar specifically designed for soil management according to the properties of the soil and the environmental conditions.
(iii) The dynamic mechanism of interaction between microorganisms and biochar should be understood thoroughly in order to maximize its remediation efficiency.
(iv) Further research is required to comprehensively explore the influencing factors for pesticide degradation by microorganisms and biochar.
(v) Production and application of functionalized biochar as a potential material for soil amendment and remediation should be evaluated.

CONCLUSION

Biochar has attracted huge amount of research interest due to its abundant usage and wide potential. Among which crop enhancement, soil improvement, soil remediation, carbon sequestration and pollution control were take the most important roles. Moreover, biochar altered the physical, chemical and biological properties of the amended soil. Overall, the impact of biochar on the plant growth is mainly depend on type of biochar, soil and crop. This review clearly described that use of biochar in agricultural and environmental ecosystems is one of the viable options for improve soil productivity, plant growth and development. Available research evidences strongly justify that continued research and development efforts need for understanding more about the benefits, potentiality as well as limitations of biochar and expanding its uses for agriculture in economical way. Further research should be conducted to evaluate the economic benefits along with the environmental and agronomical perspectives for the implementation and intensive use of biochar in agriculture.

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