A review paper: the potency of biochar as bioconditioner and carbon-offset

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Abstract. Biochar presents the biochar whereby its use focuses on soil improver, known also as a biomaterial-derived product, resulting from decomposition of biomass in an oxygen-free or pyrolysis environment. This study observes the effect of the biochar amendment against pH and activity of soil microorganism. Bacterial identification has been carried out using standards applied in the Indonesian Centre for Biodiversity and Biotechnology (ICBB) laboratory. The result showed that the increase in the activity of soil microorganisms increased 3-fold compared to controls. References survey were conducted to show the benefits of biochar amendment: seedling growth, increased agricultural commodities and carbon offsets.

1. Introduction

Biochar stands for bio and charcoal, and this relatively new term is used to describe that biochar that presently serves as an alternative energy, in fact can exert other benefit, when properly used and implemented at the soil/land area. Hence, biochar presents biochar, whereby its use focuses on soil improver. Biochar has become more popular, since the discovery of black-colored soil in the Amazon Valley, often called as Terra Preta which was formed more than 2000 years ago by the habit of the local community there to burn biomass and then bury it in the soil [1]. The soil managed by the Ameridian tribe about 500-2500 years ago in fact could maintain its organic carbon tent and high fertility even for several thousand years more when it was abandoned by the local community. The source of those soil organic stuffs and the retention of such high nutrients were brought about the high biochar content inside the soil. Meanwhile, the acidic soil in the area vicinity exhibited the low fertility levels.

Biochar also known as biomaterial-derived biochar exhibit specific characteristics such as high surface area, high volume (bulkiness), the presence of micropores, exerting particular density, and ability to hold water. Those characteristics enable the biochar to provide carbon, mitigate CO₂ emission from the earth atmosphere by holding it deep inside the soil. Biochar also seems more persistent in the soil thereby signifying itself as the main alternative as the potential carbon sink of the atmospheric carbon dioxide (CO₂). Other benefits as acquired from the use of biochar are among others improving soil fertility; affording greater surface area of the biochar particles themselves, thereby rendering them able to hold water and prevent the soil from the erosion, and fixing nitrogen and other essential ions such as calcium (Ca²⁺), potassium (K⁺), and magnesium (Mg²⁺).

In general, the fertile soil requires the organic content as much as 2-5% [2]. In this regard, biochar becomes the proper alternative in managing the soil particularly as the carbon supplier and soil-fertility enhancer (bioconditioner). Organic stuffs added into the soil significantly the various soil

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functions and unexceptionally the retention of various nutrients essentially beneficial for vegetation (plant) growth [3]. Biochar turns out more effective in retaining the availability of nutrients for plants compared to other organic stuffs such as leaves, compost or animal manure. Biochar is also able to hold phosphor elements, which cannot be retained by the usual soil organics. Biochar also provided favorable growth media for soil microbes [3, 4]. Biochar can enhance the retention of water and soil nutrients, and increase the nutrient availability. The effect of increasing the soil carbon content using biochar is more permanent compared to that using organic stuffs or other fertilizers.

2. Results and Discussion

2.1. Biochar as bio conditioner

According to [5], biochar, when added into the soil, can serve as soil-fertility enhancer. This is because biochar can improve water and air circulation in the soil, thereby triggering the growth of roots and providing favourable habitats for the growth of plant seedling (nurseries). Besides increasing the soil pH, biochar also make ease the growth of spores and increase of their number from either ecto or endo mycorrhiza, thereby earning itself the term as soil conditioner. Biochar as added to the soil besides enhancing its fertility could also function as a fixer for particular stuffs/compounds. This is closely related to the role of forest ecosystem (forest and soil) as the carbon sink in absorbing CO$_2$ from the atmosphere.

In Japan, the use of biochar in fact could the increase of rice production as much us 50%. In addition, the biochar use was able to increase the number of leaves, enlarge the area of tree canopy (crown) particularly at the town forests, thereby rendering it effective to mitigate and decrease the air pollution as well as temperature through the absorption of atmospheric CO$_2$ [6]. Further, experiments results revealed that the addition of biochar and calcium phosphate simultaneously to several forestry plant species could increase four times as many populations of mycorrhiza as that of the control (without biochar addition). In pine trees, such addition significantly brought about the development of tree branches and leaves. Likewise, the biochar addition to bamboo plants could increase the number of their sprouts. In Indonesia, [7] concluded that the addition of biochar powder as much as 10% of the media volume brought about significant effect on the initial height growth of kapur (Dryobalanops) plants.

Biochar contains numerous pores, and therefore when it is added to the soil, this proves effective to hold and retain soil nutrients. Afterwards, the nutrients will be released slowly or gradually in accordance with the amount required by the plants (slow release). In addition, biochar exhibits hygroscopic characteristics such that he nutrients in the soil will be easily leached out, and the corresponding area is therefore ready for use. The benefits of biochar with its use in integration with agriculture field are among others improving and enhancing soil condition, intensifying soil-water flow, triggering the growth of plant roots, adsorbing the residual pesticides and the excess of fertilizer in the soil, favouring the growth of soil bacteria as the microorganism media for symbiosis activities, preventing particular plant diseases, and increasing the fruit production as well as imparting its tastes.

In agriculture field, biochar can be used to increase the soil pH from the acidic to neutral condition, which is usually done by using agriculture lime that contains Ca and Mg compounds, thereby reducing and neutralizing the poison behaviour of Al and other negative effects due to acidic soil condition. Due to its characteristics that can be used to increase the soil pH, therefore the biochar finds itself beneficial uses at marginal lands lie which are scattered widespread in Indonesia. Therefore, the addition of biochar on soil can also improve physical, chemical, and biology properties of the soil. If the soil structure and textures are favourable, then it will facilitate the spore development and increase their number from either ecto or endo mycorrhiza. In Kameron, the use of biochar could increase the average harvest crops up to 240% compared to critical soil [8]. Biochar as employed at the level of 10 tons per ha exhibit similar efficiency as those of organic or inorganic fertilizers. As such, the biochar increases the harvest crops as much as in average 240% at the poor soil. These results were similar to those as encountered in the application of biochar at 20 tons per ha.
2.1.1. Increasing the soil pH and soil-microorganism activities

The critical condition of land area usually exhibits acidic pH, and this situation will not allow for the activity and growth of microorganisms, thereby rendering the area sooner or later dying with no nutrients available for plant growth. The use of biochar can increase the acidic soil pH to normal, thereby favourably assisting the growth, soil development and other activities of microorganisms. In Figure 1 is shown the effect of adding the biochar to the soil that increased its pH and activities of microorganisms in the soil.

![Graph showing the effect of biochar addition to soil pH and microorganism development](image)

Remarks: AKT = biochar from pine bark; AKM = biochar from mangium bark; SB = bacteria; NFB – nitrogen-fizing bacteria

**Figure 1.** The effect of biochar addition to the soil on the increase of soil pH (A), and the development of soil microorganisms (B)

2.1.2. Biochar could trigger the growth of plant sprouts

The Forest Product Research and Development Center has conducted the experiment using biochar to enhance the soil fertility (soil conditioner) since 1996. The biochar as employed focused more on the utilization of forestry wastes. It was preceded with the use of wood-sawdust wastes into biochar using semi-continuous kiln. In general, the nutrient content in the wood sawdust depended on the kinds of raw materials of sawdust. In general, the biochar as carbonized from the mixed wood sawdust exhibited the N-nutrient content in the range of 0.3-0.6%; total P and available P contents about consecutively 200-500 ppm and 30-70 ppm; K nutrient content about 0.9-3.0 meq/100 grams; Ca nutrient content about 1-15 meq/100 grams; and Mg nutrient content about 0.9-12 meq/100 grams [9].

The addition of biochar as the nursery media mixture brought out significant increase in the diameter of *Eucalyptus urrophylla*. The application of biochar brought out significant responses, with respect to the diameter as well as height of 1.5-month-old *Acacia mangium* stems. The addition of biochar with various wood/lignocellulosic species origin as much as 20% revealed that the growth media mixed with the vegetation-litter biochar yielded the most favorable responses, followed in decreasing order by the addition of rice-husk biochar. Likewise, the addition of biochar as much as 30% disclosed that the growth of plant sprouts was better on the media mixed with vegetation-litter biochar. The application of biochar to *Eucalyptus urrophylla* plants in the field revealed that when they reached 15-month age the increase in their height was higher using bamboo biochar than using sawdust biochar (ASG). Experiment results exhibited that the addition of biochar either as the media mixture or in the field brought about favorable effect on the growth of *Acacia mangium* and *Eucalyptus urrophylla* plants. Wood sawdust signifies as the potential raw material and turns out very prospective suggested as biochar for bioconditioner. Biochar addition effect on the growth of particular plants [10].
Remarks: ASP = rice-husk biochar; ASG = wood-sawdust biochar; AB = bamboo biochar; Kp = Compost; K = control; ASR = vegetation-litter biochar; AJ = teak-wood sawdust biochar

Figure 2. The effect of adding biochar on the growth of E. urrophylla stem diameter and growth of its corresponding 3-month old Acacia mangium plants [9]

Table 1. Growth responses of particular plants due to the incorporation of biochar

| Parameter                  | Area of the plants without biochar (control) | Area of the plants that incorporated compost biochar | Area of the plants that incorporated chemical fertilizer |
|----------------------------|---------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| Number of leaves           | 64                                          | 139                                                 | 71                                                  |
| Average length of leaf     | 5.76                                        | 7.68                                                | 6.04                                                |
| The average width of leaf  | 3.25                                        | 4.08                                                | 3.26                                                |
| Germination rate, (%)      | 80                                          | 90                                                  | 85                                                  |
| Length of roots            | 22                                          | 24                                                  | 25.5                                                |
| Length of the stem         | 14.66                                       | 17.19                                               | 18.23                                               |
| Diameter of the stem       | 1.2                                         | 1.35                                                | 1.33                                                |
| Number of seeds            | 26                                          | 89                                                  | 37                                                  |
| Weight of 100 seeds        | 28.1                                        | 44.25                                               | 33.85                                               |

2.1.3. Bio-active compost biochar

Bio-active compost biochar typifies as one of the biochar items produced from the composting (fermenting) process. These biochar item have been produced and socialized to the community since 2003. There have been a lot of benefits enjoyed by the particular community group who implemented this technology product. Various kinds of wastes as available in the vicinity of community residence could be utilized as biochar raw materials, and then were implemented at various plant species with significant and satisfactory results.

The production of bioactive compost biochar focused on enhancing the productivity of murbey leaves for the cultivation of silkworms. In addition, such application was also done to the cultivation of nilam, papaya, and Melaleuca bracteata plants. The yields as obtained were very promising and convincing, as by only adding bio-active compost biochar as much as 0.5 kg per cluster of murbey plants, this enabled them when reaching 10-month age to increase five times as many the number of murbey leaves as those of the control (without bioactive compost biochar). Besides, such addition also improved the qualities of silk yarns as produced from their corresponding worms. Such application
was also done at Ciloto (Forestry District of Cianjur) to pokchoi, broccoli, and carrot plants. The results as acquired in the unit area of 400 m² square revealed that the production increased by 1500 kg, when compared to those using the regular fertilizer commonly employed by the farmers, such as bokasi fertilizer. In addition, such use of bioactive compost biochar could also reduce the use of chemical fertilizer as much as 40%.

In 2003 was done the trial test of sawdust-biochar use on the growth of teak (*Tectona grandis*) sprouts until they reach 4 months old, located at the seedling area of Jembolo Sub Forestry District, administered by the State Forest Enterprise, Forestry District of Semarang (Central Java Province). Results revealed that the use of sawdust biochar and sawdust compost could increase the growth of teak sprouts and the number of their survival as much as 100% compared to those of the control. The use of biochar as much 50% brought about the most favorable portion for the growth of teak sprouts [11].

Application of bioactive compost biochar to the cabbage plants in Cibeureum, Garut (West Java Province) indicated that the use of such bioactive compost biochar was very favorable. This is shown by the production of cabbage which was higher and more compact in its texture, which weighed about 2 kg per cabbage fruit. Likewise, the application of bioactive compost biochar to the decorative (ornamental) plants (rose and algebra flowers) brought out very favorable results. The effect disclosed that that not only was the flower and leaf color brighter, but also the corresponding plants afforded high resistance (the flower and leaves of the plants not easily fallen off). Even, when the plants were left without cares, their flowers despite becoming dry were still in place firmly (not easily fallen off).

| No | Characteristics | Total |
|----|-----------------|-------|
| 1  | The yield, %    | 24.5  |
| 2  | Water content, %| 2.78  |
| 3  | The ash content, %| 5.74  |
| 4  | Volatile content, %| 20.10 |
| 5  | Carbon content, %| 74.16 |
| 6  | acidiy (pH)     | 10.20 |
|    | Nutrient content, ppm |       |
| 7  | Nitrogen (N)    | 5397.60 |
| 8  | Phosphorus (P)  | 1476.00 |
| 9  | Potassium (K)   | 783.13  |
| 10 | Sodium (Na)     | 313.69  |
| 11 | Calcium (Ca)    | 1506.03 |
| 12 | Magnesium (Mg)  | 1234.00 |
| 13 | Iron (Fe)       | 1617.6  |
| 14 | Copper(Cu)      | 103.64  |
| 15 | Zinc (Zn)       | 62.32   |
| 16 | Manganese (Mn)  | 112.95  |
| 17 | Sulfur (S)      | 528.92  |

The application of bioactive compost biochar to the tobacco plants brought out favorable results, yielding the leaf-cut pieces that weighed about 7.5 ounces (approximately 250 grams). Meanwhile, its corresponding weight of the control (without bioactive compost biochar) reached only 3 ounces (about 90 grams). In this way, therefore, the tobacco trees which were planted with the addition of bioactive compost biochar produced the tobacco leaves about 2 times as much the weight as that without the bioactive compost biochar. In addition, the drying of tobacco leaves where their host trees incorporated the use of bioactive compost biochar proved also more efficient, requiring only 3-4 days,
while those of the control took longer days for the drying. Likewise, the aroma and smell of tobacco leaves that used bioactive biochar were more pungent and stronger compared to those of the control.

2.1.4. Nutrient components contained in the sawdust biochar

The biochar commonly is composed of water, volatile matter, tar, wood vinegar, ash, and fixed carbon. Such composition depends on the kinds of biochar raw materials, and carbonization methods. However, in general the resulting biochar afford a comparative superiority in each use. For example, in agriculture field, all those components are needed, but in industry its water content should be kept minimum. The nutrient content in the sawdust biochar depends also on the raw material of sawdust itself. In general, the biochar carbonized from the wood sawdust exhibit the N nutrient content in the range about 0.3-0.6%; total P and available P nutrient content about consecutively 200-500 ppm and 30-70 ppm; K nutrient content about 0.9-3 meq/100 grams; Ca nutrient content about 1-15 meq/100 grams; and Mg nutrient content about 0.9-12 meq/100 grams [12].

2.2. Biochar as an additional carbon offset

The carbon offsets signify as the mitigation of greenhouse gases (GHG) measured in CO$_2$-equivalent tons. The offset or saving of carbon is realized from the changes as imposed to avoid such GHG release in the atmosphere by absorbing CO$_2$ or other GHGs (e.g. methane, nitrous oxide, hydrofluorocarbons, hexafluoro carbons, and sulphur-hexafluoride). Therefore, additional carbon offset in this context refers to intensifying the mitigation of CO$_2$ emission through the use of so-called biochar.

According to experts, billions of tons of carbon is separated from the rest of the decomposition of biomass agriculture, plantation and forestry can be stored in the soil in the world. Carbon stored in the pores of biochar or is currently better known as "biochar", is an important alternative to address greenhouse gas emissions. Biochar appears to lock carbon in a longer time, up to 15 to 20 years, even recent information suggests that biochar can be store in the soil at least 100 years, even some experts say more than 5000 years. Carbon offset is a reduction in greenhouse gas emissions measured in tons of carbon dioxide (CO$_2$) equivalent. Carbon offsets or savings resulting from changes made to avoid or absorb carbon dioxide or greenhouse gas main (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride). So, in this case the additional carbon offsets are the additional reduction in CO$_2$ emissions through the use of biochar.

As the deposits of carbon in soil biochar works by binding and storing CO$_2$ from the air to prevent it from escaping into the atmosphere. Bonded carbon content in the soil and stored up a large amount of time, estimated at hundreds to thousands of years, but the exact calculation of the amount of CO$_2$ that can be tied very rarely available. A scientist states that for an area 250 ha able to bind to 1900 tonnes of CO$_2$ a year. Biochar can increase water retention and soil nutrient and increase the availability of nutrients. Effect of increased carbon content in soil is more permanent than the addition of biochar additions of organic material forms or other fertilizer.

Further noted also that the benefits of biochar in the soil was too much more than just as a soil fertility and increase crop productivity. The results of recent research prove unique biochar as a promising alternative for the improvement of agricultural land and reduce greenhouse gas emissions and another CO$_2$ into the atmosphere. Biochar is also more persistent in the soil so that it can be a primary choice as a potential sink for atmospheric CO$_2$.

Since biochar knew can sequester carbon in soils for hundreds to thousands of years, the subject of considerable potential as a tool to slow global warming. Burning and natural decomposition of trees and agricultural materials accounted for a large amount of CO$_2$ released into the atmosphere. Biochar can store this carbon in the soil, potentially making significant reductions in atmospheric GHG levels, at the same presence on earth can improve water quality, improve soil fertility, increase agricultural productivity and reduce pressure on forest growth that has been advanced. Thus, the use of biochar as biochar, or arkoba (fermented biochar) its use should be disseminated to all actors of agriculture, forestry and plantations in order to be useful as a balancer in the carbon cycle in nature.
3. Conclusion

The biochar amendment has succeeded in improving soil quality—based on this study. Biochar has been used by microorganisms to increase its colony. A 3-fold increase in soil microorganism colonies compared to control treatments. This statement proves the direct relationship of the biochar amendment to plant growth. The pH parameters and colonies of microorganisms are the main factors in soil improvement...

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Acknowledgements
The authors thanks go to the Forest Products R & D Center for facilities provided during the research. The authors in this paper as main contributor per each.