RESEARCH ARTICLE

International Journal of Civil, Environmental and Agricultural Engineering

DOI: 10.34256/ijceae2514

Comparision of Soil Amendments using Biochar and Traditional Compost in Enhancing Soil Quality

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Received: 07-01-2025, Revised: 11-04-2025, Accepted: 16-04-2025, Published: 29-04-2025

Abstract: Biochar and farmyard manure (FYM) are regular soil amendments enhanced used worldwide-they improve soil fertility and structure and crop productivity. Biochar improves soil health with long-lasting effects on water retention, nutrient availability, and microbial activity, while FYM, though beneficial, offers short-term improvements. An experiment was carried out at the field scale on a 30 x 30 ft plot separated into three portions-one treated with biochar, the other with FYM, and one untreated control plot. The crop planted in this experiment was Black gram (CO 6) at 45 feet between rows planted and taking care of agronomic practices. The parameters studied for soils were pH, electrical conductivity, nitrogen, phosphorus, and potassium levels before and after applying the treatments. The remaining parameters are growth and yield components: plant height, leaf height, number of leaves, pod number, pod size and pod weight to properly compare the treatments' effect. Results showed that more nutrient availability is obtained in biochar-treated soil, however, than FYM; this was 10-15% higher regarding nitrogen-phosphorus and potassium levels. Growth around 20% higher in biochar was normal in the plot with pod yield at about 25% higher than that in FYM. Further, it reduced the occurrence of weeds by 30% compared with the control plot. FYM was a bit more favorable than control and was by far inferior to biochar. All of these indicate, thus, that biochar is a better organic amendment to enhance against crop health and crop productivity in sustainable agriculture.

Keywords: Biochar, FYM, Black gram, Growth parameters, Yield components.

1. Introduction

Biochar is relatively novel in the agricultural industry because of its ability to enhance the soil chemical properties including pH, organic carbon, and nutrient status which are determined by feedstock and pyrolysis conditions [1]. Compared to straw compost, its application increases the sorption capacity of the soil to a larger extent while its impact on other aspects of the health of the soil is not always better than that of straw and compost [2]. Current literature also shows that the incorporation of biochar with compost and in particular the manure compost had a positive effect on increasing the soil nitrate availability and consequently the microbial activities thus resulting to better yields [3].

COMBI, the co-composted biochar, has been used intensively for numerous advantages beyond the simple combination of compost and biochar. Due to their ability to enhance the soil structure, increase crop yields, and demonstrated potential in the remediation of soils containing toxic metals, COMBIs have considerable potential [4]. Nevertheless, the processes whereby biochar affects the soil microbial populations and plant growth are not yet fully explained. Field tests reveal that improved biochars could offer comparable yields in fields such as conventional fertilization procedures, even if the material delivers fewer nutrients, because of the complex changes to microbial populations [5].

In areas where the availability of traditional organic manure such as farmyard manure has declined or is expensive to produce, biochar has demonstrated the possibility of replenishing soil fertility and enhancing crop yields. Studies have shown that the application of biochar can improve SOM and nutrient stock, and the results often persist for several growing cycles [6]. Furthermore, the studies also establish that the incorporation of biochar enhances water retention and productivity during water scarce period enhancing water use efficiency [7]. Similar experiments have been conducted to determine the influence of biochar combined with inorganic fertilizers in drip irrigation systems to have a positive impact on the grain and biomass yield of the maize crop. Despite this, the reaction between biochar and fertilizers influences biomass yield than the grain yield and this shows that there is a need to conduct research to ensure determination of optimum levels of biochar [8].Biochar and compost application under water limited conditions have also been reported to have the possibility of enhancing both the yield and quality of products, particularly in resource constrained production systems [9].

Some of the advantages that emanate from biochar besides the aspect of yield are the enhancement on physico-chemical properties and even the biological properties of the soil. According to research, the use of biochar especially when combined with FYM improves the SOC, availability of nutrients, and overall health of the soil thereby improving performance [10]. For instance, biochar obtained from local waste streams has been found to enhance soil health and yields, which shows the potential of this technique from an agricultural standpoint [11].

The role of biochar in practicing sustainable agriculture is further enhanced by the fact that it has nutrient retention capacity and leads to enhancement of the soil structure especially in the acidic nutrient scarce soils. Studies have established that such char applies a positive impact on the soil's pH, nutrient holding ability, and microorganisms thus play a valuable role in increasing of agricultural yield [12, 13]. Also, as advocated by others, the ability of a biochar to improve nitrogen use efficiency and yield has been proven in different types of soil and yields better results than the traditional soil amendments in terms of enhancing the performance and properties of the soil [14]. When the crop is grown through intensive production practices, SOM reduces, and the chances of facing some of the soil challenges increases. Application of organic amendments such as farmyard manure and bio char minimize these effects since they improve the SOM and the health of the soil, in a way that yields improved productivity and reduces vulnerability to soil degradation [15].

Yet, despite enhancing physical and chemical conditions of the soil, the effect of organic amendments on yields and quality may be either positive or negative – hence the need to use them in a selective manner depending on the soil and management. The effects of biochar, FYM, and nitrogen on weed control have also been tested. Soil amendments such as Biochar and FYM, especially at higher levels of application significantly contributed to the weed population and biomass owing to improved nutrient availability and accessibility [16]. Furthermore, it has been demonstrated that the application of biochar contributes to carbon storage and optimization of the soil-plant systems particularly in nutrient-poor soils and greatly increases the yield of crops or the amount of soil organic carbon [17]. Biochar has been shown to help reduce the toxicity of metals in the soils and therefore can be useful in the remediation of contaminated soils. This reveals the unique ability of biochar to suppress plant uptake of metals to a greater extent than other organic amendments, improve microbial activity and general soil conditions, making it suitable for application in difficult growing conditions [18]. Similarly, organic manure supplements, biochar containing mineral powders, enhance the soil fertility and quality as a source of substitute the inorganic fertilizers [19].

Long-term use of biochar, especially when incorporated with other organic inputs such as farmyard manure has been proved to have a positive effect on the quality and productivity of the soil [20]. Research also shows that biochar enhances physical and chemical properties of soil including SOC stocks, nutrient availability and microbial vitality [21, 22] proposed to support healthy ecological systems and sustained crop production. Furthermore, biochar can suppress nutrient leaching and enhance nutrient stability and availability, which indicates its potential for application as a soil conditioner in various types of agriculture. It also notes that biochar also increases the efficiency of compost with its joint use increasing the beneficial effect on soil structure, water holding capacity [23] as well as increasing the yields of plant growth especially in the nutrient and water scarce conditions [20].

Another evidence on how biochar contributes to environmental sustainability includes: Greenhouse gases emissions are reduced through biochar application as well as the bioavailability of pesticides and heavy metals is reduced in the soil. Other findings indicate that the use of biochar can substantially reduce the release of nitrous oxide (N2O) [24]; this is considered as one of the most potent greenhouse gases [25] as well as reduce the ability of plants to absorb pesticides for environmentally sustainable agriculture [26]. Furthermore, while the use of biochar combined with compost enhances the general fertility of the soil as well as crop productivity, the method can be recommended for increasing the resilience of agricultural practices to climate change [27]. The study shows that fine textural composts affect soil properties and plant growth to a greater extent than the coarse textural composts and the combined poultry litter poultry co-composted biochar can improve plant yield and WUE under DI [28, 29].

2. Methodology

2.1 Experimental Setup

This research tested the impact of biochar and farmyard manure (FYM) on the quality of soils and the yields of Black gram (CO 6). The research was conducted on a 30 by 30 feet plot, as shown in the figure 1 which was divided into three equal sections: One part was treated with biochar, the second with regular FYM, and the third was an untreated control. This was planted with a row spacing of 45 cm between each row of black gram crop

Figure 1. Field setup

2.2 Preparation of Amendments

The biochar is made through pit method, it is an old and affordable method of making biochar, particularly for farmers who have no easy access to pyrolysis facilities. The process is as follows:

2.2.1 Site Selection and Pit Formation

As illustrated in figure 2, the pit of dimensions 1–1.5 meters deep and 2–3 meters wide was excavated in a ventilated place. The dimensions of the pit differed according to the quantity of biochar needed. The pit walls were rammed so that no soil collapsed when it was burnt.

2.2.2 Biomass layering

Locally sourced biomass residues like maize stalks, coconut shells, wood chips, and crop stubble were arranged in layers within the pit. The denser, larger particles were at the bottom, topped with lighter substances like dried leaves and small branches to aid ignition.

Figure 2. Pit formation **Figure 3.**Burning of biomass

Figure 4. Application of biochar

2.2.3 Controlled Burning Process

Biomass was burnt from the top so that it would undergo slow, incomplete burning with limited air. Fresh biomass layers were being added gradually down the fire front as the burning proceeded downward. The pit system depends on withholding air to prevent full combustion of ash. Burning of biomass has been conditioned in this way in figure 3.

2.2.4 Flame Suppression and Cooling

Once the biomass was adequately charred (usually between 4–6 hours), the fire was doused by pouring a cover of soil over the burning material or by spraying with water to cool it and disallow it to become ash. The biochar was allowed to cool overnight.

2.2.5 Sieving and Harvesting

The cooled biochar was extracted from the pit with great care and was ground into small pieces. The sieving was performed to have an even texture so that it can be applied in the soil. Therefore, figure 4 the biochar will be used.

3. Result and Discussion

Table 1.Growth Parameters of Black gram at Different Stages at Different Treatments

Growth Stages	Treatments	Height of Plant (in cm)	Number of Branches	Number of Leaves	Length of Leaves (in cm)
Vegetative Stage	**T1**	17.3	2	10	5.5
	T2	16	2	9	5.5
	T3	14.3	2	9	4.1
Flowering And Pod Developing Stage	**T1**	38.6	5	22	9.1
	T2	35.4	4	21	8.7
	T3	31.2	4	19	8
Harvesting Stage	**T1**	46.1	7	30	11
	T2	42.7	6	28	10.6
	T3	38.5	6	26	10

T1 - Biochar treated soil, **T2** - FYM treated soil, **T3** - No amended soil

Table 1. illustrates the growth performance of black gram under varying treatments (T1, T2, and T3) had significant differences among them, where T1 presented better performance in all parameters taken into consideration. The height of the plant was maximum in T1 (46.1 cm), then T2 (42.7 cm) and finally T3 (38.5 cm), signifying better nutrient availability and intake in T1. These results corroborate earlier findings that biochar improves soil chemical parameters like pH, organic carbon, and nutrient status, and consequently enhances plant growth [1]. The growth of plant height and leaf number in T1 can also contribute to enhanced nutrient retention, microbial activity, and soil structure using biochar [3, 4].

Table 2. Yield Parameters Under Different Treatment

Yield Parameters	T1 (Biochar)	T2 (Fym)	T3 (Control)
Number of pods per plant	22	19	16
Number of seeds per pod	7.5	6.8	6.2
100-seed weight (g)	4.8	4.0	3.9
Pod length (cm)	4.8	4.3	3.9
Seed yield per plant (g)	12.5	10.8	9.2
Total yield (kg/ha)	2775	2396	2042

Values in Table 2 show that biochar application (T1) enhanced the total black gram yield significantly and reached 2775 kg/ha, which is 36% above the control and 15% above FYM. Also enhanced the pods per plant (22), seeds per pod (7.5), and 100 – seed weight (4.8g), increasing the seed yield per plant (12.5g). FYM also increased yield over control but was not as effective as biochar, suggesting that although FYM adds organic matter, its impact is comparatively shortlived. The yield increase under biochar is in line with reports that biochar increases soil fertility, water-holding capacity, and microbial activity, resulting in enhanced crop productivity [6, 8, 10]. The findings also corroborate evidence that co-composted biochar- amendments (COMBI) increase crop production, improve nutrient acquisition, and advance soil structure [4, 9].

Table 3. Soil Test Report Analysis

Parameters	Report 1 (Control)	Report 2 (Biochar)	Report 3 (Fym)	Ideal For Black Gram
pH	7.63	7.56	7.61	Slightly acidic to neutral (6.5 – 7.5)
Electrical conductivity (µS/m)	901	1437	1601	< 1500
Available nitrogen (ppm)	522.55	296.05	429.96	Moderate (200-300 ppm)
Available phosphorous (ppm)	129.30	321.00	250.81	Moderate (30-50 ppm)
Available potassium (ppm)	657.34	365.24	246.68	300-500 ppm
Organic matter (%)	3.91	3.87	3.12	> 2.5

Table 3 presents the soil test report analysis after and before treatment applications. The findings illustrate that biochar-amended soil (T1) had moderate nitrogen content (296.05 ppm), high phosphorus availability (321.00 ppm), and better organic matter content (3.87%) than FYM (T2) and control (T3). The electrical conductivity was in acceptable limits, whereas pH levels were near acidic to neutral, thus suitable for black gram growth [12, 13]. Figure 5 is the graph of soil properties in each treatment.

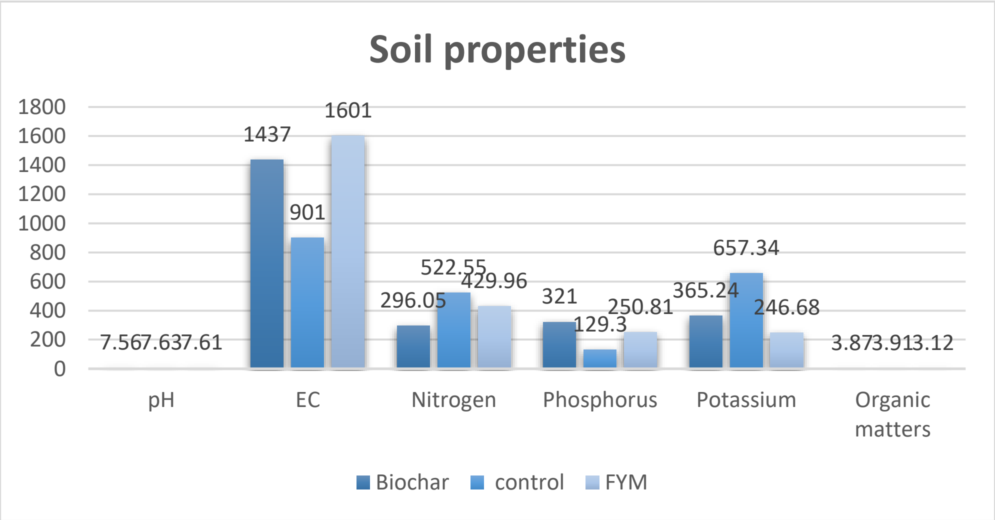

Figure 5. Soil properties of each amendment

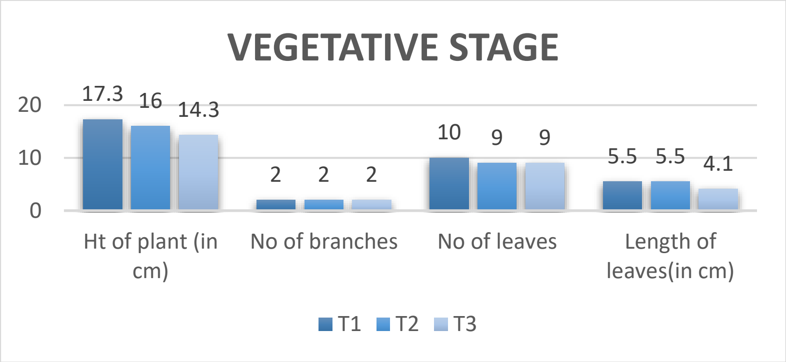

Figure 6 Readings taken in the early stage of vegetation

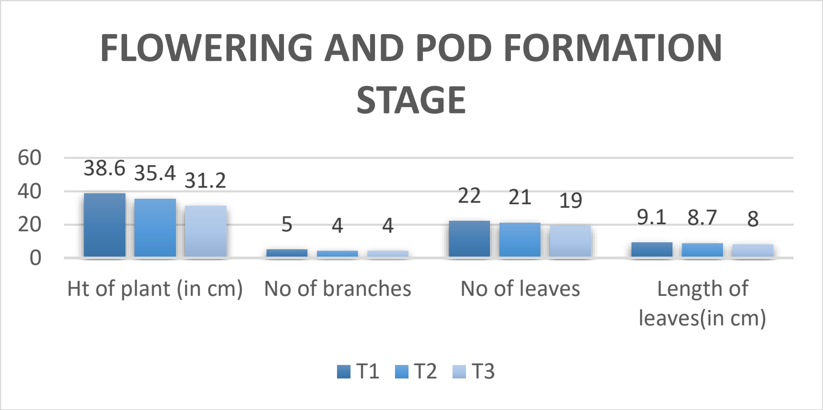

Figure 7 Readings taken in the flowering and pod developing stage

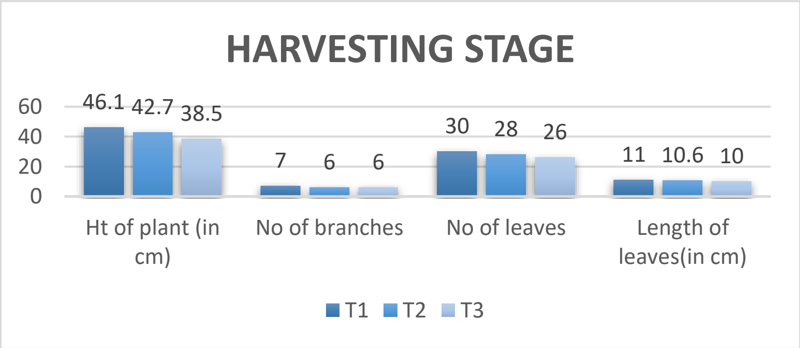

Figure 8. Readings taken in the maturing stage

The findings in Table 1, 2, 3 and Figure 6, 7, 8 indicate that the application of biochar had a beneficial effect on the soil attributes, plant growth, and yield in black gram. Biochar-amended soil (T1) performed better compared to FYM (T2) and control (T3) in all the parameters, indicating its utility as a useful soil amendment. These results conform to earlier reports showing the long-term efficacy of biochar to enhance soil fertility, nutrient availability, and crop yield [20, 22, 23].

4. Conclusion

The experiment proves that biochar application immensely improves soil fertility, plant growth, and yield over FYM and the control. Soil treated with biochar had greater phosphorus availability and nitrogen balance, avoiding excessive vegetative growth. Potassium also remained well-adjusted, supporting improved pod and seed development. Growth and yield parameters also supported the efficacy of biochar, with plant height, pod length, and seed yield per plant being greater than those in FYM-treated soil. The overall yield in biochar-treated plots was around 36% greater than the control and 15% greater than FYM-treated plots. Biochar application also decreased weed incidence by 30%, ensuring improved nutrient use by crops. These results identify biochar as a better organic amendment for sustainable farming, with long-term advantages of enhanced nutrient retention, water-holding, and weed control. Although FYM enhanced productivity in comparison to the control, its action was short-term relative to biochar.

To further enhance the efficiency of biochar in sustainable agriculture, several modifications can be considered. Nutrient enrichment of biochar by pre-charging it with compost, urea, or diammonium phosphate (DAP) has been shown to improve nutrient availability and uptake, increasing nutrient use efficiency by 25–40% and crop yield by 15–30% compared to raw biochar. Similarly, microbial inoculation of biochar with beneficial organisms such as Azospirillum, Rhizobium, or mycorrhizae can significantly improve nutrient cycling and plant-microbe interactions, leading to a yield increase of 20–35%. Surface activation of biochar is another promising modification that can significantly improve its physicochemical properties. This can be achieved through physical activation (e.g., steam or CO_2 treatment), chemical activation (e.g., using acids like HCl or H_2SO_4, or bases like KOH or NaOH), or thermal re-treatment. Steam activation at temperatures between 700–850°C enhances pore structure and increases surface area, while acid treatments can improve functional groups that facilitate nutrient adsorption. Alkaline activation with KOH or NaOH increases pH and cation exchange capacity, which boosts nutrient retention by 30–50% and enhances water-holding by 20–35%. Biochar produced at higher pyrolysis temperatures (500–700°C) tends to have higher surface area and stability, making it more effective in long-term soil improvement, whereas lower temperatures (300–400°C) preserve more labile organic compounds beneficial for short-term nutrient availability. The choice of feedstock also plays a vital role in determining biochar quality. Biochars derived from nutrient-rich materials such as poultry litter, rice husk, or sugarcane bagasse have higher native nutrient content—for instance, poultry litter biochar contains up to 3% N, 2% P, and 2% K, compared to <1% in woody biochars—leading to yield improvements of 20–40%. Optimizing these parameters based on the intended soil and crop type can maximize the benefits. Therefore, future studies should focus on long-term field experiments incorporating these biochar modifications across various agro-climatic zones and cropping systems. Additionally, integrating biochar into comprehensive nutrient management strategies and developing region-specific recommendations will be essential to fully realize its potential for sustainable agriculture.

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Funding: No funding was received for conducting this study.

Conflict of interest: The Author's have no conflicts of interest to declare that they are relevant to the content of this article.