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# Biochar as an alternative growth medium for tree seedlings in the Guinea Savanna Zone of Ghana

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**A good planting medium is required for raising tree seedlings in the nursery, however Guinea savanna soils are generally poor in nitrogen and organic matter. This poses a challenge in accessing fertile soil for tree nurseries in Northern Ghana. The experiment was conducted in the Nyankpala campus to explore the potential of plant biochar as growth media for raising tree seedlings. Growth media prepared from six different biochar formulations (Groundnut Husk Biochar; Rice Husk Biochar; Wood Biochar; Groundnut Husk Biochar + Soil; Rice Husk Biochar + Soil; Wood Biochar + Soil) and control (untreated topsoil) were each replicated in three seed boxes. Seed boxes were arranged in a Completely Randomized Design with 50 *Khaya senegalensis* seeds sown in each box. Percentage seed emergence did not vary significantly between treatments (p > 0.05) although Groundnut Husk Biochar recorded a marginally higher emergence (65.71%). Similarly, Groundnut Husk Biochar recorded a significantly higher plant height (10.23 cm) in the second week after planting (p < 0.05) as well as mean number of leaves (6.02) in the sixth week after planting (p < 0.05). In general, Groundnut Husk Biochar had the greatest effect on initial growth performance of *K. senegalensis* and could therefore be explored as a growth medium for raising tree seedlings in Northern Ghana.**

**Key words:** Biochar, growth media, *Khaya senegalensis*, plant height, soil.

## INTRODUCTION

Biochar is a carbon-rich product produced through thermal decomposition of biomass in a closed container with limited or no supply of oxygen at a temperature below 700°C (Nartey and Zhao, 2014; Lehmann, 2007). Biochar may be produced from a wide range of organic feedstock materials such as plant residue, wood biomass, and organic waste from municipal and industrial sources (Břendová et al., 2012). But, the quality and quantity of biochar produced can be influenced by feedstock properties (Zhao et al., 2013) and conditions of the carbonization process (Steiner, 2016; Gaskin et al., 2008). For instance, higher lignin content of feedstock is associated with higher biochar yield. Biochar is well known for its potential contribution to climate change mitigation due to the high residence time of the carbon in biochar (Hammes et al., 2009). This makes it a good reservoir of carbon lost in decomposition (Laird et al., 2010). Biochar has also been identified as an effective adsorbent of organic pollutants in waste water (Liu and Zhang, 2009). Aside the environmental benefits, the high

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stability and water retention capacity of biochar makes it suitable for soil amendment (Lehmann, 2007). It improves both physical and chemical properties of soils when used as soil amendment (Jha et al., 2010; Chan et al., 2008; Glaser et al., 2002).

The incorporation of biochar has been reported to influence soil structure, texture, porosity, particle size distribution and density thereby enhancing its water holding capacity (Amonette and Joseph, 2009). Bulk density and water holding capacity of sandy soils can be enhanced by the micro and macropores in biochar structure (Novak et al., 2012). Biochar can convert the labile carbon into aromatic structures of relatively low decomposition rates (Kuzyakov et al., 2009). This carbonized form makes biochar suitable for addressing nutrient leaching and carbon depletion in poor soils (Ding et al., 2016).

Despite the potential of biochar as a soil amendment (Thies and Rillig, 2009) few trails have been conducted in the savanna to ascertain its ability to improve soil condition for raising seedlings which is a great challenge to nursery managers in northern Ghana. Savanna soils are generally low in organic matter and nitrogen (FAO, 2005) which limits its ability to support the growth of tree seedlings in the nursery requiring management options to improve soil fertility (Predotova et al., 2010). This study explored the possibility of using biochar produced from plant residues as growth media for tree seedlings in the Guinea savanna zone of Ghana. This will provide valuable information to nursery managers in the zone who are expected to produce large quantities of seedlings to feed the Ghana government reforestation programme.

## MATERIALS AND METHODS

### Study area

The experiment was conducted at the tree nursery of the Faculty of Natural Resources and Environment (FNRE) of the University for Development Studies in the Tolon District (Figure 1). The site is located at latitude 9°25' N to 10° 40' N and longitude 0° 58' N to 1° 12' W with an altitude of 183 m above sea level (SARI, 1997). The area falls within the Guinea savanna agro-ecological zone which records a unimodal rainfall pattern with a mean annual rainfall of 1,034.4 mm (SARI, 2004). The mean maximum temperatures (35°C) are recorded in March and April whilst the lowest temperatures (22°C) often occur in December (SARI, 2016). The vegetation is generally grassland interspersed with some woody species. Among some of the dominant woody species indigenous to the Guinea savanna include *Vitellaria paradoxa* (shea), *Adansonia digitata* (baobab), *Parkia biglobosa* (dawadawa)*, Pterocarpus erinaceus* (rosewood) and others (SARI, 2004).

### Biochar production

Rice husk and groundnut husk feedstock were obtained from a commercial rice mill at Nyankpala. However, wood shavings feedstock was obtained from the Nyankpala market for the experiment. The various feedstocks were charred in a modified oil

barrel following the procedure described in Steiner et al. (2018). The biochar was produced on a simple top-lit updraft gasifier where a modified oil barrel was perforated with holes at the bottom to facilitate the free flow of primary air from the bottom. Also, larger L-shaped holes of 6 × 6 cm were perforated at the top sidewalls of the barrel which enabled the flow of secondary air. After which a cut was made on the top of the lid to create an opening of 20 cm with a 1 m tall chimney attached to the lid. Gasifiers were then produced in triplicates for the carbonization of the three different feedstocks. The biochar of the different plant residues was each ground into finely uniform particles before they were used as growth media.

### Seed viability test

*Khaya senegalensis* seeds obtained from the Tamale Forestry Services Division (FSD) were sorted and tested for viability prior to the experiment. One hundred seeds were randomly selected for the viability test using the floating test (Baatuuwie et al., 2019). The seeds recorded a percentage germination of 85%.

### Experimental design

Six different biochar formulations were used as experimental treatments with untreated topsoil as control; 100% groundnut husk biochar (GHB), 100% rice husk biochar (RHB), 100% wood biochar (WB), GHB + soil at a ratio of 1: 1, RHB + soil at a ratio of 1:1, WB + soil at a ratio of 1:1. Soil was collected from the FNRE mango plantation. Each treatment was replicated in three plastic seed boxes of sizes 0.45 × 0.25 m half-filled with the treatment growth medium and arranged in a complete randomized design, fifty (50) *K. senegalensis* seeds were then broadcasted in each seed box, after which they were gently covered with a thin layer of the same treatment growth medium. The seed boxes were kept under a shade net in the FNRE tree nursery. Each seed box was watered twice daily (morning and evening) with 1500 ml of water from the day of sowing to the end of the experimental period (six weeks). Weeds were removed regularly by hand to prevent competition.

Seed emergence was recorded by counting the number of seeds germinated daily per seed box for a period of thirty days after sowing. Growth parameters and chlorophyll content were recorded once every two weeks (second, fourth and sixth weeks after planting). However, plant girth was not recorded in the second week after planting because seedlings were still fragile. A TYS-B portable chlorophyll meter was used for measuring the leaf chlorophyll content, measuring tape for plant height and calipers for collar diameter (girth). Leaves were counted manually.

### Data analysis

All data collected were recorded and classified in Microsoft Office Excel 2007. Mean plant height, leaf chlorophyll content, number of leaves and plant girth were subjected to one-way analysis of variance using Minitab version 17. Means were separated using Fishers least significant differences (LSD) and considered significant at α = 0.05.

## RESULTS AND DISCUSSION

### Effect of biochar on *K. senegalensis* seed emergence

Percentage seed emergence did not vary significantly between treatments (P = 0.65), but seed emergence under GHB was marginally higher (65.71%) than all other
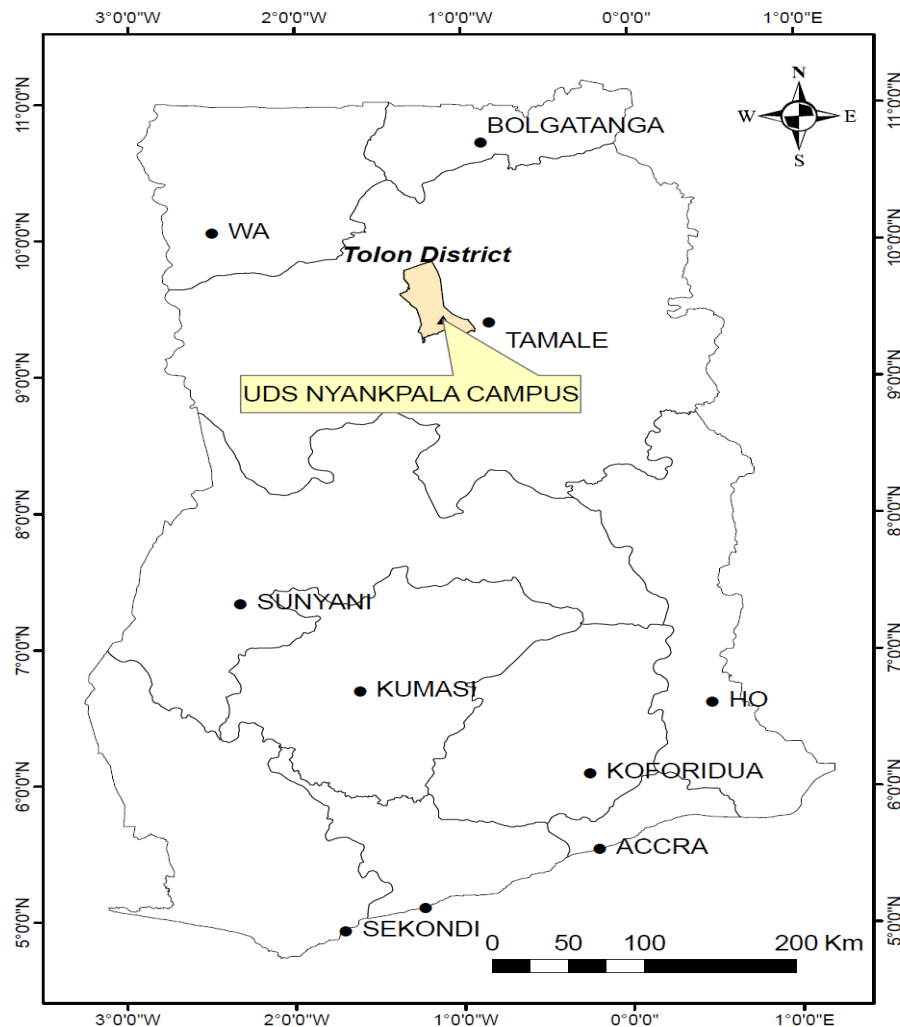
**Figure 1.** Map of the study area.
Source: Baatuuwie et al. (2019).

treatments. The RHB recorded the least percentage seed emergences (46.67%) (Figure 2). The relatively higher percentage emergence (65.71%) recorded under GHB than all other treatments might be due to the presence of Karrikins in GHB. Karrikins in biochar is reported to trigger germination of dormant seeds and regulate plant development (Kochanek et al., 2016). Biochar is also known to enhance soil pH (Novak et al., 2009), therefore the ability of a plant biochar to positively influence the pH of a growth media could aid in overcoming the inhibitory factors to germination.

**Effect of biochar on initial growth performance of *K. senegalensis***

There was a significant difference in plant height (P = 0.001) between treatments in the second week after

planting. However, plant height did not differ significantly between treatments in the $4^{th}$ (P = 0.18) and $6^{th}$ (P = 0.49) weeks after planting (Table 1). GHB recorded a marginally higher mean seedling height (10.32 cm) among all other treatments whilst the least (8.26 cm) was recorded in the control at the end of the experiment.

The control recording the least plant height (4.7 cm) in the sixth week after planting (Table 1) affirms the fact that savanna soils are poor in nitrogen and organic matter which barely support plant growth without major amendments (FAO, 2005). Therefore, biochar associated growth media might have some elevated levels of nitrogen and other nutrients for seedling growth. This is an indication that biochar properties might have influenced physical and chemical properties of the growth media providing favorable conditions for the *K. senegalensis* seedlings. On the contrary, plant height did not differ significantly in the $6^{th}$ week after planting but
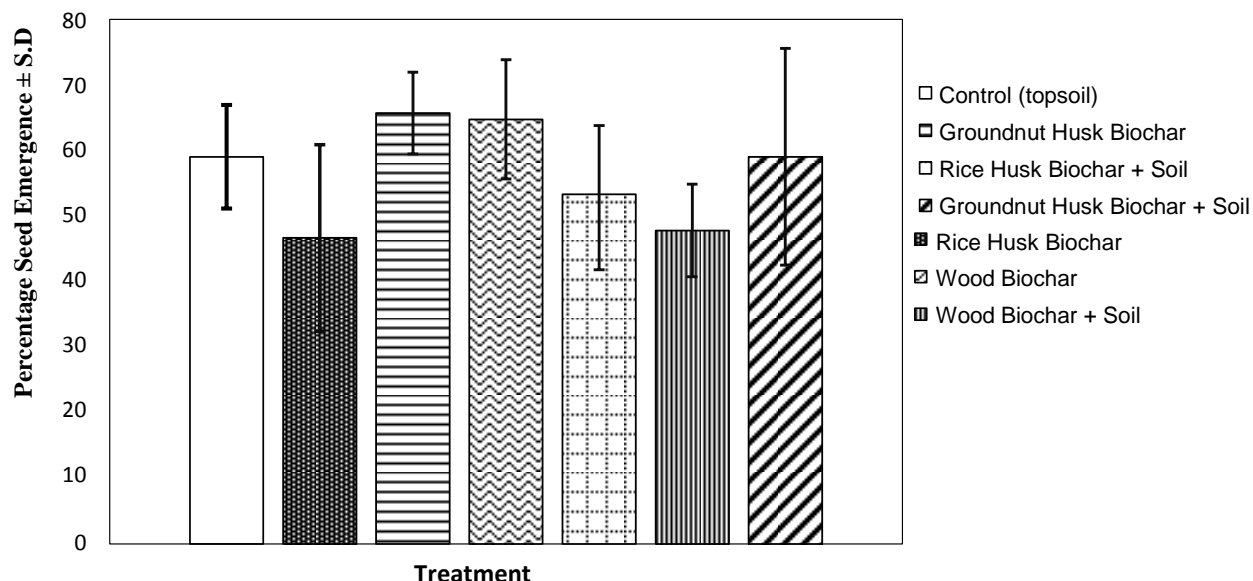
**Figure 2.** Emergence of *K. senegalensis* seeds under different biochar treatments.

**Table 1.** Mean height (cm) of *K. senegalensis* seedlings under different biochar treatments.

| Treatment | Plant height (cm) ± S. D | | |
| --- | --- | --- | --- |
| | Week 2 | Week 4 | Week 6 |
| Control | 4.7 ± 0.31[d] | 7.23 ± 1.33[b] | 8.26 ± 1.53[a] |
| RHB | 6.35 ± 0.45[a] | 8.72 ± 0.72[ab] | 9.09 ± 0.99[a] |
| GHB | 6.29 ± 0.36[a] | 9.72 ± 0.16[a] | 10.32 ± 1.19[a] |
| WB | 5.71 ± 0.81[ab] | 8.93 ±1.10[ab] | 9.51 ± 1.78[a] |
| GHB+Soil | 5.42 ± 0.05[bc] | 8.32 ± 1.05[ab] | 9.54 ± 0.82[a] |
| RHB+ Soil | 5.41 ± 0.14[bcd] | 8.40 ± 1.31[ab] | 10.15 ± 1.18[a] |
| WB+ Soil | 4.78 ± 0.08[cd] | 8.34 ± 0.65[ab] | 9.79 ± 0.83[a] |
| **P - value** | 0.001 | 0.184 | 0.497 |

Means sharing a common superscript in a column are not significantly different at $\alpha = 0.05$.

GHB recorded a marginally higher plant height (10.32 cm) than all other treatments. This could be an outcome of the high adsorption capacity of GHB which enabled accumulation of soil ions for plant root access (Saleh et al., 2011). Mean number of leaves per plant did not differ significantly between treatments in the second (P = 0.47) and fourth weeks (P = 0.84) after planting (Table 2). However, there was a significant difference between treatments (P = 0.047) in the sixth week after planting with seedlings growing on GHB recording the highest mean (6.02) number of leaves whilst RHB + Soil recorded the least (4.97).

The significantly higher number of leaves (6.02) recorded on GHB in the sixth week after planting might be attributed to the porous nature of GHB which created an atmosphere for microbial colonization and perhaps facilitated nutrient absorption and adsorption. GHB is

reported to exhibit both monolayer and multilayer adsorption properties which enhances the adsorption of chemical elements such as ammonium ions (Clough et al., 2013). This makes the GHB surface heterogeneous in nature with the ability to adsorb all kind of plant nutrient elements. Lee et al. (2016), equally indicated the porous nature of GHB as a property through which it adsorbs dissolved ions such as calcium.

Plant girth did not differ significantly between treatments (P = 0.730) in the sixth week after planting although RHB had the largest plant girth (1.99 ± 0.1210) (Table 3). Contrary to the fact that most growth parameters were higher under GHB, the largest plant girth was recorded under RHB (1.99 cm). This could be due to the high ash content of rice husk (60 to 70%) attributed to the active uptake of silicon in rice (Carter et al., 2013). Again, rice husk provides a readily soluble

**Table 2.** Mean number leaves per plant under different biochar treatments.

| Treatment | Number leave ± S. D | | |
|---|---|---|---|
| | Week 2 | Week 4 | Week 6 |
| Control | 2.22 ± 0.21[a] | 4.39 ± 0.39[a] | 5.22 ± 0.73[abc] |
| RHB | 2.38 ± 0.33[a] | 4.23 ± 0.42[a] | 4.65 ± 0.56[c] |
| GHB | 2.28 ± 0.14[a] | 4.85 ± 0.26[a] | 6.02 ± 0.47[a] |
| WB | 2.45 ± 0.21[a] | 4.62 ± 0.43[a] | 5.48 ± 0.35[ab] |
| GHB+SOIL | 2.39 ± 0.32[a] | 4.58 ± 0.20[a] | 5.13 ± 0.26[bc] |
| RHB+SOIL | 2.47 ± 0.12[a] | 4.66 ± 0.89[a] | 4.97 ± 0.48[bc] |
| WB+SOIL | 2.10 ± 0.17[a] | 4.31 ± 0.32[a] | 5.48 ± 0.34[abc] |
| **P - value** | 0.470 | 0.842 | 0.047 |

Means sharing a common superscript in a column are not significantly different at α = 0.05.

**Table 3.** Mean girth (cm) of *K. senegalensis* seedlings under different biochar treatments.

| Treatment | Plant girth (cm) | |
|---|---|---|
| | Week 4 | Week 6 |
| Control (topsoil) | 1.24 ± 0.10[b] | 1.77 ± 0.273[a] |
| RHB | 1.25 ± 0.056[ab] | 1.99 ± 0.121[a] |
| GHB | 1.39 ± 0.055[a] | 1.63 ± 0.237[a] |
| WB | 1.30 ± 0.048[ab] | 1.83 ± 0.163[a] |
| RHB+SOIL | 1.27 ± 0.029[ab] | 1.87 ± 0.326[a] |
| GHB+SOIL | 1.29 ± 0.035[ab] | 1.77 ± 0.391[a] |
| WB+SOIL | 1.25 ± 0.169[ab] | 1.75 ± 0.1434[a] |
| **P-value** | 0.355 | 0.730 |

Means sharing a common superscript in a column are not significantly different at α = 0.05.

**Table 4.** Mean chlorophyll index (mg m$^{-2}$) ± S.D under different biochar treatments.

| Treatment | Chlorophyll content ± S. D | | |
|---|---|---|---|
| | Week 2 | Week 4 | Week 6 |
| Control (Topsoil) | 30.40 ± 13.16[a] | 44.62 ± 10.24[a] | 49.92 ± 6.26[a] |
| RHB | 18.32 ± 2.34[b] | 26.52 ± 1.77[bc] | 25.07 ± 1.45[c] |
| GHB | 17.11 ± 0.91[b] | 21.4 ± 2.93[c] | 27.91 ± 6.99[bc] |
| WB | 16.01 ± 3.79[b] | 23.88 ± 2.87[bc] | 24.57 ± 0.15[c] |
| RHB+SOIL | 22.72 ± 6.05[ab] | 31.98 ± 3.06[b] | 31.74 ± 1.60[b] |
| GHB+SOIL | 19.01 ± 1.51[b] | 27.32 ± 4.17[bc] | 31.15 ± 2.35[bc] |
| WB+SOIL | 15.89 ± 3.01[b] | 28.81 ± 5.89[bc] | 27.97 ± 1.16[bc] |
| P – value | 0.092 | 0.002 | 0.0001 |

Means sharing a common superscript in a column are not significantly different at α = 0.05.

form of lime (Nattaporn et al., 2013) which can increase nutrient availability for plant root uptake facilitating stem development.

Chlorophyll content of *K. senegalensis* leaves did not vary significantly between treatments in the second week after planting (P = 0.092). However, chlorophyll content (mg m$^{-2}$) differed significantly between treatments in the 4$^{th}$ (P = 0.002) and 6$^{th}$ (P = 0.0001) weeks after planting. Generally, in the 6$^{th}$ week after planting, seedlings of the

control had the highest chlorophyll index (49.92 ± 6.26) whilst the WB recorded the least (24.57 ± 0.15) chlorophyll content (Table 4).

Chlorophyll content deviated from the trend for all other measured parameters with control (topsoil) recording a significantly higher chlorophyll content (49.92 ± 6.26) than all other treatments (P = 0.0001) in the 6$^{th}$ week after planting (Table 4). Perhaps the black colour of biochar served as a "black body" which absorbed sunlight

thereby reducing the amount of solar radiation available for chlorophyll formation.

## Conclusion

Biochar prepared from different plant residues have varied effects on seed emergence and plant growth when used as growth media. GHB had the greatest effect on seedling emergence, plant height and number of leaves. However, in terms of plant girth, RHB mixed with soil produced seedlings with the largest stems. The topsoil (control) without any amendment had a unique influence on *K. senegalensis* seedlings, producing seedlings with high chlorophyll content. In general, GHB had the greatest effect on plant growth and could be used by nursery managers for raising tree seedlings in the Guinea savanna zone of Ghana.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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