

## Comparative effects of charred bamboo and its ash on the growth of *Entandrophragma angolense* (welw.) C dc seedlings.

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### ABSTRACT

*Entandrophragma angolense* is relatively slow growing species and its growth needs to be enhanced by soil nutrients amendment. Uniformed two weeks old seedlings of *E. angolense* were transplanted into the polythene pots filled with 2kg of degraded soil and mixed with different levels of biochar and ash produced from bamboo. A 2 x 7 factorial experiment was laid out in Completely Randomized Design (CRD) with four replications to assess the effects of charred bamboo and its ash on the stem girth, leaf area, leaf production and shoot height of *E. angolense*. The germination data were subjected to descriptive statistics and analysis of variance (ANOVA). There were significant differences ( $p < 0.05$ ) among the treatments in leaf area and shoot height while there were no significant differences ( $p > 0.05$ ) among the treatments in stem girth, leaf production and interactions among levels of biochar and ash. On stem girth, leaf production and shoot height, T<sub>6</sub> (15g of bio char + 15g of ash + degraded soil) had the highest mean value of 4.27 mm, 4.59 and 37.55cm respectively while T<sub>2</sub> (30g of bio char + 0g of ash + degraded soil) had the highest leaf area (73.31cm<sup>2</sup>). The biochar and ash from bamboo had significant effects on the growth and development of *E. angolense* seedlings on degraded soil.

**Keywords:** Degraded soil, Pyrolysis, Biochar, Ash, *E. angolense*

### Resume

*Entandrophragma angolense* est une espèce à croissance relativement lente et sa croissance doit être renforcée par un amendement des éléments nutritifs du sol. Des plants en uniforme d'*E. Angolense* âgés de deux semaines ont été transplantés dans des pots en polyéthylène remplis de 2 kg de dégradé et mélangés avec différents niveaux de biochar et de cendre produite à partir de bambou. Une expérience factorielle 2 x 7 a été présentée dans une conception complètement aléatoire (CRD) avec quatre réplifications pour évaluer les effets du bambou carbonisé et de ses cendres sur la circonférence de la tige, la surface foliaire, la production de feuilles et la hauteur de pousse d'*Entandrophragma angolense*. Les données de germination ont été soumises à des statistiques descriptives et à une analyse de variance (ANOVA). Il y avait une différence significative ( $p < 0,05$ ) entre les traitements dans la surface foliaire et la hauteur des pousses alors qu'il n'y avait pas de différence significative ( $p > 0,05$ ) entre les traitements dans la circonférence de la tige, la production de feuilles et les interactions entre les niveaux de biochar et de frêne. Sur la circonférence de la tige, la production de feuilles et la hauteur des pousses, T<sub>6</sub> (15 g d'omble chevalier + 15 g de cendre + sol dégradé) avait la valeur moyenne la plus élevée de 4,27 mm, 4,59 et 37,55 cm respectivement tandis que T<sub>2</sub> (30 g d'omble chevalier + 0 g de cendre + sol dégradé) avait la plus grande surface foliaire (73,31 cm<sup>2</sup>). Le biochar et les cendres de bambou ont eu des effets significatifs sur la croissance et le développement des semis d'*E. Angolense* sur un sol dégradé.

**Mots clés:** Sol dégradé, Pyrolyse, Biochar, Cendre, *E. angolense*

Courtesy of Google Translator"

Received: 05/11/2020

Accepted: 20/12/2020

DOI: <https://dx.doi.org/10.4314/jcas.v16i3.1>

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## INTRODUCTION

Plants generally need certain basic nutrients for optimum growth and development. There are seventeen (17) macro and micronutrients which plants need to survive. Three of these nutrients are taken from the air and from water: hydrogen, oxygen and carbon. A fertile soil must be able to contain the remaining fourteen (14) nutrients in the soil and if any one of the nutrients is deficient, it can slow plant growth or cause stunted growth (Plaster, 1996). The physico-chemical properties of the soil play a vital role in plant's ability to extract adequate moisture and nutrients from it; more so that the yield of crops is the function of soil potential to supply essential requirements (Diacono and Montemuro, 2010). There are four main primary factors that affect plant growth: light, water, temperature and nutrients. These factors affect the plant's growth hormones, making the plant to either grow more quickly or more slowly. Changes in any of the factors probably as a result of environmental degradation can negatively influence plant growth (Mader *et al.*, 2002). Arable and forest tree crops required soil with appropriate nutrients for optimum growth and development in spite of the fact that tree crops obtain needed nutrients beyond sub soil while arable crops are sustained with nutrients from topsoil (Mader *et al.*, 2002). Arable land can be severely degraded through erosion to the extent of exposing unproductive subsoil of soil profile (Bahr *et al.*, 2013). Soil degradation is due to a combination of loss of nutrients and organic matter, a decrease in the soil moisture holding capacity, changes in the soil structure and texture and reduction in soil depth (Bahr *et al.*, 2013). Several observations have been made that many indigenous timber and fruit tree species in the tropics such as *Entandrophragma angolense* grow slowly despite the normal edaphic and environmental conditions (Oni and Ojo, 2002). The amendment of soil nutrients is therefore essential to instigate the rapid growth of some

of these indigenous tree species especially *E. angolense*.

*E. angolense* is a large tropical forest tree that belongs to the family Meliaceae popularly called the mahogany tree (Hutchinson and Dalziel, 1958). *Entandrophragma* comprises about 10 species and is confined to tropical Africa. Other Common names include Mukusu (Uganda), Tiama (Ivory Coast), Edinam (Ghana), Kalungi (Zaire)(Njar *et al.*, 1995). In West Africa, *E. angolense* is most common in moist semi-deciduous forest, particularly in regions with an annual rainfall of 1600–1800 mm the tree reaches a height of 48.8m and has a moderately straight bole (Chudnoff, 1984). It strongly prefers well-drained localities with good water-holding capacity (Njar *et al.*, 1995). The species has many medicinal uses like preparation for anti-malarial and anti-ulcer preparation. Other uses like furniture, joinery, cabinetmaking, boat construction, decorative veneers and plywood cannot be underestimated (Njar *et al.*, 1995). Despite the inestimable benefits of this tree, its natural stand has been threatened and there is no known plantation of the species. According to Spokas *et al.*, (2009) *E. angolense* seedling is relatively slow and its growth needs to be enhanced by ensuring availability of required soil nutrients with appropriate provision of light, water, temperature. Usually, the addition of organic matter such as compost and manure into soil can help retain nutrients and aid the soil's productivity. But these organic materials decompose very fast under the prevailing climatic conditions so that their benefits are often short lived (Bol *et al.*, 2000). Biochar has however been reported to last hundreds of years in the soil because of its aromatic structure which makes it resistant to microbial degradation (Chan *et al.*, 2007; Lehmann and Joseph, 2009). Biochar is a charcoal-like material that is produced from plant materials such as grass, agricultural and forest residues that are decomposed at high temperatures, often during renewable energy

production. During the process, the physical and chemical properties of the plant material change into a highly porous, stable, carbon-rich material known as biochar. Recent research suggests it has the potential to be used as a soil conditioner and as a container substrate amendment in agriculture and horticulture, and it may improve several soil and substrate physical, chemical and biological properties (Yuan *et al.*, 2011). In order to reduce pressure on the forest, bamboo can be used as a substitute for timber in biochar production, as it will decrease deforestation. Besides, bamboo is highly sustainable as it can be regenerated within two to three years while timber could take longer than 25 years (FAO, 1997). Bamboo charcoal is one kind of manufactured biochar, it has highly micro-porous physical structure.(Cheng *et al.*, 2006). The porosity is about five times greater and the absorption efficiency ten times higher than that of wood charcoal. Bamboo charcoal may be an ideal amendment for nutrient conservation and heavy metal stabilization due to its excellent adsorption capability, the positive effect was related to the high adsorption capacity of biochar particles during composting (Zhao *et al.*, 2013). Recent research found that biochar could act as soil fertilizers or conditioners to increase crop yield and plant growth by supplying and retaining nutrients (Yao *et al.*, 2010). Cheng *et al.*, (2006) found that bamboo biochar is an effective fertilizer when incorporated with sludge composting thereby effectively reducing nitrogen losses in the soil. In view of the fact that biochar is considered much more effective than other organic matter in retaining and making nutrients available to seedlings at nursery stage (Spokas *et al.*, 2009); this study therefore investigated the effect of bamboo biochar and its ash on the growth of *E. angolense* seedlings with a view of determining the best concentration level of biochars and ash for the optimum growth of *E. angolense* seedlings for plantation establishment.

## MATERIALS AND METHODS

### Study Area

The experiment was carried out at the Federal College of Forestry nursery, Jericho Hill, Ibadan. The College is located on the latitude 07°23' 18"N to 07° 23' 40"N and longitude 03° 36' 20"E to 03°32' 41"E. The climate of the study area is the West African monsoon with dry and wet seasons. The dry season is usually from November through March and is characterized by dry cold wind of harmattan. The wet season usually starts from April to October with occasional strong winds and thunderstorms. Mean annual rainfall is about 1548.9 mm, falling within approximately 90 days (FRIN, 2015). The mean maximum temperature is 31.9°C, minimum 24.2°C while the mean daily relative humidity is about 71.9% (FRIN, 2015).

### Experimental Procedure

Seeds of *E. angolense* were collected from a mother tree within the premises of the Forestry Research Institute of Nigeria. They were processed and soaked in water for eight (8) hours to facilitate germination before sown into a germination box filled with river sand in depth of about 5mm, and watering was done once a day. Degraded soil was collected from the College farm while it was analyzed to ascertain its initial physico-chemical status (Table 1). The bamboo culms used for the biochar and ash were gotten from the mango orchard, after the College farm Practical site, Federal College of Forestry, Ibadan. Bamboo culms were pyrolyzed to charcoal (biochar) under thermal condition as described by Odesola and Owoseni, (2010). The biochar was then ground and passed through a 2-mm sieve. For the ash, dry bamboo was gathered and burnt right in the presence of excess air. The burning continued for about an hour until the bamboo was completely turned into a whitish-black substance known as the ash. The polythene pots with size 12 x 9cm were filled with 2kg of degraded soil ( $1 \times 10^{-6}$ kg/ha) mixed with different levels of biochar and ash.

After 2-3 weeks of germination, 42 healthy seedlings were pricked out of from the box and then transplanted into polythene pots filled with two kilograms (2 kg) of growing media and monitored for one week so as to stabilize and overcome pricking shock. The biochar and ash were applied two weeks (2 weeks) before transplanting into the degraded soil in powdered form at different grams. A 2 x 7 factorial experiment was laid out in Completely Randomized Design (CRD) with four replications to assess the effects of charred Bamboo and its ash on the stem girth, leaf area, leaf production and shoot height of *E. angolense*. The first factor was biochar and ash while the second factor was different levels of biochar and ash. The treatments combinations were:  $T_1 = 0\text{g}$  of bio char +  $0\text{g}$  of ash +  $2\text{kg}$  of degraded soil (control),  $T_2$

=  $30\text{g}$  of bio char +  $0\text{g}$  of ash +  $2\text{kg}$  of degraded soil,  $T_3 = 0\text{g}$  of bio char +  $30\text{g}$  of ash +  $2\text{kg}$  of degraded soil,  $T_4 = 25\text{g}$  of bio char +  $5\text{g}$  of ash +  $2\text{kg}$  of degraded soil,  $T_5 = 20\text{g}$  of bio char +  $10\text{g}$  of ash +  $2\text{kg}$  of degraded soil,  $T_6 = 15\text{g}$  of bio char +  $15\text{g}$  of ash +  $2\text{kg}$  of degraded soil,  $T_7 = 10\text{g}$  of bio char +  $20\text{g}$  of ash +  $2\text{kg}$  of degraded soil,  $T_8 = 5\text{g}$  of bio char +  $25\text{g}$  of ash +  $2\text{kg}$  of degraded soil. The collection of data commenced two (2) weeks after transplanting into polythene pot and carried out on a weekly basis for twelve (12) weeks. Data collected on stem girth (mm), shoot height (cm), leaf area ( $\text{cm}^2$ ) and numbers of leaves of *E. angolense* seedlings were subjected to Analysis of Variance (ANOVA) using SPSS 2016 version and significant mean separated at 5% level using Duncan Multiple Range Test (DMRT).

## RESULTS AND DISCUSSION

**Table 1: Pre-cropping physical and chemical properties of degraded soil, Biochar and Ash**

Element(s)	Degraded soil	Biochar	Ash
pH ( $\text{H}_2\text{O}$ )	6.72	8.25	7.49
O. C ( $\text{g kg}^{-1}$ )	1.67	39.57	45.29
Total Nitrogen ( $\text{g kg}^{-1}$ )	1.06	31.37	0.27
Av. P ( $\text{mg kg}^{-1}$ )	1.28	46.18	24.29
Exchangeable cations ( $\text{Cmolkg}^{-1}$ )			
Mg	0.83	2.56	2.27
Na	0.27	0.17	0.15
K	0.38	24.73	22.53
Ca	0.97	0	0
Extractable Micronutrients ( $\text{mg kg}^{-1}$ )			
Mn	1.64	0	0
Fe	3.06	0	0
Zn	1.92	27.40	15.98
Cu	1.85	0	0
Particle size distribution ( $\text{g kg}^{-1}$ )			
Sand	780		
Silt	100		
Clay	120		
Textural class	Sandy Loam		

The pre-cropping physical and chemical properties of soil, biochar and ash studied were presented in Table 1. The soil has a slightly acidic reaction (6.72) while the biochar (8.25) and ash (7.49) are slightly alkaline. The soil is deficient in total N (1.06 g kg<sup>-1</sup>), organic carbon (1.67 g kg<sup>-1</sup>) and available P (1.28 mg kg<sup>-1</sup>) which is below the critical range (Adeoye and Agboola, 1985). The soil is moderate in potassium k (0.38 cmol kg<sup>-1</sup>) however sufficient in exchangeable bases with sandy loam textural class. Biochar and ash had slightly alkaline reaction (8.25 and 7.49 respectively). Biochar had the highest amount of Nitrogen (31.37 g kg<sup>-1</sup>), Phosphorus (46.18 mg kg<sup>-1</sup>), Potassium (24.73 g kg<sup>-1</sup>) and Zinc (27.40 mg kg<sup>-1</sup>) while ash has the highest amount of carbon (45.29 g kg<sup>-1</sup>).

There were significant differences ( $p < 0.05$ ) among the treatments in leaf area with highest separated mean by T<sub>2</sub> (71.33±0.55 cm<sup>2</sup>) while T<sub>8</sub> (51.10±0.61 cm<sup>2</sup>) had the least mean (Table 2). Table 3 shows mean separation for leaf area as influenced by of biochar and ash on shoot height (cm) of *E. angolense* seedlings within period of study. The T<sub>6</sub> (44.09±0.16 cm) was significant different from other treatments most especially T<sub>8</sub> (36.62±0.17 cm). This is in line with findings of Yuan *et al.*, (2011) that reported improved growth performance through biochar from crop residue with higher pH. The acidic soil when amended with the biochar became less acidic. In the natural environment, the pH of the soil has an enormous influence on soil biogeochemical processes. Soil pH is, therefore, described as the “master soil variable” that influences myriads of soil biological, chemical, and physical properties and processes that affect plant growth and biomass yield (Minasny *et al.*, 2016; Brady and Weil, 1999). The highest shoot height and leaf area produced by the treatment with equal levels of biochar and ash on the degraded soil could be ascribed to higher pH from biochar and ash. **Nitrogen (N)**, Potassium (K), and Carbon contents play

significant role in plant growth and productivity. The higher level of these nutrients in biochar and ash of bamboo and influence on the shoot development depicts their importance on plant growth. It could also be ascribed to the organic carbon that were added to the soil which probably increased the water holding capacity of the soil (Farrel and Jones, 2010; Beesley and Marmiroli, 2011).

Though, statistically there was no significant difference ( $p > 0.05$ ) in stem girth and leaf production but from figure 1, T<sub>6</sub> (15g of bio char + 15g of ash + degraded soil) had the average highest mean stem girth of 4.27mm, followed by T<sub>1</sub> (0g of bio char + 0g of ash) with a mean value of 4.25mm while T<sub>7</sub> (10g of bio char + 20g of ash + degraded soil) had the least mean value of 3.50mm.

**Table 2: Mean separation for leaf area as influenced by biochar and ash on Leaf area (cm<sup>2</sup>) of *Entandrophragma angolense* seedlings within period of study**

Treatments	Mean
T <sub>1</sub>	59.92±0.41 <sup>b</sup>
T <sub>2</sub>	71.33±0.55 <sup>a</sup>
T <sub>3</sub>	54.83±0.31 <sup>c</sup>
T <sub>4</sub>	51.19±0.14 <sup>d</sup>
T <sub>5</sub>	61.16±0.22 <sup>b</sup>
T <sub>6</sub>	56.11±0.31 <sup>c</sup>
T <sub>7</sub>	55.89±0.52 <sup>c</sup>
T <sub>8</sub>	51.10±0.61 <sup>d</sup>

Means with the same superscript are not significantly different ( $p > 0.05$ )

Table 3: Mean separation for leaf area as influenced by iochar and ash on Shoot height (cm) of *Entandrophragma angolense* seedlings within period of study

Treatments	Mean
T <sub>1</sub>	37.54±0.22 <sup>b</sup>
T <sub>2</sub>	39.17±0.12 <sup>ab</sup>
T <sub>3</sub>	41.63±0.11 <sup>ab</sup>
T <sub>4</sub>	40.89±0.25 <sup>ab</sup>
T <sub>5</sub>	43.46±0.32 <sup>a</sup>
T <sub>6</sub>	44.09±0.16 <sup>a</sup>
T <sub>7</sub>	41.25±0.23 <sup>ab</sup>
T <sub>8</sub>	36.62±0.17 <sup>c</sup>

Means with the same superscript are not significantly different ( $p > 0.05$ )

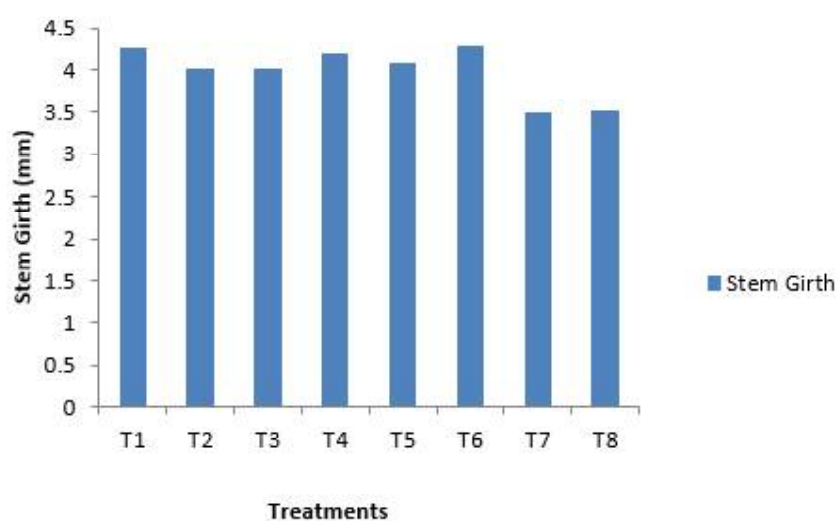
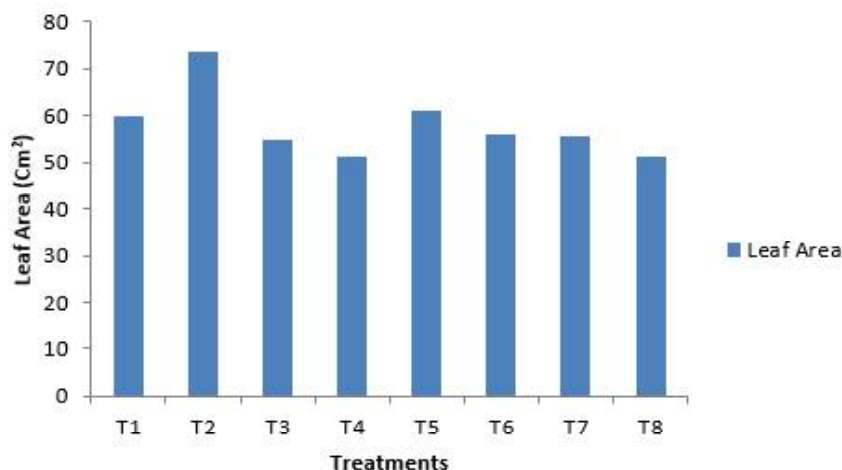


Figure 1: Effect of biochar and ash on stem girth of *E.angolense* seedlings.

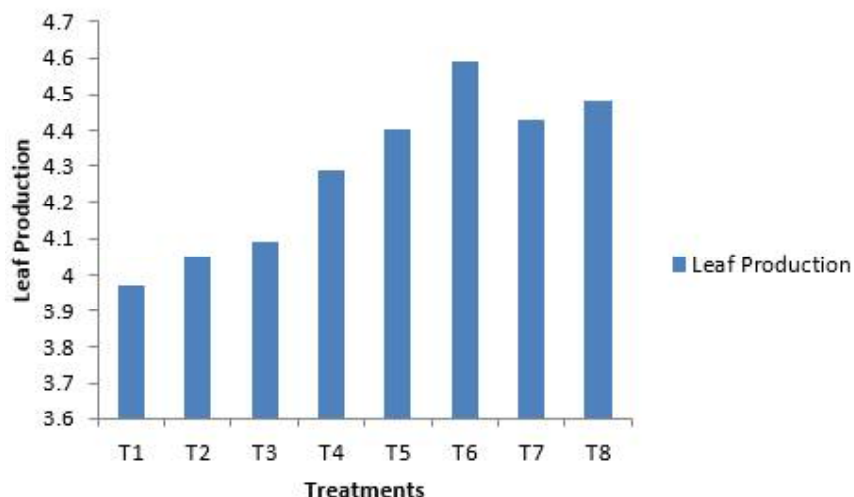
Figure 2 shows that T<sub>2</sub> (30g of bio char + 0g of ash + degraded soil) had the highest leaf area with a mean value of 73.31cm<sup>2</sup>, followed by T<sub>5</sub> (20g of bio char + 10g of ash+ degraded soil) with a mean value of 61.18cm<sup>2</sup> while T<sub>8</sub> (5g of bio char + 25g of ash + degraded soil) had the least mean value of 51.11cm<sup>2</sup>. This corroborated the findings of Lehmann, (2007) who reported on improvement of acidic soil using biochar and inorganic fertilizer (N:P:K 15:15:15) as treatments. It was found that independently, biochar can increase soil fertility of acidic soils (low pH soils), increase agricultural productivity and provide protection against some foliar and soil-borne diseases. The biochar is composed of many major and minor elements that trees need for growth (Lehmann, 2007). Since most of these elements are extracted from the soil and atmosphere during the tree's growth, they are common in our environment and are also essential in production of crops and forages. The biochar and ash of the carbonized bamboo has higher quantity of P and K which are considered as nutrients that all plants needs in fairly large quantities (relative to their size) for healthy growth. In addition to these macro-nutrients, wood ash is a good source of many micronutrients needed in trace amounts for adequate plant growth. This result confirms the assertion that all plants require adequate supply of essential nutrients to grow well in degraded soil ( Adelanı *et al.*, 2020; Arif *et al.*, 2012; Fagbenro *et al.*, 2012; Bar *et al.*, 2013). Other macronutrients such as Nitrogen, Calcium, Sulphur (S), and Magnesium promote Green leaves, vegetative growth, and sugar formations are being sustained by the presence of biochar (Yao *et al.*,2010). Essential elements from the soil are absorbed by plants through their roots and from the air (mainly consisting of

nitrogen and oxygen) through their leaves. Nutrient uptake in the soil is achieved by cation exchange through diffusion process, wherein root hairs pump hydrogen ions ( $H^+$ ) into the soil through proton pumps. All which amount physiological development of the plants. It was found from a study that biochar could act as soil fertilizers or conditioners to increase crop yield and plant growth by supplying and retaining nutrients (Lehmann, 2007; Bar *et al.*, 2013). Cheng *et al.*, (2006) found that bamboo biochar is an effective fertilizer when incorporated with sludge composting thereby effectively reducing nitrogen loses in the soil which eventually enhances plant growth.



**Figure 2: Effect of biochar and ash on the leaf area (cm<sup>2</sup>) of *E. angolense* seedlings.**

As shown in figure 3, T<sub>6</sub> had the highest mean leaf production of 4.59, followed by T<sub>8</sub> with a mean value of 4.48 while T<sub>1</sub> (control) had the least mean value of 3.97. This result was in accordance with the findings of Glaser *et al.*, (2002) who carried out a research on the amelioration of physical and chemical properties of highly weathered tropical soil using biochar and ash as treatments that Biochar and ash act as soil conditioner thereby enhancing plant growth most especially on leaf production while producing other services such as improving soil physical and biological properties. Being one of the important parts of the plant, leaves have several essential functions such as photosynthesis, transpiration, guttation and storage, among others. Meanwhile, for plant foliage to flourish, optimum soil nutrients are required which can be sustained by biochar. According to Tryon, (1999) a gradual increase in ash concentration in the soil at different proportion increase the porosity, water holding capacity,  $pH$ , conductivity, cation exchange capacity (C.E.C), sulphate, carbonate, bicarbonate, chloride and other essential soil minerals.



**Figure 3: Effect of biochar and ash on Leaf production of *E. angolense* seedlings.**

Figure 4 show that T<sub>6</sub> had the highest shoot height with a mean value of 44.08cm, followed by T<sub>5</sub> with a mean value of 43.45cm while T<sub>1</sub> had the least (37.55cm). This is in accordance with Lehmann and Joseph (2009) who carried out a study on amendment of degraded soil management using biochar. It was found that the application of biochar and ash can increase yields on formerly degraded soils by as much as 300 percent or more.

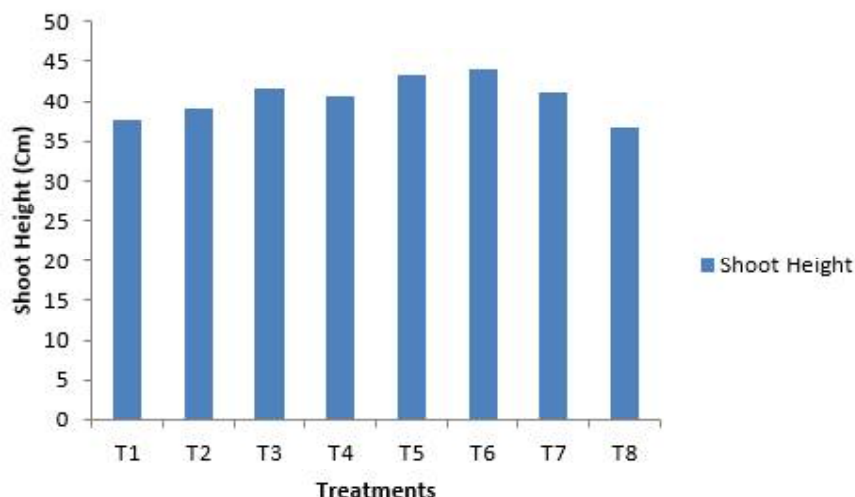


Figure 4: Effect of biochar and ash on Shoot height of *E. angolense* seedlings

## CONCLUSION AND RECOMMENDATION

Biochar and ash had influence on the growth and development of *E. angolense* seedlings in the nursery. The biochar and ash from bamboo had significant effects on the growth and development of *E. angolense* seedlings on degraded soil in terms of its height and leaf production. Different levels of biochar and ash mixed with degraded soil had varying influences on the species growth parameters. Therefore, it could be inferred that biochar and ash application in equal proportion is effective to be used on degraded land towards improvement of the soil nutrient status and it can also be used as alternative to inorganic fertilizers for seedlings production.

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