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Assessment of the Effect of Biochar and *Leucaena Leucocephala* on the Growth and Yield of Maize (*Zea mays*)

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ABSTRACT

Studies have been conducted to assess the effect of Leucaena leucocephala biomass on various crops but none has compared the effect of L. leucocephala biomass and its biochar on crops. The study therefore aimed at assessing the effect biochar and L. leucocephala have on the growth and yield of maize. It was hypothesized that biochar would have a better effect on the growth of maize than Leucaena biomass. There were six (6) treatments comprising T1= L. leucocephala, T2=Biochar, T3=Biochar + Fertilizer, T4= L. leucocephala + Fertilizer, T5=Fertilizer and T6=Control. The biochar was prepared from L. leucocephala cuttings whiles the leaves of L. leucocephala were used as its biomass. The fertilizer used was ammonia. Besides the control, all treatments were designed to supply 160kgN/ha. The result of the study showed that Leucaena biomass and biochar had same effect on the yield but Leucaena biomass had a better effect on the growth of maize than biochar. Nitrogen content of the soil increased significantly in response to both Leucaena biomass and biochar treatments. This study concludes that L. leucocephala biomass (under short term) will produce the same effect on its yield but have a better growth effect than its biochar. This therefore implies that a farmer should use Leucaena instead of biochar since it has a better effect on the growth of maize and is as well less costly. The study also implies that L. leucocephala and its biochar increases the productivity of the soil thus contributing to sustainable production. The study recommends that biochar should be applied at different rates and the study should be conducted for a longer period to realize significant differences. It also recommends that soil analysis should be replicated for each treatment to compare effects among the treatments.

Keywords : Leucaena Leucocephala, Zea mays, Maize, Biochar

I. INTRODUCTION

Maize (Zea mays) is among the world's three most important cereal crops, the other two being wheat and rice. It is a very important and common crop in most of the tropical countries. In Ghana for instance, maize crops are consumed by most people [1]. It is grown in all agro-ecological zones by a lot of rural households in all parts of the country except the Sudan savanna zone [2]. Its consumption rate is high but there is a gap between its current yield (1.7 tons/ha) and its attainable yield (5.5 tons/ha). This is as a result of dependence on rainfall, poor soil fertility, use of local seed varieties and low inputs use [3]. There is the need to close this yield gap using approaches that sustain soil fertility. Studies have shown that the application of biochar contribute to yield sustainability in several crops [4].

Biochar is a charcoal-like substance produced through a pyrolysis process which involves heating of herbaceous or ligneous biomass in an environment with low oxygen. It increases fertility, prevents soil degradation and as well sequesters carbon in the soil. Biochar improves soil through different means such as; reducing leaching of nutrients, increasing cation exchange capacity which results in improving soil fertility, moderating soil acidity for proper growth of crops such as maize, increasing water retention and increasing number of beneficial microbes [5]. Another role of biochar is to sequester carbon and store it in the soil for a long period to reduce global warming [6]. Although Biochar has all these advantages, it is not a nutrient source (cannot add appreciable amount of nutrients to the soil) but a soil conditioner which improves productivity. There are many feed stocks that can be used for biochar production which include crop residue, food waste, animal manure and some multipurpose trees such as Leucaena leucocephala. Leucaena leucocephala is a tree which has a high ability to fix nitrogen (100-300kg N/ha a year), and this can be attributed to its numerous root nodulation. Its leaves also contain more than enough nitrogen to sustain a maize crop, this enables its usefulness in an alley cropping system.

Although L. leucocephala leaves are nitrogenous, they decompose quickly which results in the leaching of nutrients from the crop root zone area even before the crop picks up [7]. In recent times, the application of biochar has emerged as one of the practical applications that can contribute significantly to sustaining yields of crops under low input agricultural practices previously in tropical countries like Ghana.

Most soils in the tropical areas are deficient in nitrogen, phosphorus or both [8] and are unable to support sustainable crop production without external inputs [9], and maize is no exception. Maize yield and productivity in Ghana is currently low and this can be attributed to factors such as irregular and erratic rainfall, decline in fertility as a result of continuous cropping and challenges of fertilizer use (such as high cost, low availability) [10]. This is likely to lead to a shortfall between domestic production and human consumption, and this is more likely to increase as the population growth rate in Ghana is 2.19% [11].

Therefore its production should be high enough to meet the demand in the country. Also population growth rate in the country is high thus demanding higher yields to meet both present and future demands. There is the need to find ways of improving soils to increase maize production. This study fills the information gap on the effect L. leucocephala in its natural and charred forms have on the growth and yield of maize.

II. METHODS AND MATERIAL

A. The study area

The study was conducted at the Faculty of Renewable Natural Resources Agroforestry Research Farm.

B. Rainfall

It has a bimodal rainfall pattern being the major rainy season and the minor rainy season. (Major rainy season; between May and July and Short dry season; in August and a long one between December and March. Minor rainy season; from September to November). The annual rainfall ranges between 1,200 mm and 1,500 mm. The area has a mean temperature of 26.6˚C and an annual humidity of 67.6% [12]. The soils are deeply weathered.

C. Soil Characteristics

The soil profiles are matured and often show clay accumulation in the subsoil. They consist of thin (about 20 cm), dark greyish brown, humus-stained, sandy loam and silt loam top soils which are usually moderate fine granular in structure and friable in consistency. The sub soils are thick, often more than 120 cm thick over the weathered substratum. Coarse and prominent mottles occur in plinthic horizons. The texture of the subsoil is highly variable. It may be sandy clay loam, silty clay loam, sandy clay or silty clay with common to many (10%-40%) quartz gravels and stones and hard iron and manganese dioxide concretions. The soils are moderate to strong medium sub angular blocky to angular blocky structured with firm to very firm consistence.

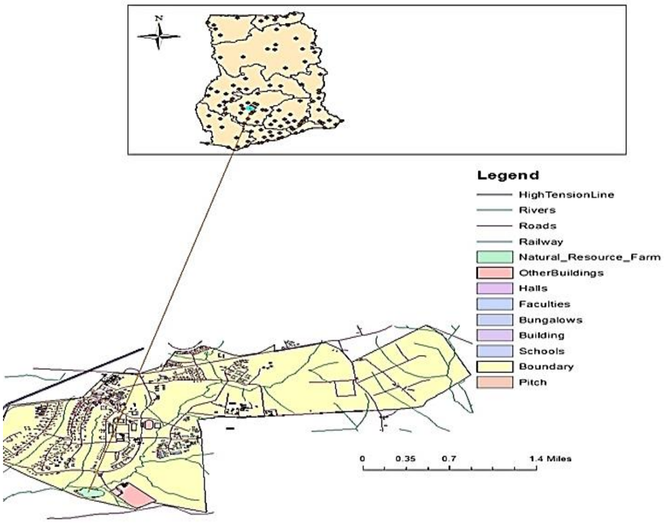

Figure 1: Map of my study area

D. Experimental Design

Randomized Complete Block Design (RCBD) was used for precision and validity of the results; the land used for the research is sloppy and therefore Abontem, an early maturing variety of maize was used. This was planted at a distance of 75 cm x 40 cm. Abontem was used because it would be able to give the required results within the research time frame. There were 6 treatments randomly arranged in 4 blocks. The 6 treatments are:

Treatment 1: Sole L. leucocephala biomass (1.08kg/2.7m^2) which is equivalent 4t/ha
Treatment 2: Sole Biochar biomass (0.54kg/2.7m^2) which is equivalent to 2t/ha
Treatment 3: Biochar (0.54kg/2.7m^2) and Ammonium sulphate (0.103kg/2.7m^2)
Treatment 4: L. leucocephala (0.54kg/2.7m^2) and Ammonium sulphate (0.103kg/2.7m^2)
Treatment 5: Ammonium sulphate (0.206kg/2.7m^2) equivalent to 762.96kg/ha
Treatment 6: Control (no input)
The Leucaena and fertile treatments (applied solely or together) were designed to provide nitrogen at the rate of 160KgN/ha.

Table 1: **Random arrangement of treatments in blocks**

B1	B2	B3	B4
T2	T3	T5	T6
T1	T2	T2	T1
T6	T4	T4	T3
T4	T6	T1	T5
T3	T1	T3	T2
T5	T5	T6	T4

E. Field preparation

The land area 10m×11m was measured and cleared. The area was divided into four (4) blocks with six (6) plots within each block giving a total of twenty-four (24) plots. Each plot had an area of 1.2m×2.25m. Both blocks and plots were spaced by 50cm. Bamboo sticks were then used to demarcate the plots. After the land was prepared, the seeds were planted.

F. Application of the treatments

Biomass of L. leucocephala was taken from the Faculty of Renewable Natural Resources Agroforestry Research farm in KNUST and biochar made from L. leucocephala cuttings were used. The biochar was made by piling up sand over the L. leucocephala cuttings to reduce oxygen, it was then subjected to heat. The amount of L. leucocephala biomass applied to each plot was 1.08kg/2.7m^2 which is equivalent to 4t/ha with the exception of plots which do not require sole L. leucocephala application. The amount of biochar and ammonium sulphate applied to each plot (with the exception of plots which do not require sole biochar or ammonium sulphate) was 0.54kg/2.7m^2 which is equivalent to 2t/ha and 0.206kg/2.7m^2 equivalent to 762.96kg/ha respectively. In plots with treatment 3, 4 & 5, each treatment was applied to supply 50% of the required nitrogen for maize growth. All these amounts are applied based on the nitrogen requirement of maize.

G. Cultural Practices

- **Weed control**

The plots were weeded once in every month using hoe as well as hand pulling.

- **Insect Pest Control**

The maize crop was infested by stem borers and these stem borers were controlled using insecticides and sometimes hand picking. The insecticide used was SUNPYRIFOS (CHLORPYRIFOS-ETHYL). It was applied as soon as attack of the insects was observed. Also contain strainers were found attacking the crop and the same treatment was used to control them.

- **Watering, Fertilizer application and Harvesting**

Watering was done twice in a day (morning and evening) as the rains became limiting. Whereas, fertilizer application was done with the use of watering cans and water holes. Fertilizer was applied two weeks after planting using the broadcasting method. However, harvesting was executed 12 weeks after planting.

PLATE 1: Fertilizer application period

PLATE 2: Harvest period

A. Effect of the application of different levels of Leucaena Biomass and Biochar on the average growth in height of maize

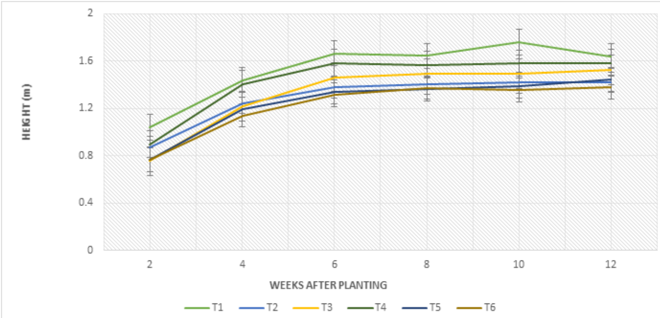

Figure 2 portrays weekly growth in height of maize in response to the different treatments. For all the treatments, growth increased steadily from the 2nd week slowly tapering off at week 8 to week 12. The height growth rate of the treatments over the study period ranked the order; T3=0.08m/week > T4=0.07m/week > T5=0.068/week > T6=0.06138/week > T1=0.06m/week > T2=0.055m/week. Height growth rate of the treatments over the study period ranked the order; T3=0.08m/week > T4=0.07m/week > T5=0.068/week > T6=0.06138/week > T1=0.06m/week > T2=0.055m/week.

Within the same week, differences in height were not statistically significant and this can be attributed to several reasons.

Even though the treatments were at different levels, they were imposed in such a way that the nitrogen supplied was the same in all treatments except control. It is possible that the equal amount of nitrogen supplied effected the same growth pattern in all the treatments.

A study conducted by [13] with sweet corn supports this study. They did a similar work on sweet corn with different biochar rates and were expecting to realize significant differences on plant growth but the result turned out to be the otherwise (no significant differences). They also realized that there were no significant differences between certain parameters which include; soil pH, electrolytic conductivity and soil temperature below the soil surface. These insignificant differences of the soil parameter could have however contributed to the statistically insignificant differences of the growth of the sweet corn.

They also explained that this analysis was done in the first year therefore it was too early to speculate the significant effects of biochar on soil properties, crop growth, and yield. It takes quite some years to observe significant changes in soil and crop attributes after biochar addition. Therefore this confirms the insignificant differences observed in this study.

Furthermore they reported that different feedstock affect crops differently. Some differ in their supply of nitrogen or any other nutrient, effect on bulk density, root length of crops and root dry weight. Depending on the feed stock, some can have increased or decreased height growth, large leaf surface area, development of pods in some crops. They discovered that herbaceous feed stocks for biochar production yield more significant effect than ligneous feed stocks. This is being confirmed by [14] when he reported in his study that there was an increase in available phosphorus after the application of biochar which could have resulted from high amount of phosphorus found in the maize stalk thus affecting the Fe, Al, pH and CEC of the soil. Therefore since the biochar used in this study was produced from a ligneous biomass (Leucaena cuttings), it could be that the biochar could not produce enough nitrogen to vary its effect from the other treatments. Also since the decomposition of biochar would require a long period of time, it is likely the biochar could not release all its nutrients to observe significant difference as compared to the other treatments.

In contrast to this study [15] reported that biochar significantly influenced stem growth but her study was done using tomatoes. Also [16] reported that Leucaena significantly affects the growth and development of tomatoes. This implies that the crops can also influence significant or insignificant differences.

TABLE 2 : Effects of Treatments on growth in Height (For 12wks) of Maize

Treatments	Height (m)
T1 (Leucaena)	1.52 ± 0.07^a
T2 (Biochar)	1.29 ± 0.05^b
T3 (Biochar + Fertilizer)	1.32 ± 0.06^b
T4 (Leucaena + Fertilizer)	1.44 ± 0.06^b
T5 (Fertilizer)	1.25 ± 0.06^c
T6 (Control)	1.25 ± 0.06^c

*Values are means of four replicates ± S.E
*Means with the same letter(s) in a column are not statistically significant

Although there were no significant differences between the treatments among the weeks, cumulatively, there were significant differences and these differences are recorded in the table 4.1.
It was recorded that L. leucocephala could significantly affect the crop and this can be attributed to the release of nutrients through decomposition of its leaves. A study in the West African Journal reported that 50% Leucaena leaf litter decomposes at about 60 days and it takes about 120 days for 80% of the litter to decompose. Since the study period was about 82 days, it implies that more than 50% of the Leucaena leaves decomposed to release nutrients which effected the significant differences [17].

From table 2, it can also be realized that L. leucocephala did better than biochar. This is because L. leucocephala decomposes to add nutrients to the soil but biochar does not release substantial amount of nutrients thus Leucaena effected the crop better than biochar.

Although biochar does not release substantial amount of nutrients (even for a long period), it amends the soil which tends to increase the productivity of the soil which will eventually have effect on the crop. This explains why biochar effected significant differences from that of the control experiment.

There were no significant differences between T3 (Biochar + Fertilizer) and T4 (Leucaena + Fertilizer). Biochar retains nutrients in the soil therefore it is very likely that the fertilizer in the treatment was retained which then affected the growth of the crop. T4 could have done better but it is also likely that leaching occurred therefore not all the nutrients had effect on the soil. These two reasons could have attributed to both having the virtually same results.

T5 (Fertilizer) and T6 (Control) had the same results and this could have resulted from leaching of the fertilizer in T5. Leaching causes the fertilizer not to have effect on the crop and this eventually led to the same result as the control. T3 (Biochar +Fertilizer) and T5 (Fertilizer) are quite similar but T3 did better because it could prevent or reduce leaching but T5 could not.

A. Effect of the application of Leucaena and biochar at different levels on the average growth in diameter of maize

Similar to growth in height, there was an increase in diameter growth from the 2nd week to the 10th week. There were no significant differences in growth diameter between the treatments in each week throughout the study. The diameter growth rate of the treatments over the study period were as follows; **T1**=1.37mm/week > **T4**=1.35mm/week > **T5**=1.20mm/week > **T2**=1.10mm/week > **T3**=1.08mm/week > **T6**=1.06mm/week.

At the end of the study T1 had the highest growth. T6 had the lowest and the intermediate was T5. Average growth rates ranged from 1.06mm/week to 1.37mm/week for T6 and T1 respectively.

Growth in diameter ranged from 3.62mm at week one for all treatments to 12.08mm to 14.59mm for T6 and T1 respectively.

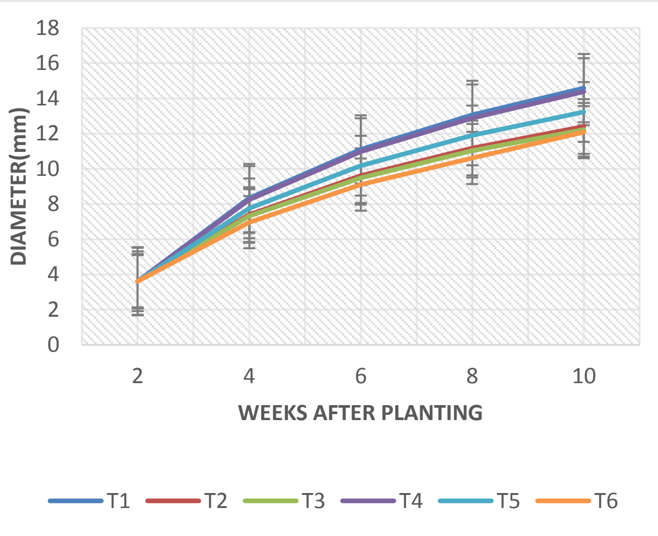

Figure 3: Diameter progression of maize over the study period in response to treatments

There were insignificant differences recorded among the weeks for the diameter growth of maize throughout the study and this can as well be attributed to so many reasons.

According to [18], different biochar types affect crops differently as a result of the temperature the biochar is subjected to. In one of their experiments, the biochar subjected to high temperature negatively affected the yields of corn plants. Thus it is likely that the temperature used to produce the biochar in this study has a relation with the insignificant differences of the diameters. Probably, the temperature resulted in the loss of too much nitrogen therefore it couldn't significantly affect the diameters of the crop.

They further said that the size of biochar particles affects crop differently. It is more likely that biochar with the larger surface area will increase the Cation Exchange Capacity (CEC) of the soil than the biochar with the smaller surface area. The increase in the CEC will furthermore increase the fertility of the soil which would significantly affect the growth of crops. On the other hand, the small surface area would not be able to significantly increase the CEC of the soil and eventually the growth of the crops. In this study, the biochar had a small surface area and this may be the reason for the insignificant differences between biochar and other treatments (among the weeks) as the biochar could not significantly affect the soil due to its small surface area.

As reported by [19], biochar's effect can significantly be seen in soils which are inefficient in retaining nutrients therefore it is supposed that the soil was already good at retaining nutrients so its effect was not significantly seen on the maize crop.

Cation exchange capacity of fresh biochar is very low but increases with time as the biochar ages. The biochar used was fresh therefore its cation exchange capacity was very low thus effecting insignificant changes [20].

He also reported that biochar increases porosity, surface area, lowers bulk density in mineral soil alters water retention, aggregation and decrease soil erosion. With this statement the biochar treatment should have significantly affected the maize but this study proved otherwise.

Lastly, he reported that biochar has a higher surface area related to other types of soil organic matter and can therefore improve soil texture and aggregation. This implies that biochar should have significantly affected the diameter of the maize crop than Leucaena but the study did not prove so. This insignificant difference could also have resulted from the short duration of the study. Perhaps significant difference would have been realized in a long term.

NB: Interpolation of the growth in diameter should be taken with caution because diameter measurements for two of the sampling days were extrapolated from regression curves as a result of missing values.

B. Effect of the application of Treatments at different levels on the yield of Maize at the end of the study

The graph shows the yield of the maize at the end of 12weeks in response to different treatments at different levels applied at the beginning of the study. The graph tells us that the treatment yields ranged from 0.53kg to 0.86kg (1196kg/ha to 3185kg/ha). Analysis of variance indicated that $P > 0.05$, therefore there were no significant differences between the different treatment There are many reasons that could account for this insignificant yield treatments.

The insignificant yield treatments could have resulted from the application method of biochar. Since the technique of top-dressing was used it is very much likely that the biochar was eroded either by wind or water thus it could not have effect on the soil consequently leading to the insignificant differences [21].

Also wood-based feed stocks generate biochar that are coarser and predominantly xylemic in nature, whereas biochar from crop residues generate finer and more brittle structure. Therefore since the biochar used for this study was gotten from Leucaena cuttings, it could not produce a finer biochar thus it had a small surface area depriving it from improving the cation exchange capacity of the soil [22].

Earthworms prefer soils amended with biochar to non-biochar amended soils. Owing to this, the soil should have been improved enough to cause significant differences in this study. However he also reported that the statement is not true for all biochar amended soils thus justifying the results of this study [23].

In contrast to this study [24] conducted a study in which he observed that biochar influenced the yield of maize significantly. His result may be due to the different rates of biochar he applied in his study. Unlike his study, this study did not use different rates hence no significant difference was realized. The contrast may have also resulted from the different environmental conditions his study was subjected to.

He also recorded that the combined treatment of biochar and inorganic nitrogen produced maize yields which were significantly higher than sole biochar and sole inorganic fertilizer. This report contradicts this study since there were no differences between the combined treatments and the sole treatments. However his significant differences recorded may have resulted from the different rates of biochar applied and the long period of the study.

Furthermore [25] also gave a contradicting report which stated that Leucaena mulch produced larger yield of about 21% in comparison to control. Their result could be attributed to complete decomposition of the Leucaena mulch. But in this study, the mulch was not completely decomposed hence no significant differences were recorded.

C. The Mean number of days taken by Maize in each Treatment to tassel

The table 4.2 indicates the mean number of days it took 50% maize in each treatment to tassel. The number of days ranged from 47 to 49. The table therefore tells us that T1 tasseled in 47 days (which is the earliest) while T5 took much longer days than all the other treatments, but since analysis of variance depicts that $p > 0.05$, it means that statistically they all took same number of days to tassel. This result could be attributed to all crops in each treatment planted at the same time, thus tasseling about the same time. Also since biochar did not significantly interact with the soil, there was no way it could have affected the number of days to 50% tasseling significantly.

Table 3 : Effects of Treatments on days to 50% tasseling

TREATMENT	MEAN (DAYS)
T1 (Leucaena)	47.5 ± 0.6455
T2 (Biochar)	49.0 ± 0.5774
T3 (Biochar + Fertilizer)	48.75 ± 0.4787
T4 (Leucaena + Fertilizer)	48.25 ± 0.6292
T5 (Fertilizer)	49.5 ± 0.6455
T6 (Control)	48.0 ± 0.4082

D. Short term effect of Treatments on soil Nitrogen content

Soil nitrogen content for all plots were assessed before and after application of treatments. The soil in all the treatment areas had the same nitrogen content which was 0.13% at the beginning of the study but at the end of the study, the nitrogen content of the soil of all the treatments increased with the exception of T6. Statistics show that there were significant differences in the nitrogen content of the soil before and after the study as $p < 0.05$.

Table 4 : Analysis of soil nitrogen content at the initial and final stage of the study for the various treatments

TREATMENT	BEFORE (%)	AFTER (%)
T1 (Leucaena)	0.13	0.15
T2 (Biochar)	0.13	0.14
T3 (Biochar + Fertilizer)	0.13	0.15
T4 (Leucaena + Fertilizer)	0.13	0.14
T5 (Fertilizer)	0.13	0.14
T6 (Control)	0.13	0.10

P= 0.0007, t-stat=-7.45

The significant increase in nitrogen in all treatments except T6 could have resulted from the addition of nutrients (including nitrogen) from the various materials in the treatments. Leucaena biomass through the decomposition of its leaves releases nutrients, the fertilizers also provide nutrients in their available forms for the crops to pick. The biochar also retains the nutrients added to the soil. All these tend to increase the amount of nitrogen in the soil. The decrease in the nitrogen content of soil recorded in T6 can be attributed to crop removal and leaching.

In line with the results of this study, [26] recorded significant differences at the initial and final stage of his study with regard to the nitrogen content of the soil. This record was also realized in a short term. He also reported that there were significant increases of the nutrient content (including nitrogen) of the soil due to increased rates of biochar application to the soil.

Also [27], reported that Leucaena significantly increased soil nitrogen content than that of control. This must have been realized due to the decomposition of the leaves to release nutrients.

On the other hand, it has been reported that it takes a long time to see the effect of biochar on the physical and chemical properties of the soil, but in this study significant differences is being recorded within a short period.

III.CONCLUSION

This study indicates that Leucaena biomass had effect on the growth of maize and Biochar also had effect on the growth of maize. Comparatively, Leucaena had more effect on the growth of maize than biochar. The study also identified that Leucaena and biochar increased the nitrogen content of the soil. However, the research found out that Leucaena and biochar had no short term effect on the yield of maize. The study also showed that the combination of biochar and fertilizer affects the growth better than fertilizer being applied solely.

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