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# Influence of Biochar Enriched with Poultry Manure on Nutrient Uptake and Soil Nutrient Changes in *Amaranthus Caudatus*

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**Abstract**

The availability of appropriate and effective fertilizers is one of the limitations of organic and ecological farming in Nigeria. A pot experiment was conducted in a screenhouse to determine the optimum rate of biochar-poultry manure combination for growth and nutrient uptake of Amaranthus (*Amaranthus caudatus* L.), as well as residual soil nutriens. The study comprised four treatments viz; control, 50% poultry manure and 50% biochar at 10, 20 and 30 $tha^{-1}$. The treatments were laid out in a completely randomized design (CRD) with four replicates. Seeds were sown in plastic containers filled with 25kg soil, with a drain underneath. Seedlings were thinned to 2 plants/pot at 2 weeks after planting. Plants were harvested at 6 weeks by ratooning and theregrowths were also harvested after 6 weeks. Soil pH increased with 50% poultry manure and 50 % biochar at $20tha^{-1}$while the organic carbon content was increased with $20tha^{-1}$. An increase in soil N, P and K was reflected in increased dry shoot weight and N, P and K uptake with biochar and compost at $20tha^{-1}$ application. Application of 50% poultry manure and 50% biochar at $20tha^{-1}$ gave the optimum Amaranthus nutrients uptake with optimum residual soil nutrient contents which areeffective for ecological farming.

**Keywords:** Biochar, Carbon, Crop performance, Organic manure, Nutrient uptake

## L'influence du biochar enrichi en fumier de volaille sur l'absorption des nutriments et les modifications des nutriments du sol chez *Amaranthus Caudatus*

**Résumé**

La disponibilité d'engrais appropriés et efficaces est l'une des limites de l'agriculture biologique et écologique au Nigéria. Une expérience en pot a été menée dans un abri grillagé pour déterminer le taux optimal de combinaison biochar-fumier de volaille pour la croissance et l'absorption des nutriments d'Amaranthus (Amaranthus caudatus L.), ainsi que les nutriments résiduels du sol. L'étude comprend quatre traitements à savoir; témoin, 50 % de fumier de volaille et 50 % de biochar à 10, 20 et 30 tha-1. Les traitements ont été disposés dans une conception complètement randomisée (CRD) avec quatre répétitions. Les graines ont été semées dans des conteneurs en plastique remplis de 25 kg de terre, avec un drain en dessous. Les semis ont été éclaircis à 2 plants/pot 2 semaines après la plantation. Les plantes ont été récoltées à 6 semaines par ratissage et les repousses ont également été récoltées après 6 semaines. Le pH du sol a augmenté avec 50 % de

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fumier de volaille et 50 % de biochar à 20tha-1, tandis que la teneur en carbone organique a augmenté avec 20tha-1. Une augmentation du N, P et K du sol s'est traduite par une augmentation du poids des pousses sèches et de l'absorption de N, P et K avec le biochar et le compost à 20tha-1 d'application. L'application de 50% de fumier de volaille et de 50% de biochar à 20tha-1 a donné l'absorption optimale des nutriments d'Amaranthus avec une teneur optimale en nutriments résiduels du sol qui sont efficaces pour l'agriculture écologique.

**Mots-clés :** Biochar, Carbone, Performance des cultures, Fumure organique, Absorption des nutriments

## Introduction

In the past few decades, chemical fertilizers have widely spread throughout the world lending credence to the fact that the soil is an inert medium for plants roots, rather than as a living biosphere in which the crop is only one of hundreds or thousands of interacting species. However, it is now realized that in fields under intensive monoculture receiving heavy applications of chemical fertilizers alone, a slow decline in productivity is recorded (Oloyede and Oyelade, 2019) Furthermore,the use of chemical fertilizers impact various negative effects on the agricultural ecosystems, such as degradation of the soil, loss of genetic diversity, reduction in soil microbial diversity, contamination of ground-water resources, and pollution of the atmosphere (Olowoake *et al,* 2021). One of the ways of sustaining soil productivity and increased yield on tropical soil is by the addition of soil amendments like biochar. Biochar is an emerging and highly promising organic material for soil organic matter maintenance and sustainable soil productivity (Fagbenro and Onawumi, 2013). Biochar is a carbon-rich solid material produced from the pyrolysis of organic materials (Lehmann and Joseph, 2009). Biochar has been reported to increase available nutrients and prevent their leaching when added to soil as an amendment, stimulate activities of important soil microbes, act as an effective carbon sink for several hundred years, sequester atmospheric $CO_2$ in soil, suppress emissions of other greenhouse gases and mitigate the detrimental effects of agrochemicals (Thies and Rillig, 2009). While biochar has been shown to have a positive conditioning effect on soil, on its own it may be limited as a nutrient supplier, because of its relatively low nutrient composition and recalcitrance to biodegradation (Partey *et al,*. 2014). Application of biochar to soils in combination with either organic or inorganic fertilizers has been reported to have pronounced effects on plant growth and yield (Chan *et al*. 2007; Dou *et al*., 2012). Biochar can effectively retain $NH_3$, $NH_4^+$and $NO_3^-$ in animal manure (Steiner *et al.* 2010). Ishizaki and Okazaki 2004 reported that bulking manure with biochar reduced N loss. Also, it enhances humification and produces mature manure with a high fertilizer value; thereby increasing the yield of crops. According to Musa *et al*., (2019) biochar and poultry manure when added to soil, boosted the mineralization of the soil after amendment and also improve the growth and yield of tomato, *Amaranthus*, like several other leafy vegetables, require a soil with a high nitrogen content with adequate nutrient reserve for optimum yield (Mbonu and Arifala, 2006). Musa *et al*., (2019) reported that biochar and poultry manure affects the soil properties, influences the microorganisms in the soil and improves crops performances. There is an increasing interest in understanding their potentials synergies in crop production so as to improve Amaranthus yield through ratooning in organic agriculture This study was conducted to determine the optimum rate of biochar in combination with poultry manure that supports growth of Amaranthus (*Amaranthus caudatus* L.) and to assess changes to soil nutrients.

## Materials and Methods

A screenhouse study was conducted in 2020 at Kwara State University, (Latitude $8^0$ 71'N and Longitude $4^0$ 44'E), Malete. Topsoil (0–15 cm depth) was collected from Kwara State University Teaching and Research Farm, Malete. Samples were air-dried and passed through a 2mm sieve. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962) and the soil pH was determined in 0.01M $CaCl_2$. Soil organic carbon and the total N were

**Table 1:** Chemical composition of biochar and poultry manure

| | Nutrient (%) | | |
|---|---|---|---|
| | Nitrogen (N) | Phosphorus (P) | Potassium (K) |
| Biochar | 1.10 | 0.50 | 0.65 |
| Poultry manure | 2.50 | 0.21 | 3.41 |

evaluated by the Walkey and Black (1934) method and the micro-Kjeldahl digestion method (Bremmer and Mulvaney, 1982), respectively. For plant analysis, 2.0g ground plant samples were taken into a beaker and digested using wet digestion of a mixture of Nitric, Sulphuric and Perchloric acid. (Okalebo*et al*., 1993) and analyzed for N, P and K. Available P was extracted by the method of Bray and Kurtz (1945), while exchangeable bases (Ca, Mg, K and Na) contents were extracted with neutral 1M NH4OAc at a soil solution ratio of 1:10 and measured by flame photometry. Magnesium was determined with an atomic absorption spectrophotometer (AAS). Micronutrients were extracted with 0.1 EDTA and determined using atomic absorption spectrophotometer. Sawdust-based biochar was collected from the Institute of Agriculture Research & Training Ibadan. Poultry manure (PM) was obtained from the poultry unit of the Teaching and Research Farm of Kwara State University. The chemical composition of Biochar and Poultry Manure used in the study is given in Table 1.

Plastic containers were filled with 25 kg of the soil with a drain underneath. Pots were arranged in the screenhouse in a completely randomized design with three replications. Pots were watered to field capacity and left to drain for 24 hours. Four treatments consisting of the control, a combination of 50 % poultry manure (PM) and 50% biochar (BC) at 10, 20 and 30t $ha^{-1}$ in three replicates. A combination of poultry manure and biochar (PM + BC) was incorporated into the soil two weeks before sowing Amaranthus seeds.

Five grams of seeds of *Amaranthus* were mixed with 500g sand and drilled in a 20-cm-diameter ring in each pot, and thinned to two seedlings after two weeks of germination. Watering and weeding were done throughout the experimental period. The plants were grown for six weeks after which they were harvested. For residual effect, plants were ratooned by cutting at 5cm above the soil line and plant regrowth was assessed at 2, 4 and 6 weeks after regeneration and harvested at six weeks after regeneration. Plant and soil samples were taken and analysed at the end of each growth cycle to determine the nutrient contents. The dried *Amaranthus* shoots were milled using Willey E. D. 5 milling equipment.

The following growth parameters were taken at an interval of two weeks; plant height, number of leaves, stem girth and dry weight. The parameters were taken in each growth cycle. Plant height was measured from the root collar to the growing tip. Plant stem girth was determined using a vernier caliper. Nutrient uptake was determined by multiplying total dry matter yield (g) with nutrient content (%).

The data collected were subjected to statistical analysis of variance and the growth cycle by biochar rate interaction was used to explain the data if it was significant. The means were separated using the Least Significant Difference (LSD) at 5% probability.

## Results

Soil pH ($H_2O$) was 6.7, which could be described as slightly acidic. The organic carbon, total N and available P values were 0.72, 0.08 (g/kg) and 5.12 mg/kg respectively. The textural class of the soil is sandy loam. The exchangeable K, Mg, Ca, Na, Exch. Acidity and Mn are 0.4 mg/kg, 1.3cmol/kg, 5.5 mg/kg, 0.8cmol/kg, 0.3cmol/kg and 121 mg/kg respectively (Table 2 ).

**Table 2:** Physico-chemical properties of experimental soil

| Parameters | Soil test value |
|---|---|
| pH | 6.7 |
| Org. C (%) | 0.72 |
| Total N ( %) | 0.08 |
| P (mgkg$^{-1}$) | 5 |
| **Exchangeable bases (c mol kg$^{-1}$)** | |
| K(mgkg$^{-1}$) | 0.4 |
| Mg (c mol kg$^{-1}$) | 1.3 |
| Ca (mgkg$^{-1}$) | 5.5 |
| Na(c mol kg$^{-1}$) | 0.8 |
| Exch. Acidity(c mol kg$^{-1}$) | 0.3 |
| **Extractable micronutrients** (mgkg$^{-1}$) | |
| Fe | 120 |
| Zn | 1 |
| Cu | 1 |
| Mn | 121 |
| **Mechanical composition (g/kg)** | |
| Sand | 770 |
| Silt | 150 |
| Clay | 80 |
| Textural class | Sandy Loam |

### *Amaranthus* growth and yield parameters

*Amaranthus* growth was affected by enriched biochar rate, growth cycle and their interaction (Table 3). Plant height at 6weeks was affected by enriched biochar rate and cropping cycle. Application of different rates resulted in comparable plant heights; the tallest plants were with treatment with 20 tha$^{-1}$at initial growth (23.1cm), but 32.6cm was produced by 30 tha$^{-1}$in regenerated plants (Fig 1 A). Stem girth was influenced by enriched biochar rate and cropping cycle, but no interaction between the duo (Table 3). Stem girth increased with enriched biochar at 20 tha$^{-1}$during the regrowth period (Figure 1B). Initial growth plants generally had thinner stems (Figure 1B).

The number of leaves/plants was affected by compost rate and cropping cycle, but no interaction between them (Table 3). Enriched biochar application at 20t/ha produced numbers of leaves/plant which were higher than 0and 10t/ha (Figure 1C). Plants from regrowths had more leaves than from initial growth (Figure 1C).

Enriched biochar rate, cropping cycle, and their interaction affected fresh yield (Table 3). Fresh shoot weight was highest with 20 tha$^{-1}$. The application of 10t/ha resulted in lower fresh yields (Figure 1D). Initial yields was lower than regrowth yield (Figures 1D).

### Nutrient uptake by *Amaranthus*

Nutrient uptake of N, P, and K in Amaranthus plants differed significantly ($P<0.05$) among the enriched biochar at different rates during the initial and regrowth period (Table 4). For the N, P and K uptake, the highest value of 0.23 mgkg$^{-1}$N, 0.77mgkg$^{-1}$ P and 36.98 mg kg$^{-1}$ K were observed in plants treated with enriched biochar at 20 tha$^{-1}$and were significantly ($P<0.05$) higher than the values of other treatments including control. During the regrowth period, the uptake of N, P and K followed the same pattern from initial growth. *Amaranthus* plant showed that enriched biochar at 20 tha$^{-1}$had the highest uptake of N, P and K and the values were 2.57 mg kg$^{-1}$ N/pot, 2.92mgkg$^{-1}$ P/pot and 124.37mgkg$^{-1}$K. All these values were significantly ($P<0.05$) different from all other treatments.

**Table 3:** Analysis of variance of *Amaranthus* growth and yield parameters

| Source | df | Plant height | Stem girth | Number of leaves | Fresh weight |
|---|---|---|---|---|---|
| Enriched biochar rate (R) | 3 | 695.82** | 31.51** | 165.93* | 359.75** |
| Cropping cycle ( C) | 1 | 740.37** | 21.13** | 1107.04** | 752.08** |
| R x C | 3 | 50.15 ns | 1.69 ns | 73.49 ns | 88.99* |

Ns: *, **Non-significant or significant at $P \leq 0.05$ or $P \leq 0.01$, analysis of variance.

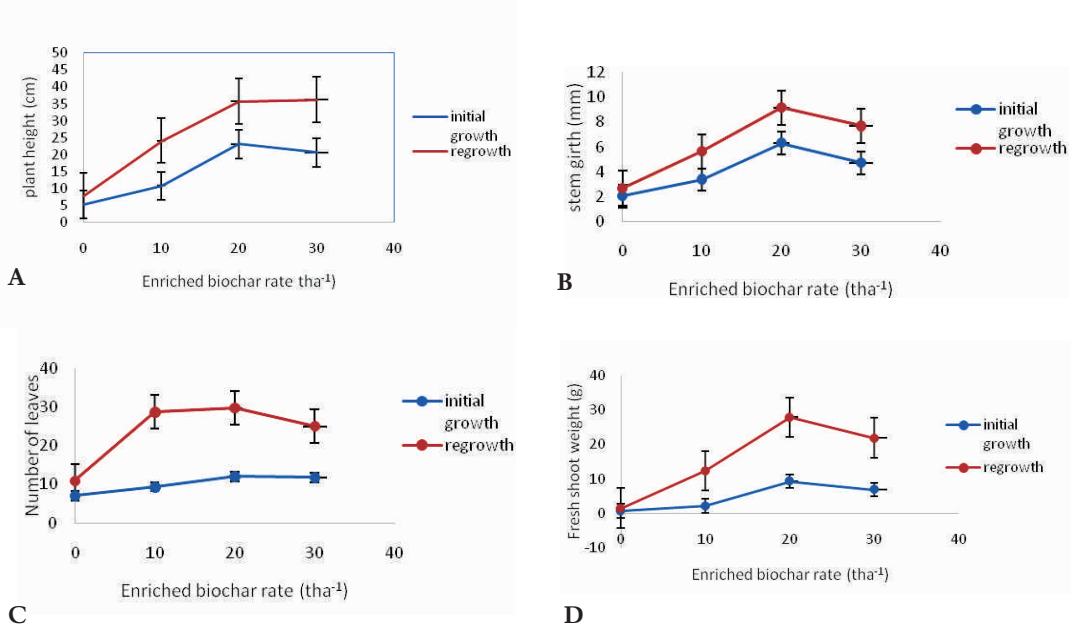



**Figure 1:** Growth of Amaranthus at 6 weeks after planting with enriched biochar rate and cycle of growth

**Table 4:** Nutrient uptake of *Amaranthus* as influenced by application of enriched biochar rate

| Cropping cycle | Enriched Biochar rate ($tha^{-1}$) | N | P | K |
|---|---|---|---|---|
| | | | mg $kg^{-1}$ | |
| Initial growth | 0 | 0.05c | 0.02c | 0.06d |
| | 10 | 0.21c | 0.19b | 2.05c |
| | 20 | 0.23a | 0.77a | 36.98a |
| | 30 | 0.59b | 0.76a | 6.94b |
| Regrowth | | | | |
| | 0 | 0.06c | 0.04c | 2.17c |
| | 10 | 0.80c | 0.87b | 10.52bc |
| | 20 | 2.57a | 2.92a | 124.37a |
| | 30 | 1.78b | 2.45a | 39.73b |

**Note:** Means having the same letter along the columns indicate no significant difference using Least Significant Difference at 5% probability level

### Soil nutrient changes

Soil pH, organic C, N, P, and K contents were affected by enriched biochar application (Table 5). At initial growth of Amaranths, pH value ranged from 6.41 in unfertilized soil to 6.09 in 20 t/ha enriched biochar. Application of enriched biochar at 20t/ha increased soil pH value than other treatments. Soil available P content in soil ranged between 6mg $kg^{-1}$ from unfertilized soil and 27 $mgkg^{-1}$ from enriched biochar at 20 $tha^{-1}$, which was higher than other treatments. However, there was a general increase in soil available P after comparing with the pre-cropping results (Table 2). K content from soil treated with enriched biochar at 20 $tha^{-1}$was significantly different

**Table 5:** Nutrient composition of the soil as affected by enriched biochar rate

| Cropping cycle | Enriched Biochar rate (t/ha) | pH | P mg kg$^{-1}$ | OC ____ % | N ____ | K mg kg$^{-1}$ |
|---|---|---|---|---|---|---|
| Initial growth | 0 | 6.41c | 6.00d | 0.41c | 0.05b | 0.19c |
| | 10 | 6.54b | 14.95c | 0.41c | 0.06a | 0.22b |
| | 20 | 6.93a | 27.48a | 0.54a | 0.06a | 0.23a |
| | 30 | 6.09a | 22.60b | 0.43b | 0.05b | 0.23a |
| Regrowth | | | | | | |
| | 0 | 7.03d | 0.04c | 2.17c | 0.02c | 0.20b |
| | 10 | 7.11c | 0.87b | 10.52bc | 0.03b | 0.20b |
| | 20 | 7.31a | 2.92a | 124.37a | 0.10a | 0.21a |
| | 30 | 7.15b | 2.45a | 39.73b | 0.03b | 0.20b |

**Note:** Means having the same letter along the columns indicate no significant difference using Least Significant Difference at 5% probability level

from other treatments. Organic C was highest due to treatment with 20 t/ha and was significantly different from other treatments. Applications of 0 tha$^{-1}$and unfertilized soil resulted in lower organic C contents than 20 tha$^{-1}$. The pH values after regrowth of Amaranths ranged from7.03 in the unfertilized pot to 7.31 in enriched biochar at 20 tha$^{-1}$.

Pot treated with 30t/ha increased in pH value than 10t/ha. Soil available P content in Amaranths pot extended between 0.04mgkg$^{-1}$ from unfertilized pot to 2.92 mgkg$^{-1}$ from 20 tha$^{-1}$pot. However, there was a general increase in soil available P when compared with the initial growth values (Table 5). The unfertilized pot had available K content of 0.20 cmol/kg, while soil from pot treated with enriched biochar soil available K from 0.20 to 0.21mgkg$^{-1}$. Soil N ranged between 2.17 % from unfertilized pot to 124.37 % from enriched biochar at 20 tha$^{-1}$. Enriched biochar at 30 tha$^{-1}$had a nitrogen content of 0.03 %.

## Discussion

The soil was slightly acidic. The pH of most agricultural soils in the tropics has been reported to range from 5.0 to 6.8 (Udo and Ogunwale, 1977). Total N and available P were below the critical level (Enwezor *et al*., 1979); Exchangeable K was high (Adeoye, 1986). Therefore, the soil needs major nutrients for crop optimum production. The low soil N and P status are expected to benefit from the application of soil amendments. Biochar was not rich in nutrients but due to enrichment of biochar with poultry manure, the rate of applications (10 to 30 tha$^{-1}$) supplied sufficient macro and micronutrients. This was revealed in plant height, stem girth, number of leaves of the *Amaranthus caudatus*. Nutrients supplied with the rate of 20 tha$^{-1}$produced yields higher than 30 tha$^{-1}$. A similar increase in yield with organic fertilizer plus (OFP) has been reported in the leafy vegetable *Telfaria* spp. (Olowoake and Adeyemo, 2020). Growth and yield parameters of regenerated plants were increased than the initial growth because they were sustained by the residual nutrients from enriched biochar. These results indicate that organic fertilizer has a high potential for building up residual nutrients in the soil. Better growth and yield of *Amaranthus* from enriched biochar could also be adduced to rise in soil pH compared to the control. The increase in soil pH could change the type of nutrient elements and enable some elements'absorption by the root (Ding *et al*. 2016). Again, an increase in cations in soil amended with biochar brings an enhancement in soil fertility and retention of nutrients which may be adduced to the high specific area and a number if carboxylic groups of biochar (Adekiya *et al*., 2020). The presence of biochar with poultry manure contributed to the soil available P. The residual P increased in the regeneration of Amaranths. Plant nutrient uptake highly hinged on the nutrient release from the soil solid phase in the form of mineral and organic materials to the soil solution (Olowoake, *et al*., 2021). Soil P level was reflected in plant P uptake, indicating that the requirement for this element is high.

## Conclusion

Based on the results obtained from the experiment, the application of 20t/ha of enriched biochar is an essential soil amendment that can enhance soil nutrient status and amaranths production. It is therefore, reasonable to use 50% poultry manure (PM) and 50% biochar (BC) at 20 $tha^{-1}$ as a substitute for expensive mineral fertilizer.

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