Response of *Amaranthus cruentus* to biochar combined with urea fertilizer in Calabar, Nigeria

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Abstract
A pot experiment was carried out in the screen house of the University of Calabar Teaching and Research Farm to determine the responses of Amaranthus cruentus to biochar combined with urea fertilizer. Eight treatments which comprised the control (no amendment), sole applied biochar (B) at 20 t/ha, sole urea (U) at 60 kg N/ha, ½ B + ½ U, ¾ B + ¼ U, ¼ B + ¾ U, Full B + ½ U and ½ B + Full U were laid out in a completely randomized design (CRD) with three replications. The experimental soil was loamy sand with a pH of 5.1. The combination of biochar with urea significantly ($p < 0.05$) increased plant growth, root growth, fresh shoot yield, nutrient concentration and crude protein contents in Amaranthus more than when biochar is singly applied. The highest shoot yield of 3578 kg/ha was obtained from the combination of 5 t/ha biochar + 45 kg/ N/ha urea (¼B + ¾U) followed by urea alone (60 kg N/ha) treated plants whereas the highest crude protein content in Amaranthus plant was from urea alone treated plants. However, based on the significant response of Amaranthus in treated soils to applied amendments compared to untreated soil, it could be concluded that both the sole and combined treatments had positive effects on crop productivity.

Keywords: *Amaranthus*, biochar, nutrient concentration, root and shoot yield, urea

Introduction

In Nigeria, as in most other tropical countries of West Africa where the daily diet is dominated by starchy staple foods, vegetables are the cheapest and most readily available sources of proteins, vitamins, minerals, and essential amino acids (Onwordi *et al.*, 2009). Vegetables, particularly the leafy vegetables, abound where there is adequate supply of water and the soil conditions are not limiting.

Amaranthus cruentus is a popular leafy vegetable cultivated in Nigeria and other West African countries which produces grain as well as leaves for human and animal utilization (Olofintonye *et al*., 2015).

It has high levels of essential micro – nutrients like iron (an important element against anemia), manganese and zinc (Mnkeni *et al*., 2007). The protein found in young plants of amaranths can be important for people without access to meat or other sources of protein (Iren *et al.,* 2016a). The demand for this crop as a vegetable has increased, especially in the urban centers where people are not involved in primary production (Schippers, 2002). This has made the vegetable to become an important commodity in the market and its production an important economic activity for farmers.

However, the yield per hectare in Nigeria is low (7.60 t $ha-^{1}$) when compared to that of United States (77.27 t ha^{-1}) and world average (14.27 t ha^{-1}) (FAO, 2007). This low yield in Nigeria is attributed to the low fertility of native soils in most parts of Nigeria. Amaranths appreciate nitrogen but high levels of nitrogen will delay the onset of flowering, allowing a considerably higher foliar yield (Schippers, 2000).

This poor soil fertility status raises concerns about the sustainability of agriculture in the area and has spurred the development of management practices to restore or improve their fertility status. Applications and the continuous use, dependence and exploitation of chemical fertilizer usually caused air and ground water pollution by eutrophication of water bodies (Bhardwaj *et al.,* 2014), thus posing a serious threat to human health and environment. Conversely, applications of mulches, composts, and manures increase soil fertility; however, under tropical conditions, the increase is short term because the added organic matter is quickly oxidized and added bases are rapidly leached (Novak *et al.,* 2009).

Biochar is a stable form of charcoal produced from heating natural organic materials (crop biomass, woodchips, manure and other agricultural waste) in a high temperature of below 1000°C and low oxygen; the process is known as pyrolysis (Lehmann *et al*., 2006). The potential of biochar to increase plant biomass and crop yields has been demonstrated in a number of tropical agricultural studies (Novak *et al*., 2009; Singh *et al.,* 2010; Biederman and Harpole, 2013).

The big difference between biochar and a normal charcoal is the particular chemical property that permits the cation retention, a property that increase with biochar ageing and surface weathering (Cheng *et al*., 2008; Cheng and Lehmann, 2009). Biochar is defined as the carbonaceous product obtained when plant or animal biomass is subjected to heat treatment in an oxygenlimited environment and when applied to soil as an amendment (Lehmann and Joseph, 2009). Biochar has the potential to be used for a wide range of applications. In agronomy, biochar appears to increase soil fertility and reduce nutrient leaching, thereby improving crop production in coarse-textured soils (Verheijen *et al*., 2010; Uzoma *et al*., 2011). Soil nitrogen (N) mineralization rates have been found to be affected by biochar amendments and particularly manure based biochars, can be a source of N for plants (Gaskin *et al*., 2008). Compared to other soil amendments, the high surface area and porosity of biochar enables it to adsorb or retain nutrients and water and also provide a habitat for beneficial microorganisms to flourish (Glaser *et al*., 2002, Lehmann and Rondon, 2006, Warnock *et al*., 2007). Moreover, biochar is considered to be relatively stable in soil with mineralization rates that are slower than that found in the original biomass (Spokas *et al*., 2010).

Although, studies have shown that adding biochar to the soil improves plant nutrient uptake, water use and plant productivity which leads to reduction in the use of fertilizers (Glaser *et al.,* 2002; Lehmann, 2007), great uncertainty exists regarding the complementary use of biochar with urea fertilizer. Biochar, if managed appropriately, may then be a low cost soil amendment with a high adoption potential for local farmers. At the moment there is restricted research that has been conducted on plant specific responses to boichar application. As with every new discovery, there is need to assess the potential impacts of combining biochar with an inorganic fertilizer like urea on crop productivity. Thus, this study was designed to evaluate the response of *Amaranthus cruentus* to the combined application of biochar and urea fertilizer in an acidic *ultisol* in Calabar.

Materials and methods

Field studies

A pot experiment was carried out in the screen – house of the University of Calabar Teaching and Research Farms, Calabar, Cross River State. Forty five (45) plastic buckets of 10 L capacity were perforated at the bottom to allow for easy drainage of water. Biochar made from wood feedstock was milled using mechanical blender and sieved with a 4 mm size plastic sieve to obtain its smooth fine powder. *Amaranthus* cruentus seeds and urea were obtained from Agricultural Development Project (ADP) office in Calabar, Cross River State. Top soil was taken at a depth of 0 – 20 cm from the University of Calabar Teaching and

Research Farms with the help of a spade. Soil samples collected were air – dried and sieved using a 4 mm size plastic sieve. Ten kilograms (10 kg) of the sieved soil was weighed to all the Forty five (45) plastic buckets and placed in the screen house.

The experiment was laid out in a completely randomized design (CRD) with eight treatments consisting of sole use of biochar at 20 t/ha as recommended by Yusif *et al.* (2016) as full dose, sole use of urea fertilizer at 60 kg N/ha as full dose and their various combinations. The combinations were ½Biochar + ½Urea, ¾ Biochar + ¼ Urea, ¼ Biochar + ¾ Urea, Full Biochar+ ½ Urea, ½ Biochar + Full Urea and a Control (no amendment). These treatments were replicated three (3) times to give a total of twenty four experimental units. To each of the experimental units containing 10 kg of soil, the various treatments were applied. Biochar was added to specified pots and thoroughly mixed with the soil, watered to field capacity and left for two (2) weeks before sowing *Amaranthus* seeds to allow mineralization to take place. *Amaranthus* seeds were directly sown into the pots and the seedlings were later thinned to two plants per pot after few days of emergence. Urea fertilizer treatment was applied to specified pots two weeks after planting using the ring method of application. For crop maintenance, weeds were hand – picked and crops were watered every evening using 0.25 L of water per pot.

Agronomic parameters measured included plant height, number of branches, stem girth, and number of leaves per plant. Plant height was measured with a meter rule as the height from the base of the crop (ground level) to the tip of the plant, number of branches was counted, stem girth was measured at a point of 5 cm from the ground by tying a string around the plant stem and the length of the string read off from a meter rule while the number of leaves was counted to be the fully opened leaves per plant. These measurements commenced 3 weeks after planting (WAP) and continued at weekly interval until the end of the experiment (6 WAP).

Composite soil sample was taken before the experiment air – dried, sieved with a 2 mm size sieve and stored for onward analysis. Plant samples were obtained at the end of the experiment by uprooting the two plants from each pot. The fresh shoot and root weights were determined at harvest. The uprooted plants were rinsed, oven– dried at 65^0 C, milled and stored for laboratory analysis.

Laboratory studies

Samples of biochar and soil were subjected to chemical analysis using standard procedures as outlined by Udo *et al.* (2009). The oven – dried milled plant samples were digested using nitric per chloric acid mixture. Then nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and Magnesium (Mg) concentrations in the plants were determined as described by Udo *et al.* (2009). Crude protein was determined by multiplying the nitrogen content in plant samples by a factor of 6.25.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT (2007) and significant means compared using the Duncan new multiple range test (DNMRT) at 5 % level of probability.

Results and discussion

Properties of the soil and biochar

Table 1 shows the initial properties of the soil used for the experiment. The result of the particle size analysis (sand = 83.3 %, silt = 13.0 % and clay = 0.7 %) showed that the soil used for the experiment was loamy sand and strongly acid in reaction (pH 5.1). The soil was low in organic carbon (1.15 %), total nitrogen (0.08 %) and potassium (0.10cmol/kg) while the available phosphorus (31.02 mg/kg) was high based on the ratings given in Adaikwu and Ali (2013) for Nigerian soils. The exchangeable bases (Ca, 2.4 cmol/kg; Mg, 1.2 cmol/kg; K, 0.11 cmol/kg, Na, 0.06 cmol/kg) were low. The low exchangeable bases values obtained from the experimental site indicate low fertility status and may be due to high rainfall which causes erosion and leaching away of bases. Biochar used contained 1.3 % N, 0.05 % P, 1.72 % K, 1.92 % Ca, 1.05 % Mg and an organic carbon content of 35.9 %, C: N ratio of 27.61 with an alkaline pH of 7.8.

Influence of the application of biochar fortified with urea fertilizer on growth parameters of Amaranthus cruentus

The influence of the application of biochar fortified with urea fertilizer on growth parameters of A*maranthus cruentus* is presented in Table 2. Number of leaves per *Amaranthus* plant was not significantly ($p > 0.05$) affected by applied amendments at 4 weeks after planting (WAP) but at 6 WAP, significant increases were observed among treatments. The highest number of leaves (34.00) was obtained from soil amended with a combination of ¼ B + ¾ U (5 t/ha biochar + 45 Kg N/ha urea) this was followed by plants treated with urea fertilizer alone (60 kg N/ha) while the lowest number of leaves per *Amaranthus* plant was from the control. Differences in the number of leaves do affect the overall performance of *Amaranthus* as the leaves serve as photosynthetic organ of the plant (Iren *et al*., 2016a). This is in line with the fact that adequate nitrogen supply is responsible for vigorous growth and leaf production of plants.

A similar trend was observed for plant height with no significant difference ($p > 0.05$) in plant height at 4 WAP and the highest plant height at 6 WAP (24.57 cm) being from soil amended with ¼ B + ¾ U. There was no significant ($p > 0.05$) difference in stem girth at 4 WAP but at 6 WAP, the widest stem (2.30cm) was recorded in soil amended with urea alone although this was not significantly wider than that obtained from ¼ B + ¾ U (Table 2). There was no significant ($p > 0.05$) difference in stem girth of *Amaranthus* in all the other treated plants compared with the control.

The significant increase in growth at advanced stage of growth in treated soils shows the response of *Amaranthus* to applied nutrients. The non significant increase in biochar alone (20 t/ha) treated soil relative to the control confirms the result of Punnose and Anitha (2017) who reported poor growth of *Amaranthus* in sole applied biochar treated soil. This reveals that biochar alone is not sufficient to boost the yield attributes of *Amaranthus.* This could be attributed to low content of N in the biochar. The poor growth of *Amaranthus* in the control soil implies that for sustained crop productivity, constant renewal of nutrients stock is necessary for optimum plant growth and development. Positive responses of *Amaranthus* to applied nutrients have been recorded in many studies (Ullah *et al.*, 2008; Iren *et al.*, 2016a & b).

Influence of the application of biochar fortified with urea fertilizer on fresh shoot and root weight of Amaranthus cruentus

The fresh shoot weight of *Amaranthus* was significantly ($p < 0.05$) increased by all the treatments relative to the control with the highest weight of 17.89 g/10 kg soil (3578 kg/ha) obtained by plants treated with ¼B + ¾U (5 t/ha biochar + 45 kg/ N/ha urea), followed by urea alone treated plants (16.24 g/pot) and the least from the control (6.34 g/pot) as presented in Table 3. All the treated soils significantly increased fresh shoot weight of *Amaranthus* relative to control especially those that receive more of urea fertilizer and less of biochar. However, the fresh shoot weight of plants treated with biochar alone was significantly higher compared with the control plants. This is contrary to the result obtained by Punnose and Anitha (2017) who reported poor yield performance of *Amaranthus* in sole applied biochar treated soil.

The fresh root weight of *Amaranthus* was significantly ($p < 0.05$) increased by all the treatments relative to the control (Table 3). The highest weight of 3.00 g/pot was obtained by plants treated with full biochar and half urea (20 t/ha biochar + 30 kg N/ha urea). The combinations of higher rates of biochar with lower rate of urea enhanced the proliferation of plants roots more than the other treatments. Biochar additions to the soil enhanced root proliferation thereby leading to more nutrient uptake and high yield.

Influence of the application of biochar fortified with urea fertilizer on nutrient concentration and crude protein content in Amaranthus cruentus

Application of the amendments significantly increased the nitrogen concentration of *Amaranthus* plant relative to the control with the highest value of 3.570% obtained from urea alone treated soil although it was statistically similar with other treatments except Full B + ½ U (Table 4). The highest nitrogen concentration obtained in urea treated plants is an indication of the readily available N from urea fertilizer and the immediate uptake of it by the plants. Among the combined treatments, the highest N – concentration was obtained from soil amended with ¼B + ¾U (3.220 %).

Phosphorus concentration in *Amaranthus* plant was significantly reduced in all the treated pots except the pot that received biochar alone when compared with the control. The highest potassium concentration in *Amaranthus* was obtained in soil amended with ½ B + ½ U (10 t/ha + 30 kg N/ha). The sole application of both biochar and urea did not significantly increase the potassium concentration in the crop when compared with the control. There were no significant differences in calcium and magnesium concentration in *Amaranthus* plants among treatments and the control.

The highest crude protein content (22.31%) in *Amaranthus* plant was obtained in soil that received urea alone even though it was not significantly higher than the crude protein content in other treated plants except plants that received Full B + ½ U and the control. This is due to the very high nitrogen content (46%) in Urea which could have increased the crude protein of *Amaranthus* because nitrogen acts as a building material for the formation of protein in plants (Agbede, 2009). Among combined treatments, ¼B + ¾U produced the highest crude protein (20.13 %) in the plant. The high crude protein obtained in this study from urea treated plants could be as a result of the mineralization and fast release of nitrogen in urea fertilizer. When nitrogen supply is restricted or low, yield, as well as protein content is reduced (Iren *et al.*, 2016a).

Conclusions

From the study, it has been shown that;

- The combination of biochar with urea improved the root growth, fresh shoot yield, nutrient concentration and crude protein contents in *Amaranthus* more than when biochar is singly applied.
- The best shoot yield was obtained from the combination of 5 t/ha biochar + 45 kg/ N/ha urea (¼B + ¾U), followed by urea alone (60 kg N/ha) treated plants.
- However, based on the significant response of *Amaranthus* in treated soils to applied amendments compared to untreated soil, it could be concluded that both the sole and combined treatments had positive effects on crop productivity.

References

Adaikwu, A. O. & Ali, A. (2013). Assessment of some soil quality indicators in Benue State. *Nigerian Journal of Soil Science*, 23(2): 66-75.

Agbede, O. O. (2009). *Understanding Soil and Plant Nutrition*. 1st Ed. Keffi, Salman Press Nig. Ltd. Pp. 260.

Bhardwaj, D., Ansar, M. W., Sahoo, R. K. & Tute, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbiology Cell Fact*, 8: 13-66.

Bierderman, L. A. & Harpole, W.S. (2013). "Biochar and its effects on plant productivity and nutrient recycling: A met – analysis."*GCB Bioenergy*, 5(2): 202 – 214.

Cheng, C. H., Lehmann, J. & Engelhard, M. (2008).'Natural oxidation of black carbon in soils: Changes in molecular form and surface charge along a climosequence',*GeochimicaetCosmo chimicaActa*, 72: 1598-1610.

Cheng, C. H. & Lehmann, J. (2009).Ageing of black carbon along a temperature gradient. *Chemosphere*, 75: 1 – 7.

FAO (2007). Food and Agriculture Organization (2007). FAOSTAT.FAO Statistic Division. Rome.

Gaskin, J.W., Steiner, C., Harris, K., Das, K. C. & Bibens, B., (2008). Effect of Low – Temperature Pyrolysis Conditions on Biochar for Agricultural Use. T Asabe, 51: 2061 – 2069.

Glaser, B., Lehmann, J. & Zech, W. (2002).Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal – a review. *Biology and Fertility of Soils*, 35: 219-230.

GENSTAT (2007). Fishers least significant test (FLSD) laws, Agricultural trust, Rothamsted experimental station copyright release 7.2DE.

Iren, O. B., Udo, I. A., Asawalam, D. O. & Osodeke, V. E. (2016a).Comparative effects of different nitrogen sources from organic manure and urea fertilizer on growth, crude protein and nutrient uptake of *Amaranthus* *cruentus*. *European Journal of Academic Essays*, 3(8): 296 – 303.

Iren, O. B., Ijah, C. J., Asawalam, D. O. & Osodeke, V.E. (2016b). Comparative effect of pig manure, urea fertilizer and their combination on the performance of *Amaranthus* cruentus in a Rainforest Ultisol, Nigeria. *Integrity Research Journal – Journal of Agricultural Science and Practice*, 1: 52 – 57.

Lehmann J, Gaunt J. & Rondon M. (2006). 'Bio-char sequestration in terrestrial ecosystems a review', Mitigation and Adaptation Strategies for Global Change, 11: 403–427.

Lehmann, J. (2007). *A handful of carbon*. Nature, 447: 143 – 144. *Bio-energy in the black. Frontiers in Ecology and the Environment*, 5: 381 - 387.

Lehmann, J. & Rondon, M. (2006). Bio Char soil management on highly weathered soils in the humid tropics. In: N. Uphoff *et al.* (Eds.), *Biological approaches to sustainable soil systems. Florida*: CRC Press, Taylor and Francis Group, 517 – 530.

Lehmann, J. & Joseph, S. (2009). Biochar for environmental management: an introduction. In: Lehmann J and Joseph S (eds.): *Biochar for Environmental Management: Science and Technology*. Earthscan, London, pp. 1-12.

Mnkeni, A. P., Masika, P. & Maphapha, M. (2007). Nutritional quality of vegetable and seed from different accessions of *Amaranthus* in South Africa. *Water SA*, 33 (3): 377- 380.

Novak, J. M., Busscher W. J., Laird, D.L., Ahmedna, M., Watts D. W. & Niandou, M. A. S. (2009).Impact of Biochar Amendment on Fertility of a Southern Coastal Plain Soil. *Soil Sci*, 174: 105 – 112.

Olofintonye, J. A. T., Abayomi Y. A. & Olugbemi, O. (2015).Yield responses of grain amaranth (*Amaranthus* cruentus L.) varieties to varying planting density and soil amendment. *African Journal of Agricultural Research*, 10 (21): 2218 – 2225.

Onwordi, C. T. Ogungbade, A. M. &Wusu, A. D. (2009). The proximate and mineral composition of three leafy vegetables commonly consumed in Lagos, Nigeria. *African Journal of Pure and Applied Chemistry*, 3(6): 102–107.

Punnose, A. & Anitha, S. (2017). Biochar on the Growth and Yield Performance of Amaranth (*Amaranth Tricolor L.*).*Trends in Biosciences*, 10 (16): 2908 – 2912.

Schippers, R. R. (2000). African indigeneous vegetables. An overview of the cultivated species. Chatham, UK: Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation, 214p.

Schippers, R. R. (2002). African indigenous vegetables: An overview of the cultivated species. Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation.Chaltham. UK. 214 p.

Singh, B., Singh, B. P. & Cowie, A. L. (2010).Characterization and evaluation of biochar for their application as a soil amendment. *Soil Research*, 48(7): 516-525.

Spokas, K. A., & Reicosky, D. C. (2010). "Ethylene: Potential key for biochar amendment impacts." *Plant Soil*, 333 (1-2): 443 – 452.

Udo, E. J., Ibia, T. O., Ogunwale, J. A., Ano, A. O. & Esu, I. E. (2009).Manual of Soil, Plant and Water Analyses. Sibon Boooks publishers Ltd, Lagos, Nigeria. 183 p.

Ulah, M. S, Islam, M. S., Islam, M. A. & Haque, T. (2008).Effects of organic manures and chemical fertilizers on the yield of brinjal and soil Properties. *J. Bangladesh Agric. Univ*. 6: 271-276.

Uzoma, K., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A. & Nishihara, E. (2011)."Effect of cow manure biochar on maize productivity under sandy soil condition". *Soil Use Manage*, 27 (2): 205 – 212.

Verheijen, F. G. A., Jeffery S., Bastos, A. C., Van der Velde, M. & Diafas I. (2010). Biochar application to soils. A critical scientific review of effects on soil properties, processes and functions. EUR 24099 EN, Office for the Official Publications of the European Communities, Luxembourg.

Warnock D. D., Lehmann, L., Kuyper, T. W. & Rillig, M. C. (2007).'Mycorrhizal responses to biochar in soil- concepts and mechanisms', *Plant and Soil*, 300: 9-20.

Yusif, S. A., Muhammad, I., Hayatu, N. G., Haliru, M., Mohammed, M. A., Hussain, A. M. &

Fardami, A. Y. (2016). Effects of Biochar and Rhizobium Inoculation on Selected Soil Chemical Properties, Shoot Nitrogen and Phosphorus of Groundnut Plants (*Arachis hypogaea* L.) in Sokoto State, Nigeria. *Journal of Advances in Biology & Biotechnology, 8(2): 1-6.*

Table 1. Physical and chemical properties of the soil at the experimental site

Parameter	Value
Sand (%)	83.30
Silt (%)	13.00
Clay (%)	3.70
Textural class	Loamy sand
pH (H_2O)	5.1
Organic Carbon (%)	1.15
Total Nitrogen (%)	0.08
C: N ratio	14.38
Organic matter (%)	1.98
Available P (mg/kg)	31.02
Ca^{2+} (cmol/kg)	2.40
Mg^{2+} (cmol/kg)	1.20
K^+ (cmol/kg)	0.10
Na^+ (cmol/kg)	0.06
H^+ (cmol/kg)	1.20
Al^{3+} (cmol/kg)	0.20
ECEC (cmol/kg)	5.16
Base Saturation (%)	72.87

Table 2. Influence of biochar fortified with urea fertilizer on mean number of leaves, plant height and stem girth of *Amaranthus cruentus*

Treatments	Number of leaves		Plant height (cm)		Stem girth (cm)	
	4 WAP	**6 WAP**	**4 WAP**	**6 WAP**	**4 WAP**	**6 WAP**
Control	12.67a	16.00d	9.30a	17.20cd	1.50a	1.67c
B-alone (20 t/ha)	11.67a	18.67cd	9.37a	17.90cd	1.37a	1.93bc
U-alone (60 kg /ha)	9.67a	22.67bc	9.90a	22.37b	1.53a	2.30a
½ B + ½ U	11.33a	17.00cd	8.90a	18.10c	1.43a	1.83bc
¾ B + ¼ U	10.67a	17.00cd	8.87a	15.30d	1.30a	1.77bc
¼ B + ¾ U	17.67a	34.00a	10.67a	24.57a	1.37a	2.27a
Full B + ½ U	11.33a	17.67cd	10.13a	21.20b	1.60a	1.90bc
½ B +Full U	8.33a	21.33bcd	10.53a	18.77c	1.37a	1.73bc

Means within a column not sharing a letter in common differ from each other significantly at 5% level of probability following Duncan new multiple range test (DNMRT)

Table 3. Influence of the application of biochar fortified with urea fertilizer on fresh shoot and root weight of *Amaranthus cruentus*

Treatments	Fresh shoot weight		Fresh root weight	
	g/pot	**kg/ha**	**g/pot**	**kg/ha**
Control	6.34d	1268d	1.02c	204c
B – alone	11.85c	2370c	2.90a	580a
U – alone	16.24ab	3248ab	2.15b	430b
½B + ½U	14.30bc	2860bc	2.75ab	550ab
¾B + ¼U	11.79bc	2358bc	2.90a	580a
¼B + ¾U	17.89a	3578a	2.84a	568a
Full B + ½U	10.44c	2088c	3.00a	600a
½B + Full U	14.29bc	2858bc	2.19b	438b

*Mean values followed by the same letter(s) within the same column are not significantly different according to DNMRT at 5 % probability.

Table 4. Influence of biochar fortified with urea fertilizer on nutrient concentration and crude protein content in *Amaranthus cruentus*

Treatments	**Nutrient concentration (%)**					**Crude protein (%)**
	N	**P**	**K**	**Ca**	**Mg**	
Control	1.913c	0.2167a	2.307bcd	2.440a	1.367a	11.96c
B – alone	2.940ab	0.2067a	2.790abc	2.040a	0.840a	18.38ab
U – alone	3.570a	0.1700c	2.320bcd	2.800a	1.440a	22.31a
½ B + ½ U	2.847abc	0.1533c	3.084a	2.613a	1.220a	17.79abc
¾ B + ¼ U	3.080ab	0.1833bc	2.550abcd	2.040a	1.030a	19.25ab
¼ B + ¾ U	3.220ab	0.1867bc	2.207cd	2.520a	1.237a	20.13ab
Full B + ½ U	2.450bc	0.1800bc	2.700abc	2.560a	1.127a	15.31bc
½ B + Full U	2.660abc	0.1767c	2.600abcd	2.360a	1.460a	16.63abc

Mean values followed by the same letter(s) within the same column are not significantly different according to DNMRT at 5 % probability.