sciendo DOI: 10.2478/ats-2019-0008 AGRICULTURA TROPICA ET SUBTROPICA, 52/2, 73–78, 2019

*Original Research Article*

# Weed control efficacy of hoe weeding and commercially formulated mixture of metolachlor + prometryn herbicide under maize production in soil amended with biochar

Olusegun Raphael **Adeyemi**[1], David Obaloluwa **Hosu**[1], Patience Mojibade **Olorunmaiye**[1], Adeniyi Adebowale **Soretire**[2], Joseph Aremu **Adigun**[1], Kikelomo Olamide **Ogunsola**[1]

[1] *Department of Plant Physiology and Crop Production, Federal University of Agriculture, Abeokuta, Nigeria,*
[2] *Department Soil Science and Land Management, Federal University of Agriculture, Abeokuta, Nigeria,*

***Correspondence to:***
**O. R. Adeyemi**, Department of Plant Physiology and Crop Production, Federal University of Agriculture, Abeokuta, Nigeria, : +2348068349022; e-mail: adeyemiolusegun3@gmail.com

## Abstract

Successful cultivation of maize depends largely on efficient weed control, adequate supply of essential nutrients and sufficient soil moisture. Screenhouse and field trials were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Nigeria during the early and late cropping season of 2013 to evaluate effects of biochar integrated with manual weeding and pre-emergence herbicides on weed control efficiency and productivity of maize. The screenhouse trial was a 6 × 5 factorial experiment fitted into Completely Randomized Design in three replicates. The two factors were biochar: 0, 2, 4, 6, 8 and 10 t ha$^{-1}$ and weed control methods: weedy check, hoe weeding at 6 Weeks After Sowing (WAS), hoe weeding at 3, 6, and 9 WAS, pre-emergence herbicide application (Codal Gold) at 1.0 and 2.0 kg a.i./ ha$^{-1}$. The field trial was laid out in split-plot arrangement fitted into Randomized Complete Block Design with three replicates. The three main treatments plots on the field consisted of the optimum rates of biochar obtained in the screenhouse (10 t ha$^{-1}$) compared with 20 t ha$^{-1}$ and 0 t ha$^{-1}$ which served as the control. The sub-plots treatments consisted of weed control methods used in the screen house experiment. Data were collected on grain yield and weed dry matter. The result showed that biochar at 10 and 20 t ha$^{-1}$ in the screenhouse and field trials, respectively, resulted in significantly ($P < 0.05$) higher grain yield compared with other rates tested. Highest grain yield was obtained in pots hoe weeded thrice at 3, 6 and 9 WAS. Whereas similar grain yield was recorded in plot weeded once at 6 WAS and that hoe weeded at 3, 6 and 9 WAS in the field experiment. Biochar application of 20 t ha$^{-1}$ gave optimum maize yield. Among the weed control treatments manual weeding either at 6 WAS or at 3, 6 and 9 WAS recorded the highest grain yields. Therefore, incorporation of biochar with either preemergence herbicide or manual hoe weeding would enhance the growth and yield of maize.

**Keywords:** pre-emergence herbicides; biochar; weed biomass accumulation; chlorophyll content;

## INTRODUCTION

Maize (*Zea mays* L.) is the dominant cereal crop grown in Nigeria. Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain. Nigeria is the 10$^{th}$ largest producer of maize in the world, and the main producing country in tropical Africa with an annual production in excess of 6 million metric tons (USAID, 2010). It is an important source of carbohydrate, protein, iron, vitamin B, and minerals (Onuk and Ibrahim, 2010). Maize is fast becoming a very important commodity in animal feed, food and beverage industries. Increased maize production will translate directly into higher consumption, better nutrition and enhanced trading for maximum benefits (USAID, 2010).

In the tropics, the limiting factors in crop production include weed management, tillage practices, low yielding varieties and sub-optimal planting density (Adeyemi et al., 2008). Weeds thrive in soils of low fertility, a factor which leads to the abandonment of farmlands by farmers. The tragic consequence of the abandonment of farmlands is the decrease in food production. In order to alleviate these problems, more resistant organic matter such as "char" could be used as the source of soil organic materials applied to soil (Lehman et al., 2003). This material, which is known as "agrichar" or more commonly called "biochar" has been proven to have the same positive impact as the organic manure or other organic materials as a soil amendment (Wolf, 2008). Biochar improves soil properties, such as soil pH, Cation Exchange Capacity (CEC) (Chan et al., 2008; Masulili et al., 2010), soil aggregation, soil water holding capacity and soil strength (Chan et al., 2008), and increase soil biology population and activity (Rondon et al., 2007).

Weed management in maize production is the most difficult and resource consuming aspect when weeding is not carried out at an appropriate time or when the right method is not employed. Uncontrolled weed growth causes yield loss of 40–60% in maize in the tropics (Chikoye et al., 2005). In monocrop maize, weeds are generally controlled using cultural (hand or hoe-weeding), mechanical (slashing), chemical (pre-plant, pre or post-emergence herbicides) and integrated management practices. Herbicide use has been reported to be more profitable than hoe-weeding in the production of various crops in Nigeria (Adigun et al., 1993). Judicious use of herbicides has been reported to reduce labour requirement, cost of weed control, increase crop yields by reducing weed competition and consequently increase profitability (Ogungbile et al., 1982).

An integrated weed management approach that combines the use of a low rate of pre-emergence herbicide with hand weeding later in the season will help the farmer to avoid the high cost of labour at the peak of labour use periods, such as the onset of rains in the tropics. Consequently, this study was carried out to assess the weed control method that is able to guarantee optimum maize production and also provide environmentally-friendly sustainable agriculture.

Till date, there is a dearth of research information on the use of biochar to complement weed control strategy in maize production in the tropics. The hypothesis of this study is that biochar applied as soil amendment will give the maize crop competitive advantage over weeds thus enhancing the effectiveness of manual and pre-emergence chemical weed control in maize production. The objective of this study therefore was to evaluate the weed control efficiency of biochar integrated with manual and pre-emergence weed control on the growth and yield of maize.

## MATERIALS AND METHODS

### Experimental site

The experimental site was located at the Teaching and Research Farms of the Federal University of Agriculture, Abeokuta in the forest-savanna transition agroecological zone (7°20′N, 3°23′E), Alabata, Ogun State during early and late cropping seasons of 2013.

### Treatments and Experimental Design

The experiment was carried out in two phases: screen house and field trial. The screen house experimental design was a 6 × 5 factorial arrangement in Completely Randomized Design (CRD) with three replicates. The treatments consisted of biochar at six rates (0, 2, 4, 6, 8 and 10 t/ha) and five weed control methods; weedy check, pre-emergence herbicide-codal Gold (commercially formulated mixture of prometryne and metolachlor) at 1.0 kg a.i./ha (active ingredient), pre-emergence herbicide-codal Gold at 2.0 kg a.i./ha, Manual weeding at 6 weeks after sowing (WAS) and Manual weeding at 3, 6, and 9 WAS. Plastic buckets (filled with 10 kg of soil collected from weed infested field) which received the appropriate doses of the pre-emergence herbicide at stipulated rate, were arranged within 10 $m^2$ of land (2 m×5 m) and sprayed with the amount of the herbicide with aid of well-calibrated CP3 knapsack sprayer calibrated to discharge 300 l/ha of water using a green deflector nozzle type.

The field experiment was laid out in Randomized Complete Block Design (RCBD) in a split-plot arrangement and replicated three times. The main plot treatments consisted of biochar at three rates (0, 10 (most superior rate in the pot trial) and 20 t $ha^{-1}$) whereas the subplot treatments were five (5) weed control methods as described in the pot experiment. The land was ploughed twice and harrowed once two weeks later. There was 1 m pathway between each main plot, 0.5 m between each subplot and 1.5 m between replicates. Each of the main plots was surrounded by 0.5 m high bunds to prevent erosion and flow of treatments between plots during rainfall or irrigation. Soil amendment (biochar from maize cob) was incorporated into the soil at the depth of 5 cm–10 cm. The plots treated with pre-emergence herbicide (Codal Gold) were sprayed with 1.0 and 2.0 kg a.i/ha with the aid of knapsack sprayer calibrated to discharge 300 l/ha of water.

### Cultural practices

High yielding and drought tolerant maize variety (Oba super 2) were planted on April 13$^{th}$ during the 2013 early season at the depth of 5 cm. In the field trial, three seeds of the maize variety were sown on August 20$^{th}$ during the 2013 late season and thinned to one plant per stand two weeks after sowing (WAS) at the spacing of 75 cm × 25 cm giving a total number of 53,333 plants/ha. Weeding was done using West African hoe according to the treatment structure.

### Data collection

Data were recorded on maize yield and yield components, total weed density and biomass.

**Table 1.** Effects of biochar rates and weed control methods on the yield and yield components of maize in pot trial during the early wet season of 2013, Alabata, Abeokuta

| Treatments | Cob Girth (cm) | Effective Cob Length (cm) | Grain Yield (g plant$^{-1}$) | 1000 Grain Weight (g) | Harvest Index | Shelling Percentage/ plant | % Yield Reduction |
|---|---|---|---|---|---|---|---|
| **Biochar Rates t ha$^{-1}$ (B)** | | | | | | | |
| 0 | 1.22 | 3.85 | 2.90 | 30.00 | 3.92 | 17.58 | 91.39 |
| 2 | 1.65 | 5.45 | 8.00 | 48.00 | 10.78 | 25.93 | 76.26 |
| 4 | 2.67 | 8.41 | 9.80 | 56.00 | 10.80 | 35.03 | 70.92 |
| 6 | 2.07 | 6.55 | 9.70 | 53.00 | 14.52 | 23.95 | 71.22 |
| 8 | 2.51 | 7.40 | 16.80 | 70.00 | 19.16 | 41.89 | 50.14 |
| 10 | 3.35 | 7.01 | 33.70 | 135.00 | 43.65 | 58.05 | – |
| LSD (0.05) | 0.784 | ns | 0.009 | 0.024 | 0.213 | 15.59 | |
| **Weed Control Methods (W)** | | | | | | | |
| Weedy check | 1.361 | 3.006 | 5.00 | 46.03 | 8.60 | 19.25 | 76.19 |
| Pre–emergence herbicide at 1.0 kg a.i./ ha$^{-1}$ | 2.639 | 7.461 | 16.00 | 82.00 | 17.58 | 38.28 | 23.80 |
| Pre–emergence herbicide at 2.0 kg a.i./ ha$^{-1}$ | 1.989 | 6.422 | 16.00 | 60.00 | 19.39 | 33.91 | 23.80 |
| Manual weeding at 6 WAS | 2.072 | 5.722 | 10.00 | 52.00 | 12.72 | 29.04 | 52.38 |
| Manual weeding at 3, 6 and 9 WAS | 3.072 | 9.611 | 21.00 | 85.00 | 25.58 | 48.20 | – |
| L S D (0.05) | 0.716 | 2.754 | 0.008 | 0.026 | Ns | 14.23 | |
| Biochar × weed control | ns | ns | ns | ns | Ns | Ns | |

WAS = Weeks after Sowing, LSD = Least Significant Difference, ns = not significant

### Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) using the Statistical Package GENSTAT 12th Edition while significant treatments means were compared using Least Significant Difference (LSD) at 5% level of probability.

## RESULTS

### Effects of biochar rates and weed control methods on grain yield and yield components of maize

Application of biochar significantly affected grain yield and other yield components of maize such as cob girth, 1000 grain weight, harvest index and shelling percentage in the screenhouse experiment (Table 1). It was observed that as the biochar rates increased from 0 t ha$^{-1}$ to 10 t ha$^{-1}$, the grain yield and harvest index increased significantly. Highest grain yield (33.70 g/plant), 1000 grain weight (0.14 g), harvest index (43.65 %), and shelling percentage (58.05 %) were recorded in the pots treated with biochar rate at 10 t ha$^{-1}$ compared with pots without biochar application. Also, 91.39 percentage yield reduction was recorded in pots without biochar application. Grain yield, cob girth, cob length, 1000 grain weight and shelling percentage were significantly ($P \leq 0.05$) affected by different weed control methods in the pot trial (Table 1). Highest grain yield was recorded from maize plants manually weeded at 3, 6 and 9 WAS (21.00 g/plant). However, similar grain yield was observed in pot treated with pre-emergence herbicide at 1.0 kg a.i./ha$^{-1}$ (16.00 g plant$^{-1}$) and 2.0 kg a.i./ha$^{-1}$ (16.00 g plant$^{-1}$) compared to weedy check. Uncontrolled weed infestation in maize production resulted in 76.19% yield reduction. While a yield reduction of 62.38% was recorded when manual weeding was done once at 6 WAS (Table 1).

In the field trial, biochar rates had significant effects on shelling percentage and grain yield. The shelling percentage was reduced from 77.01% in plots without biochar rates to 61.21% when biochar was applied at the rate of 20.0 t ha$^{-1}$. Moreover, grain yield showed a significant increase as the biochar rates increased where the highest grain yield (1.70 t ha$^{-1}$) was recorded in plots treated with biochar at 20 t ha$^{-1}$ as compared with plots without biochar application (Table 2). Weed control methods were observed to have significant effects ($P < 0.05$) on the cob girth, cob length and grain yield of maize (Table 2). Pre-emergence herbicide application at 2.0 kg a.i./ha$^{-1}$, hoe-weeding at 6 WAS and hoe-weeding at 3, 6 and 9 WAS had similar effects on cob girth. Also, significantly higher effective cob length (13.22 cm) was observed in plots hoe-weeded at

**Table 2.** Effects of Biochar Rates and Weed Control Methods on Maize Yield and Yield Components in field trial during the Late Wet Season of 2013, Alabata, Abeokuta

| Treatments | Cob Girth (cm) | Effective Cob Length (cm) | Shelling % | Harvest index | 1000 Grain weight (kg) | Grain Yield (t ha$^{-1}$) | % Yield Reduction |
|---|---|---|---|---|---|---|---|
| **Biochar Rates (t ha$^{-1}$)** | | | | | | | |
| 0 | 3.183 | 11.30 | 77.01 | 54.0 | 0.32 | 1.17 | 31.17 |
| 10 | 3.424 | 11.63 | 74.58 | 65.0 | 0.33 | 1.26 | 25.88 |
| 20 | 3.481 | 12.29 | 61.21 | 56.0 | 0.35 | 1.70 | – |
| LSD (0.05) | ns | ns | 8.97 | ns | Ns | 0.12 | |
| **Weed Control Methods** | | | | | | | |
| Weedy check | 3.009 | 9.66 | 69.06 | 41.0 | 0.32 | 0.64 | 67.18 |
| Pre-emergence herbicide at 1.0 kg a.i. ha$^{-1}$ | 3.298 | 11.45 | 70.65 | 56.0 | 0.32 | 1.29 | 33.85 |
| Pre- emergence herbicide at 2.0 kg a.i. ha$^{-1}$ | 3.409 | 12.21 | 65.67 | 60.0 | 0.34 | 1.44 | 26.15 |
| Hoe-weeding at 6 WAS | 3.484 | 12.16 | 75.46 | 70.0 | 0.34 | 1.56 | 20.00 |
| Hoe-weeding at 3, 6 and 9 WAS | 3.613 | 13.22 | 73.83 | 65.0 | 0.36 | 1.95 | – |
| LSD (0.05) | 0.29 | 1.30 | ns | ns | Ns | 0.43 | |
| Biochar × weed control (B × W) | ns | ns | ns | ns | Ns | 0.68 | |

WAS = Weeks after Planting
LSD = Least Significant Difference
ns = not significant

**Table 3.** Interaction of biochar rates and weed control methods on maize grain yield during the early wet season of 2013 at Alabata, Abeokuta

| Weed Control Methods | Biochar Rates (t ha$^{-1}$) | | |
|---|---|---|---|
| | 0 | 10 | 20 |
| **Weedy check** | 0.55 | 0.78 | 0.60 |
| **Pre-emergence herbicide at 1.0 kg a.i./ha$^{-1}$** | 1.52 | 0.89 | 1.45 |
| **Pre-emergence herbicide at 2.0 kg a.i./ha$^{-1}$** | 1.22 | 0.97 | 2.12 |
| **Hoe- weeding at 6 WAS** | 0.84 | 2.04 | 1.82 |
| **Hoe- weeding at 3, 6 and 9 WAS** | 1.74 | 1.63 | 2.49 |
| **LSD (0.05)** | | 0.68 | |

WAS = Weeks after Planting
LSD = Least Significant Difference

3, 6 and 9 WAS but was not significantly different from pre-emergence herbicide application at 2.0 kg a.i./ha$^{-1}$ and hoe-weeding at 6 WAS only. The result also revealed that significantly reduced grain yield (0.64 t ha$^{-1}$) was recorded when plots were kept weed infested throughout as compared to plots where weed was either removed chemically or manually. Also, plots that received pre-emergence herbicide at both low and high rates were not significantly different from one another with regards to grain yield (1.29 and 1.44 t ha$^{-1}$) but produced significantly lower grain yield as compared with hoe-weeding thrice. Interaction of hoe weeding at 3, 6 and 9 WAS × biochar rate at 20 t ha$^{-1}$ gave the highest grain yield compared with other combinations, but similar with the interaction of hoe weeding at 6 WAS × biochar rate at 10 at t ha$^{-1}$ and interaction of pre-emergence herbicide application at 2.0 kg a.i./ha$^{-1}$ × biochar at 10 t ha$^{-1}$ (Table 3).

### Effect of biochar rates and weed control methods on weed parameters

The result of the field trial showed that biochar rate at 10 t ha$^{-1}$ significantly reduced weed dry weights at 9 WAS (1.6 gm$^{-2}$). But, application of biochar beyond this level resulted in increased weed biomass accumulation. Similarly, weed control methods significantly affected weed density and weed dry weight at 3, 6 and 9 WAS during the field study (Table 4). At 3 WAS, plots treated with pre emergence herbicide at both low and high rates (1.0 kg 2.0 kg a.i./ha$^{-1}$) drastically reduced the weed population (0.4 and 0.7 m$^{-2}$) compared to hoe-weeding at 3, 6 and 9 WAS, hoe-weeding at 6 WAS and weedy

**Table 4.** Effects of biochar rates and weed control methods on weed parameters in field trial during the late wet season of 2013 at Alabata, Abeokuta

| Treatments | Total Weed Density (plants m$^{-2}$) | Weed Dry Weight (gm$^{-2}$). | | |
|---|---|---|---|---|
| | | 3 WAS | 6 WAS | 9 WAS |
| **Biochar Rates (t ha$^{-1}$)** | | | | |
| 0 | 54.0 | 0.81 | 4.97 | 9.9 |
| 10 | 53.9 | 1.09 | 8.19 | 1.6 |
| 20 | 50.3 | 0.68 | 6.13 | 8.1 |
| LSD (0.05) | ns | ns | ns | 2.26 |
| **Weed Control Methods** | | | | |
| Weedy check | 124.9 | 1.66 | 16.29 | 34.00 |
| Pre–emergence herbicide at 1.0 kg a.i./ha$^{-1}$ | 17.7 | 0.06 | 1.99 | 7.40 |
| Pre–emergence herbicide at 2.0 kg a.i./ha$^{-1}$ | 12.7 | 0.06 | 0.83 | 7.40 |
| Hoe– weeding at 6 WAS | 70.7 | 1.64 | 12.21 | 1.30 |
| Hoe– weeding at 3, 6 and 9 WAS | 37.6 | 0.88 | 0.84 | 0.90 |
| L S D (0.05) | 3.09 | 1.04 | 4.98 | 8.74 |
| Biochar X Weed Control | ns | ns | ns | ns |

WAS = Weeks after Sowing
LSD = Least Significant Difference
ns = not significant

check where significantly higher number of weeds (24.4, 16.0 and 28 /m$^2$) were recorded, respectively (Table 4). In terms of weed dry weight at 3 and 6 WAS, lowest weed dry weight were recorded on plots treated with pre-emergence herbicide and hoe-weeding at 3, 6 and 9 WAS compared to plots weeded at 6 WAS and weedy check (Table 4).

## DISCUSSION

The highest grain yield observed in biochar treated pots or plots suggested that biochar has inherent ability to promote soil nutrients availability which could have been otherwise leached beyond the root zone. This result is in agreement with the findings of Zhang et al. (2011) who found out that maize yield was increased from 11.6% to 18.2% under biochar amendment at rates of 20–40 t ha$^{-1}$. The grain yield obtained is relatively comparable with the average yield of maize in Nigeria (2–3 t/ha) even without fertilizer application, as most of higher yield previously obtained were with fertilizer.

Moreover, significantly higher yield observed in both trials when manual weeding was done suggested that hoe weedings were superior to other weed control methods employed in this study with respect to maize grain yield. This result is in agreement with the report of Forcella (2000) and Perry et al. (2004) who stated that hoeing is superior to herbicide application in maize and the effectiveness of hand hoeing treatments is attributed to the notion that hoeing was most likely more efficient in eradicating and stunting the growth of weeds than herbicide treatments. Similarly, Hassan and Ahmed (2005) found that maize yield and yield components (ear length, ear weight, ear kernel weight and weight of 100 grain) were increased with hand hoeing thrice more than applying herbicides alone, as compared with unweeded control.

Application of pre-emergence herbicide was superior to hoe-weeding in weed population reduction at 6 WAS probably because, population of dominant weeds such as *Tridax procumbens, Oldenlandia corymbosa, Phyllanthus amarus;* grasses (*Digitaria gayanus, Digitaria horizontalis, Panicum maximum*) and *Cyperus esculentus* was effectively controlled by Codal Gold at 1.0 and 2.0 kg a.i./ha$^{-1}$. Similar results were obtained by El-Metwally et al. (2012) who observed that fluroxypyr was more effective than the other treatments against broad-leaved weeds, while hoeing treatment was more efficient in reducing the number and dry weight of grass.

## CONCLUSION

Application of biochar significantly increased maize grain yield. Also, hoe weeding was observed to enhance the grain yield of maize. Moreover, pre-emergence herbicide application of Codal Gold at 1.0 and 2.0 kg a.i ha$^{-1}$ was observed to effectively control weeds biomass production at 3 and 6 WAS. However, interaction of hoe weeding at 6 WAS × biochar application at 10 t ha$^{-1}$ resulted to optimum maize grain yield. Therefore, incorporation of biochar with either preemergence herbicide or manual hoe weeding would enhance the growth and yield maize.

## REFERENCES


Adeyemi O. R., Smith M. A. K., Ojeniyi S. O. (2008): Effect of land preparation techniques on weed control effectiveness in okra (*Abelmoschus esculentus* L. Moench). Nigerian Journal of Weed Science 21: 72–83.

Adigun J. A., Lagoke S. T. O., Kumara V., Erinle I. D. (1993): Weed management studies in transplanted tomato in the Nigeria savanna. Samaru Journal of Agricultural Research 10:29–39.

Chan K. Y., Van Zwieten B. L., Meszaros I., Downie D., Joseph S. (2008): Using poultry litter biochars as soil amendments. Australian Journal of Soil Research 46: 437–444.

Chikoye D., Udensi U. E., Lum A. F. (2005): Evaluation of a new formulation of atrazine and metolachlor mixture for weed control in maize in Nigeria. Crop Protection 24: 1016–1020.

El-Metwally I. M., Abd El-Salam M. S., Tagour R. M. H, Abouziena H. F. (2012): Efficiency of plant population and reduced herbicides rate on maize productivity and associated weeds. Journal of Applied Science Research 8: 2342–2349.

Forcella F. (2000): Rotary hoeing substitutes for two–third rate of soil-applied herbicide. Weed Technology 14: 298–303.

Hassan A. A. A., Ahmed M. K. A. (2005): The influence of some herbicides and additional hoeing in maize growth and yield and yield components. International Journal of Agriculture and Biology 7: 708–710.

Lehmann J., da Silva Jr., J. P., Steiner C, Nehls T., Zech W., Glaser B. (2003): Nutrient availability and leaching in an archaeological anthrosol and a ferralsol of the central Amazon Basin; fertilizer, manure and charcoal amendments. Plant and Soil 249: 343–357.

Masulili A, Utomo W., Syekhfani M. S. (2010): Rice husk biochar for rice based cropping system in acid soil 1 the characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. Journal of Agriculture Science (Canada) 3: 25–33.

Ogungbile A. O., Ndahi W., Lagoke S. T. O (1982): Economic Evaluation of Herbicide Use in Maize Production. In: Proceedings of the 11th annual Conference of Weed Science Society of Nigeria. Eds: B. A. Olunuga, I. O. Akobundu, A. Ayeni, Ahmadu Bello University, Zaria, Nigeria. March 1982, p. 45.

Onuk E. G., Ibrahim H. Y (2010): The impact of root and tuber expansion programme (rtep) on roots and tuber crops production in Nasarawa State, Nigeria, Production Agriculture and Technology (PAT) 6: 26–34.

Perry J. N., Firbank L. G., Champion G. T., Clark S. J., Heard M. S., May M. J., Hawes C., Squire G. R., Rothery P., Woiwod I. P., Pidgeon J. D. (2004): A ban on atrazine herbicides likely to reduce but not negate relative benefits of GMHT maize cropping. Nature 428: 313–316.

Rondon M. A., Lehmann J., Ramirez J., Hurtado M. (2007): Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with biochar additions. Biology and Fertility of Soil 43: 699–708.

United States Agency for International Development (USAID) (2010): Package of Practices for Maize Production, Washington DC, 1–23.

Wolf D. (2008): Biochar as a Soil Amendment: A Review of the Environmental Implications. University of Swansea. Unpublished document. www.organiceprints.org/13268

Zhang A., Liu Y., Pan G., Hussain Q., Li L., Zheng J., Zhang X. (2011): Effect of biochar amendement on maize yield and greenhouse gas emission from a soil organic carbon poor calcareous loamy soil from Central China Plain. Plant-Soil 351: 263–275.



*Received: February 11, 2019*
*Accepted after revisions: June 28, 2019*