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Response of Maize (*Zea mays* L.) to different biochar rates and weed control methods

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ABSTRACT
The intensity of land-use and the fertility status of a soil affect the extent of yield losses caused by weeds infestation in maize production system. The role of biochar in improving soil fertility and weed control when used as soil amendment has not received adequate attention. Screenhouse experiment was conducted at the Federal University of Agriculture, Abeokuta (7^o 20'N, 3^o 23'E to investigate the performance of maize as affected by biochar rates and weed control methods. The trial was a factorial experiment fitted into Completely Randomized Design (CRD) and was replicated three times. The treatments consisted of six biochar rates (0, 2, 4, 6, 8 and 10 tha^{-1}) and five weed control methods (no weeding, pre- emergence herbicide-codal Gold at 1.0 kg a.i/ha + manual weeding at 6 WAP, pre-emergence herbicide-codal Gold at 2.0 kg a.i/ha + manual weeding at 6 WAP, manual weeding at 6 WAP and manual weeding at 3, 6, and 9 WAP). Data were collected on weed dry weight, weed flora composition, growth and developmental parameters as well as yield parameters. All data collected were analyzed using Analysis of Variance and treatment means were separated using Least Significant Difference at p≤ 0.05. Results showed that, pots treated with biochar produced the tallest plant and highest number of leaves at 6 WAP as compared to no biochar treated pots where the least plant height and number of leaves were observed. Shortest days to tasseling (56 days) and days to silking (61 days) were recorded in pots treated with biochar at 10 tha^{-1} compared to other rates. Also, biochar rates significantly enhanced the yield and yield components of the maize crop. Plant height, number of leaves, stem girth, days to tasseling and silking, yield and other yield components were significantly improved by different weed control methods. Highest grain yield was observed in pot weeded at 3, 6 and 9 WAP while the weedy check and manual weeding at 6 WAP produced the lowest grain yield. Thus,biochar applied at the rate of 10 tha^{-1} and manual weeding at 3, 6 and 9 WAP performed better than other tested rates and therefore recommended for optimum yield in maize production.

Key Words: maize, biochar, weed control methods, pre-emergence herbicide

INTRODUCTION

Maize (*Zea mays* L.) is the dominant cereal crop grown in Nigeria. Nigeria is the 10th largest producer of maize in the world, and the largest maize producer in Africa, followed by South Africa. Despite the widespread cultivation and numerous scientific efforts geared towards increasing maize yields, production by small holder farmers is still very low (Cadoni and Angelucci, 2013). This is attributed to improper soil fertility management and high cost of farm inputs like herbicides. Several factors affecting maize growth and yield. One of the most important factors affecting maize production is weed competition with maize crop for available resources (Irena and Swanton 2001). 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 correct method (s) is not employed. Maize farmers in the tropics are mostly resource poor, practicing subsistence farming and therefore could not afford the high cost of farm inputs like fertilizer and herbicide. Considering the problems associated with herbicide usage such as high cost, many peasant farmers are discouraged to consider it as an alternative option to manual weeding in weed management.

The manual method which is the most easily afforded by indigenous farmers is inadequate and with limited effects on most perennial weeds. It does not prevent sprouting of new shoots, thereby increasing the incidence of obnoxious weed such as *Imperata cylindrica* and *Striga* spp.. (Chikoye, 2004). Manual methods of weed control do not provide seasonal long lasting control, and need to be repeated three to five times to get reasonable control. Decrease in yield often occurs despite the control measure (Chikoye, 2004).

Weeds thrive in soils of low fertility causing abandonment of farmlands by farmers. The tragic consequence of farmland abandonment is the decrease in food production. An integrated weed management approach that combines the use of a low rate of pre-emergence herbicide, application of soil amendments and hand weeding later in the season may likely 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. This approach could as well give better weed control and crop yield than when either cultural or herbicide is used alone (Hassan, et al., 2010). Among the various soil amendments that have been used in maize production are; poultry manure (Adeniyan and Ojeniyi, 2003), cow dung (Tanimu *et al*., 2012), and pig manure (Terrance *et al*., 2004). These materials can be substituted for inorganic fertilizers which could help to increase the soil fertility and aid crop to have higher competitive advantage over the weeds.

In recent time, ‘agrichar’or ‘biochar’ has been reported to have positive impact like organic manure and enhance weed control in crop production (Rondon *et al.*, 2007; Chan *et al*., 2008; Muhammad *et al*., 2012).

A lot of works have shown that biochar is able to mitigate greenhouse gas emission through carbon sequestration, improve soil chemical and physical properties such as soil pH, cation exchange capacity (CEC), soil aggregation, soil water holding capacity and soil strength as well as increasing soil microbial population and activity (Rondon *et al.*, 2007, Chan *et al*., 2008; Masulili *et al.*, 2010). Observation of Steiner *et al*. (2007) showed that in the long term, application of biochar increased plant nutrient availability and soil productivity. In soils with low organic matter content, chars are an attractive option for increasing soil organic carbon by incorporating large amounts of biochar at crop establishment. Generally, increase in soil fertility enhances weed control since the crops absorbs these nutrients and have higher competitive advantage over the weeds thereby suppressing their growth and development. Integration of biochar with weed control methods is not popular among the tropical farmers, and there are dearths of research information on incorporation of biochar in weed control strategies. The objective of this study therefore was to examine the performance of maize in relation to different application rates of biochar and selected weed control methods.

MATERIALS AND METHODS

The experiment was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (FUNAAB) (7^o 20’N, 3^0 23’E) between April and December 2013. The experiment was a 6 x 5 factorial in Completely Randomized Design (CRD) with three replicates. The treatments consisted of six biochar rates (0, 2, 4, 6, 8 and 10 tha^{-1}) and five weed control methods (Pre-emergence application of commercially formulated mixture of Metolachlor and Prometryne (Codal Gold 412.5 E.C) at 1.0 kg a.i/ha + manual weeding at 6 WAP, Pre-emergence application of commercially formulated mixture of Metolachlor and Prometryne (Codal Gold 412.5 E.C) at 2.0 kg a.i/ha) + manual weeding at 6 WAP, single manual weeding at 6 WAP, manual weeding thrice at 3, 6, and 9 WAP and weedy check. Ninety (90) plastic buckets containing 10 kg capacity of soil collected from a depth of 0-15 cm on weed infested area of FUNAAB was arranged at a spacing of 0.5 m apart. The soil was mixed thoroughly and sieved using 2.0 mm mesh sieve to remove the gravels. A composite sample from the well mixed soil was collected for the determination of water holding capacity and the physicochemical properties. Biochar incorporated was calculated on the basis of 200 mm ploughing depth commonly used (Horne *et al*., 1992; Sparling *et al*., 1992; Aslam *et al*., 1999). Plastic buckets were arranged within 10 m^2 of land (2 m x 5 m) and were sprayed with the required amount of herbicide with the aid of CP3 knapsack sprayer calibrated to deliver 300 *l*/ha spray liquid. Maize seed (Oba super 2) were planted at the depth of 5 cm, four seed per pot and was latter thinned to two plants per hole two weeks after planting. Watering and all other cultural practices were done when necessary. Weeding was done manually according to the treatments structure.

Data were collected on growth and yield parameters such as; plant height (cm), number of leaves, stem diameter (cm), days to tasseling, days to silking, cob diameter (cm), cob length (cm), grain yield, 1000 grain weight (g) and harvest index. Data on days-to- tasseling were recorded as number of days from date of sowing to appearance of tassels in each experimental unit. Days to silking were determined by counting number of days from planting to silk emergence in each pot. Weed species composition and weed dry weight were determined by harvesting weeds present in each pot at the time of weeding and subsequently classifying into their different morphological forms (broad leaves, grasses and sedges). Harvested weeds were later oven dried at $80^{o}C$ till constant weight was achieved.

Data collected were analysed using analysis of variance (ANOVA) at 5% probability level using statistical package GENSTAT 12^{th} edition. Where there was significant difference, the treatment means were separated using Fisher's Protected Least Significant Difference (LSD) at 5% level of probability (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Effects of biochar rates on growth and development of maize .

Results showed that, biochar rates significantly affected plant height and number of leaves at 6 WAP (Table 1a). Application of biochar at 10 tha^{-1} gave the highest plant height (102.71 cm) and number of leaves (11.0) compared to control pots where the least plant height (80.86 cm) and number of leaves (9.33) were recorded. However, no significant differences were observed on plant height, number of leaves and stem diameter at 3 and 9 WAP (Tables 1a and b). Increase in plant height and number of leaves observed could be attributed to the ability of biochar as soil amendment to have enhanced the nutrients availability to the crop leading to increased crop vegetative growth. Biochar has been reported to reduce exchangeable acidity, increase soil pH of acidic soils, and inherently contains significant amounts of plant nutrients such as potassium, calcium and magnesium (Chan and Xu, 2009). It was suggested that these could have been the main reasons for enhanced plant growth. This was also confirmed by Glaser *et al*. (2002), who reported that biochar has the ability to make nutrients readily available for crop uptake by increasing the cation exchange capacity.

Results showed that the numbers of days to tasseling and silking as affected by biochar rates gave significant differences upon biochar incorporation (Tables 1b). As the biochar rates increased, numbers of days to tasseling and silking were reduced significantly ($p < 0.05$).

Table 1a: Effects of biochar rates and weed control methods on plant height and number of leaves in maize grown in Alabata, Abeokuta.

Treatment	Plant Height (cm)			Number of leaves		
	3WAP	6WAP	9WAP	3WAP	6WAP	9WAP
Biochar (B) (t/ha)						
0	24.10	80.86	143.30	5.00	9.33	9.67
2	26.62	83.47	146.90	5.20	10.27	10.33
4	28.57	93.97	154.40	5.47	10.80	9.53
6	27.13	90.59	147.10	5.20	10.67	9.67
8	28.07	98.65	149.60	5.60	11.07	10.07
10	27.00	102.71	150.90	5.33	11.07	9.60
L.S.D (0.05)	ns	9.94**	ns	ns	0.14*	ns
Weed control methods (W)						
Weedy check	27.95	81.02	131.60	5.28	9.72	9.39
Pre-emergence herbicide at 1kg a.i/ha	22.90	97.53	156.30	5.44	11.17	10.28
Pre-emergence herbicide at 2kg a.i/ha	22.59	93.47	155.20	5.22	10.83	10.28
Hoe wedding at 6 WAP	30.60	87.93	146.90	5.33	9.94	9.17
Hoe weeding at 3,6 and 9 WAP	30.53	98.59	153.50	5.22	11.00	9.94
L.S.D (0.05)	4.16**	9.07*	12.06*	Ns	0.13*	0.12*
B × W						
L.S.D (0.05)	ns	ns	ns	0.28*	ns	ns

Table 1b: Effects of biochar rates and weed control methods on stems girth, number of days to 50% tasseling and silking in maize grown in Alabata, Abeokuta.

Treatment	Stem girth (cm)			Number of Days to	
	3WAP	6WAP	9WAP	50%Tasseling	50% Silking
Biochar (B) (t/ha)					
0	0.69	2.05	2.23	61.27	66.47
2	0.68	2.21	2.37	59.93	65.13
4	0.90	2.26	2.25	58.73	63.87
6	0.83	2.25	2.31	58.60	63.67
8	0.76	2.28	2.30	56.40	61.20
10	0.86	2.49	2.33	56.20	61.33
L.S.D (0.05)	ns	ns	ns	0.12**	0.12**
Weed control methods (W)					
Weedy check	0.80	1.99	1.99	61.22	66.20
Pre-emergence herbicide at 1kg a.i/ha	0.71	2.42	2.47	58.11	63.22
Pre-emergence herbicide at 2kg a.i/ha	0.62	2.31	2.45	57.61	62.83
Hoe wedding at 6 WAP	0.96	2.07	1.16	57.76	62.83
Hoe weeding at 3,6 and 9 WAP	0.85	2.51	2.43	58.00	62.89
L.S.D (0.05)	0.18*	0.25ns	0.21*	0.11**	0.11**
B × W					
L.S.D (0.05)	ns	ns	ns	0.27*	0.26*

Treatments with no biochar took more days (61 days) to tassel compared to biochar application at the rate of 10 tha^{-1} which took 56 days to tassel (Table 1b). Also, number of days to silking was significantly reduced (61days) when biochar was applied at the rate of 10 tha^{-1} in comparison with plants without biochar application where more number of days to 50% silking was recorded (66 days) (Table 1b). It should be noted that application of higher rates of biochar could have modified the physico-chemical properties of the soil. One of such effect would be CEC of the soil. With increasing application rates of biochar, there is the tendency of increasing fine particle distribution. This would affect exchange process of the soil and consequently nutrient availability (Rondon *et al.*, 2007). This is more relevant in the tropics with high precipitation. With increased exchange capacity nutrient could be held against leaching into the soil, especially nitrogen for plant growth and development. Reduced duration for vegetative growth could predispose the plant for more reproductive growth and partitioning of assimilate into reproductive structures. Physiologically synchronous flowering phenology would aid the maize plant in its pollination and fertilization. Earlier reports had indicated the negative effect of asynchronous flowering in maize on its productivity (Muhammad *et al.*, 2012). This is most pronounced when the crop is under stress condition. In this case increasing application rates of biochar would ameliorate stress condition on the field. Lemcoff and Loomis (1994) also reported that phenological events like tasseling; silking and maturity in maize were significantly delayed by increasing rate of mineral N than the other sources.

This study also showed that application of biochar significantly affected yield and other yield components such as cob diameter, 1000 grain weight, harvest index, shelling percentage and grain yield (Table 2). It was observed that as the biochar increases from 0 tha^{-1} to 10 tha^{-1}, the grain yield and other yield components increased linearly, where the highest grain yield (0.03 kg/plant), cob diameter (3.35 cm), 1000 grain (0.14 kg/plant), harvest index (43.65), and shelling percentage (58.05 %) were recorded in the pot treated with biochar rate at 10 tha^{-1}. This could be attributed to the fact that application of biochar assisted the crop to partition more assimilate towards yield more than no biochar maize and probably because nutrient availability was promoted by biochar application. According to Pan *et al*. (2009), high levels of soil organic carbon accumulation due to biochar amendment could enhance N efficiency and increase crop productivity. This is clearly confirmed by the result of the soil analysis of the amended soil (Table 3) which gave a high soil organic carbon.

This result is also in agreement with the findings of Afeng *et al*. (2011) who reported that maize yield was increased by 11.6%–18.2% with N fertilization and by 7%–16% without N fertilization under biochar amendment at rates of 20–40 tha^{-1}

Effect of biochar rates on weed density and weed dry weight (Table 2) showed that, there was no significant difference among the biochar rates. The fact is that, biochar as soil amendments enhances soil fertility, increases the growth of both weed and crop. It could therefore imply that application of biochar as soil amendment cannot be used alone as a weed control method.

Effects of weed control methods on maize growth and yield.

Effect of weed control methods on the growth parameters (plant height, number of leaves and stem diameter) is shown in Tables 1a and b. Number of leaves produced at 3 WAP was not significantly affected by weed control methods. At 6 and 9 WAP, number of leaves produced in pots treated with pre-emergence herbicide of codal gold (412.5 EC) at 1kg a.i ha^{-1} and 2 kg $a.iha^{-1}$ were significantly higher than weedy check and manual weeding at 6 WAP. The least plant height (22.59 cm) and stem diameter (0.62 cm) were recorded at 3 WAP on pots treated with pre-emergence herbicide (Codal Gold) as compared to weedy check, manual weeding at 6 WAP and manual weeding at 3, 6, 9 WAP where the highest plant height and stem diameter was recorded, probably because of phytotoxic effect of the herbicide on the maize plant. Moreover, at 6 WAP, the least plant height (81.02cm) and stem diameter (1.99cm) were observed on weedy check and pot manually weeded at 6 WAP in comparison with pot treated with the two rates of pre-emergence herbicide and manual weeding at 3, 6 and 9 WAP where the highest plant height and stem diameter were observed. This could be due to phytotoxicity effect as well as increased weed control which gave the crop higher

Table 2: Effect of biochar rates and weed control methods on the yied and yield components of maize.

Treatment	Cob girth (cm)	Cob length (cm)	Grain Yield (g/plant)	1000 Grain weight (g)	Harvest index	Shelling percentage
Biochar						
0tonne/ha	1.220d	3.85	2.90c	34.00c	3.92c	17.58b
2tonnes/ha	1.647cd	5.45	8.00c	48.00bc	10.78bc	25.93b
4tonnes/ha	2.67ab	8.41	9.80bc	56.00bc	10.80bc	35.03b
6tonnes/ha	2.067bc	6.55	9.70bc	53.00bc	14.52b	23.95b
8tonnes/ha	2.513b	7.40	16.80b	70.00b	19.16bc	41.89b
10tonnes/ha	3.347a	7.01	33.70a	135.00a	43.65a	58.05a
L.S.D (0.05)	0.784**	Ns	0.01**	0.024**	0.213**	15.59*
Weed control methods						
Weedy check	1.361c	3.006c	0.005c	0.046b	8.60	19.25
Pre-emergence herbicide at 1kg $a.iha^{-1}$	2.639ab	7.461ab	0.016ab	0.082a	17.58	38.28
Pre-emergence herbicide at 2kg $a.iha^{-1}$	1.989bc	6.422b	0.016ab	0.064ab	19.39	33.91
Manual wedding at 6 WAP	2.072bc	5.722bc	0.010bc	0.052b	12.72	39.04
Manual weeding at 3,6 and 9 WAP	3.072a	9.611a	0.021a	0.085a	25.58	48.20
L.S.D (0.05)	0.716**	2.754**	0.008*	0.026*	ns	14.23*
B X W						
L.S.D (0.05)	ns	Ns	ns	Ns	ns	ns

Note: Means followed by the same letter are not significantly different at 5% level of probability; ns-not significant, *-significant, **-highly significant, WAP-Weeks After Planting.

competitive advantage over the weeds. The ability of prometryne components of Codal Gold to inhibit photosynthesis in plants has been documented (Das, 2011). Also, pot kept weed infested produced the shortest plants at 9 WAP as compared to other weed control methods. Pot kept weed infested throughout and pot weeded at 6 WAP were similar in stem diameter and number of leaves as compared with other weed control methods (Tables 1a and b).

Weed control methods significantly affected number of days to 50% tasseling and silking (Table 1b). Uncontrolled weed infestation resulted into longer number of days to tasseling (61.22 days) and number of days to 50% silking (66.20 days) as compared to other weed control methods. This observation is at variance with the common physiological concept whereby plants grown on nutrient deficient soil tends to attain maturity faster than when nutrients are sufficient, Moreover the competition that ensued as a result of weed infestation was supposed to enable the plant to switch to reproductive phase earlier than normal which however was not so.

There were no significant differences among the means of the pot treated with Codal gold at 1 kg a.i ha^{-1}, Codal gold at 2 kg a.i ha^{-1}, manual weeding at 6 WAP and manual weeding at 3, 6 and 9 WAP on the number of days to tasseling and silking (Table 1b). Yield and yield components such as grain yield, cob diameter, cob length and 1000 grain weight were significantly ($p \leq 0.005$) affected by different weed control methods during the trial (Table 2). Coda Gold at 1.0 kg a.i/ha and codal Gold at 2.0 kg a.i/ha and hoe weeding at 6 WAP were not significantly different from one another on cob diameter, cob length and grain yield. Also, hoe weeding at 6 WAP and weedy check were not significantly different from one another.

Table 3: Weed species encountered in the experimental pot.

Plant taxa	Family	Growth form[1]	Level of Infestation[2]
Abutilon mauritianum (Jack.) Medic	Malvaceae	ABL	+
Achyranthes aspera L.	Amaranthaceae	ABL	+
Aspilia africana (Pers) C.D Adams	Asteraceae	PBL	+
Cleome viscosa L.	Cleomaceae	ABL	+
Cyperus esculentus L.	Cyperaceae	PS	+++
Desmodium scorpiurus (Sw) Desv	Fabaceae	ABL	+
Digitaria gayana (Kunth) Stapf ex	Poaceae	PG	+++
Digitaria horizontalis Willd	Poaceae	PG	+++
Euphorbia heterophylla L.	Euphorbiaceae	ABL	+
Euphorbia hirta L.	Euphorbiaceae	ABL	+
Ipomea triloba L.	Convolvulaceae	ABL	+
Oldenlandia corymbosa L.	Rubiaceae	ABL	+++
Panicum maximum Jack	Poaceae	PG	+++
Phyllanthus amarus Schum & Thonn	Euphorbiaceae	ABL	+++
Physalis angulata L.	Solanaceae	ABL	++
Mitracarpus villosus	Rubiaceae	ABL	++
Tridax procumbens L	Asteraceae	ABL	+++

[1] ABL=Annual Broadleaf, PBL=Perennial Broadleaf, PSp= Pernnial Spiderwort, PG=Perennial Grass, PS= Perennial Sedge, AG= Annual Grass [2] +++=High infestation, ++=Medium infestation. +=Low infestation.

Higher grain yield was observed in pot weeded at 3, 6 and 9 WAP (0.02 kg/plant) and pot treated with pre-emergence herbicide at 1.0 kg a.i ha^{-1} (0.02 kg $plant^{-1}$) and 2.0 kg a.i ha^{-1} (0.02kg $plant^{-1}$) compared to manual weeding at 6 WAP and weedy check with 0.01 and 0.01kg $plant^{-1}$ respectively (Table 2). The finding suggests that manual weeding at 3, 6 and 9 WAP was superior to herbicide treatments. Also, uncontrolled weed infestation in maize production can result into significant yield reduction. Forcella (2000) and Perry *et al*. (2004) reported that manual weeding (hoeing) was superior to herbicide application in maize and the effectiveness of hand hoeing treatments

Table 4: Effect of biochar rates and weed control methods on weed dry weight, cumulative weed density, cumulative broadleaf, cumulative grasses and cumulative sedges number.in maize

Treatments	Soil Organic Carbon	Weed Flora Composition			Cumulative Weed Density (no./m^2)	Cumulative Weed Dry Weight (g/m^2)
		Broad leaves	Grasses	Sedges		
Biochar (B) (t/ha)						
0	0.70	14.07	5.20	12.00	31.3	27.8
2	0.74	16.80	4.13	9.53	30.5	27.9
4	0.72	10.93	5.00	7.73	23.7	25.0
6	0.86	12.20	3.60	9.00	24.8	16.6
8	0.81	11.47	3.53	8.67	23.7	34.4
10	0.87	13.07	4.27	10.13	27.5	19.2
L.S.D (0.05)	0.11*	ns	ns	ns	ns	ns
Weed control methods (W)						
Weedy check	0.75	16.61	5.61b	12.89	35.11	89.2
Pre-emergence herbicide at 1kg a.i/ha	0.78	0.28	0.06	0.06	0.39	0.6
Pre-emergence herbicide at 2kg a.i/ha	0.78	0.33	0.28	0.00	0.61	1.0
Manual weeding at 6 WAP	0.80	17.78	7.00	13.33	38.1	31.2
Manual weeding at 3,6 and 9 WAP	0.81	30.44	8.50	21.28	60.22	3.7
L.S.D (0.05)	Ns	0.52**	0.37**	0.69**	0.67**	18.55**
B × W						
L.S.D. (0.05)	ns	ns	ns	ns	ns	ns

ns =not significant, **= significant (p<0.001), WAP=Weeks after planting was attributed to the notion that hoeing was most likely more efficient in eradication and growth stunting of the weeds than the herbicide treatments. Similarly, Hassan and Ahmed (2005) found that maize yield and yield components (ear length, ear weight, ear kernel weight and 100 grain weight) were increased with hand hoeing thrice more than applying herbicides alone, as compared with unweeded control (Table 2). Abouziena *et al.* (2008) also stated that all weed control treatments improved grain yield up to six fold compared with weedy check. Tahir *et al*. (2009) found that the application of herbicides (Stomp® 35-EC and Penthalin plus®-35EC) and manual hoeing increased maize grain yield compared to weedy check. The study concluded that manual weeding and Stomp® 35-EC can be more effective as compared to all other treatments without compromising the maize grain yield loss due to weeds.

The pots were mainly dominated by broad leaves *(Tridax procumbens* L, *Oldenlandia corymbosa* L, *Phyllantus amarus* Schum & Thonn*;* grasses *(Digitaria gayanus* (Kunth) Stapf ex*, Digitaria horizontalis* Willd , *Panicum maximum* Jack and sedges *Cyperus esculents* L.) (Table 3). These weeds were effectively controlled by Codal Gold at 1.0 kg a.i ha^{-1} and 2.0 kg a.i ha^{-}Generally, weed control methods significantly reduced weed biomass and density in the experiment (Table 4). The use of pre-emergence herbicides either at low rate (1.0kg a.i ha^{-1}) or high rate (2.0 kg a.i ha^{-1}) reduced weed density significantly than the manual weed removal. Though, both the high and low rates were significantly similar in weed density and biomass reduction. However, manual weed removal at 3, 6 and 9 WAP had similar weed biomass with the herbicide treatments. This finding is in agreement with the result of El-Metwally *et al.* (2012) who observed that Fluroxypyr was more effective than the other treatments against the broadleaved weeds, while hoeing treatment was more efficient in reducing the number and dry weight of grass.

Weed removal at 6 WAP had reduced weed population compared to that of weedy check. Weed population was significantly higher in manually weeded pot at 3, 6 and 9 WAP than other weed control treatments, probably because of the significantly higher population of broad leaves and sedges which were predominant in the pot.

Interaction between biochar rates and weed control methods on maize productivity and weed infestation

Generally, interaction between biochar and weed control methods had no significant effect on the growth parameters such as number of leaves, plant height and stem girth (Table 5). Also, interaction between biochar rates and weed control methods on the yield and other yield components were not significantly different from one another (Table 5). However, there was significant interaction observed between biochar rates and weed control methods on the number of days to tasseling and silking. (Table 5). It was observed that, when biochar was applied at the rates of 8-10 tha^{-1} and manual weeding at 6 WAP, 3, 6 and 9 WAP, pre-emergence herbicide application at 1.0 kg a.i ha^{-1} and 2.0 kg a.i ha^{-1}, the number of days to tasseling and silking was reduced compared to other treatments (Table 5). This could be as a result of the crop being able to harness the growth resource provided through biochar application together with reduced competition between the crop and weeds.

This finding confirms the fact that maize crop respond favorably to weed removal and nutrients availability especially at the early vegetative and reproductive stages of growth. Also, weeds exert great competition on the crop between 3 WAP and 6 WAP which is the most critical period in the lifecycle of the crop. This period has been described as critical period of weed interference by Nieto *et al.* (1968).

CONCLUSION

This study showed the growth and yield of maize can be enhanced through the use of biochar. Application of biochar at 10 t/ha significantly improved the yield and yield components of maize, however weed control was not affected. Moreover, manual weeding at 3, 6 and 9 WAP rated best among the weed control methods employed in the study. Thus, for enhanced productivity of maize, the use of biochar as soil amendments which is able to promote nutrients availability can be integrated with other weed control strategies such as manual weeding.

REFERENCE

Abouziena, F.H., El-Metwally I.M and. El-Desoki, E.R (2008). Effect of plant spacing and weed control treatments on maize yield and associated weeds in sandy soils. *Amer.- Eurasin J. Agric. and Environ. Sci.*, 4(1): 09-17.

Table 5: Interaction of biochar rate and weed control methods on days to 50% tasseling and days to 50% silking of maize.

Biochar rates t ha^{-1}	Weed control methods: Weedy check	Pre-emergence herbicide at 1.0 kg a.i ha^{-1}	Pre-emergence herbicide at 2.0 kg a.i ha^{-1}	Manual wedding at 6 WAP	Manual wedding at 3, 6 and 9 WAP
	50% tasseling.of maize				
0	61.67	63.67	58.67	61.33	61.00
2	58.67	59.33	61.33	57.67	62.67
4	62.67	60.33	57.00	57.33	56.33
6	61.00	57.33	57.00	60.67	57.00
8	62.00	53.33	55.33	54.33	57.00
10	61.33	54.67	56.33	54.67	54.00
L.S.D (0.05)	0.27*				
	50% silking.of maize				
0	67.00	68.67	63.67	67.00	66.00
2	64.00	65.00	66.67	62.67	67.33
4	67.67	65.33	62.33	62.33	61.67
6	66.00	62.33	62.33	65.33	62.33
8	67.00	58.33	60.33	59.33	61.00
10	66.00	59.67	61.67	60.33	59.00
L.S.D (0.05)	0.26*				

ns=not significant, *=significant (p<0.05), WAP-Weeks after planting

Adeniyan, O.N. and Ojeniyi, S. O. (2003). Comparative effectiveness of different levels of poultry manure in NPK fertilizer on residual fertility nutrient uptake and yield of maize. Moor Journal of Agricultural Research 4 (2): 191-197.

Aslam, T., Choudhary, M.A, Saggar S (1999). Tillage impacts on soil microbial biomass C, N, and P, earthworms and agronomy after two years of cropping following permanent pasture in New Zealand. *Soil & Tillage Research* 50: 103-111.

Cadoni, P., Angelucci, F., 2013. Analysis of incentives and disincentives for

Maize in Nigeria. Technical notes series, Monitoring African food and Agricultural Policies (MAFAP), FAO, Rome. 41pp

Chan, K and Xu Z. (2009). Biochar: Nutrient Properties and Their Enhancement in Biochar for Environmental Management: *Science and Technology* (Eds J Lehmann and S Joseph) (Earthsca: London, UK) 53-66 pp.

Chan, K.Y, Zwieten VL, Meszaros I, Dowine A, Joseph S (2007) Agronomic value of greenwaste biochar as a soil amendment. *Aust J Soil Res* 45:629–634

Chan, K.Y, Zwieten VL, Meszaros I, Dowine A, Joseph S (2008) Using poultry litter biochars as soil amendments. *Aust J Soil Res* 46:437–444

Chikoye, D. (2004). Wining the war Against Spear Grass (*Imperata Cylindrica)*: Problems and opportunities, symposium II, International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. *Nigerian Journal of Weed Science*. 17: 91 – 100

Chopra pankaj and Angiras, M. N., (2008), Influence of tillage and weed control methods on weeds, yield and yield attributes of maize (*Zea mays* L.). *Indian J. Weed Sci.*, 40(1&2):47-50: Science and Technology'. (Eds. J Lehmann and S Joseph) (Earthscan: London, UK) pp 53-66

Das, T.K. (2011). *Weed Science Basics and Applications.* Jain Brothers Publishers, 910 pp.

El-Metwally, I.M., Abd El-Salam, M.S., Tagour, R.M.H. and Abouziena, H.F. (2012). Efficiency of plant population and reduced herbicides rate on maize productivity and associated weeds. *J. of Appl. Sci.* Res., 8(4): 2342-2349.

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

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

Hassan, G., S. Tanveer, Khan, N. and. Munir, M (2010). Integrating cultivars with reduced herbicides rates for weed management in maize.*Pakistan Journal ofBotany*, 42(3): 1923-1929.

Hassan, A.A.A. and. Ahmed, M.K.A (2005). The influence of some herbicides and additional hoeing in maize growth and yield and yield components. *Int. J. Agri. Biol*., 7(5): 708-710.

Horne DJ, Ross C.W, Hughes KA 1992. Ten years of a maize/oats rotation under three tillage systems on a silt loam in New Zealand. 1. A comparison of some soil properties. *Soil & Tillage Research* 22: 131-143

Irena, R. and Swanton, C. J (2001). Understanding maize-weed competition: resource completion, light quality and the whole plant. *Field Crops Research* 71: 139-150.

Lemcoff, J.H. and R.S. Loomis. 1994. Nitrogen and density influences on silk emergence, endosperm development, and grain yield in maize. *Field Crops Research.* 38: 63-72.

Masulili, A., Sudarso, J.K.Y. and Utomo,W.H., (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.

Muhammd, N., M. Ashiq, A. Gaffar, A. Sattar, M. Arshad (2012). Comparative efficacy of new herbicides for weed control in maize (*Zea mays* L.).*Pakistan Journal of Weed Science Research*, 18(2): 247-254.

Nieto, J.H., Brondo, M.A. and Gonzalez J.T (1968): Critical periods of the crop growth for competition from weeds, *PANS* vol. 14, No 2: 159 – 166.

Pan, G., Lin Z., Li L., Zhang A, Zheng J.and Zhang, X. (2011) Perspective on biomass carbon industrialization of organic waste from agriculture and rural areas in China. *J Agric Sci Tech 13:75–82, in Chinese*

Pan G., Zhou P., Li Z., Smith P., Li L. and Qiu, D. (2009) Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake region, China. *Agric Ecosyst Environ* 131:274–280

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. and. Pidgeon, J.D. (2004). Ban on atriazine herbicides likely to reduce but not negate relative benefits of GMHT maize cropping. *Nature*, 428: 313-6.

Sparling GP, Shepherd G, Kettles HA 1992. Changes in soil organic C, microbial C and aggregate stability under continuous maize and cereal cropping, and after restoration to pasture in soils from the Manawaturegion, New Zealand. *Soil and Tillage Research* /24: 225_241.

Steel, R. G. D. and Torrie, J. H. (1980). *A Biometrical Approach*, 2nd Edition, McGraw-Hill Book Co., New York, 1980.

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 Soils*, *43*, 699-708.

Steiner, C., Teixeira, W.G., Lehmann, J., Nehls, T., de Macedo, J. L. V., Blum, W. E. H. and Zech, W. (2007). Long effect of manure, charcoal and mineral fertilization on crop production and fertility on highly weathered central amazonian upland soil. *Plant and Soil, 291*, 275-290.

Tahir, M., Javed, M.R,Tanveer, A., Nadeem, M.A., Wasaya, A., Bukhari.,S.A.H., and Rehman, J.Ur. (2009). Effect of different herbicides on weeds, growth and yield of spring planted maize (*Zea mays* L.). *Pak. j. Life Soc. Sci*., 7(2): 168-174.

Tanimu, J. Uyovbisere, E. O., Lyocks, S. W. J. and Tanimu, Y. (2012). Effects of cowdung on the growth and development of maize crop. *Greener Journal of Agricultural Sciences*, 3 (5): 371-383.

Terrance, D.L., Matt, L., Cynthia, A. C. and Tom, L. R (2004). Corn growth response to composted and fresh solid swine manures. *Crop Science*. Crop Science Society of America. 44:177-184