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EFFECTS OF POST-TREATED AND INCUBATED *Gliricidia* BIOCHAR SAMPLES ON THE GROWTH OF MAIZE SEEDLINGS

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ABSTRACT

Biochar (pyrolyzed biomass) has been shown to have potential in increasing crop yield. There is, however, a dearth of information in Nigeria on the effect of post-treated biochar samples on plant growth in different soil types. The objective of this study was to investigate the effectiveness of nutrient-enhanced and incubated *Gliricidia* biochar on the growth of maize plant. A pot experiment was conducted in the screen house of Bowen University, Iwo Nigeria to examine the response of maize seedlings to *Gliricidia* biochar that was post-treated either with urea/bone ash or 15:15:15 NPK fertilizer at ratio 7:1(biochar : nutrient source, w/w). The post-treated biochar samples were incubated for 0, 14, 28 and 56 days. The treated/incubated biochar samples, untreated biochar sample and poultry manure were applied at the rate of 10 t/ha while urea/bone ash and 15:15:15 NPK inorganic fertilizer were applied at 90 kg N/ha. Maize plants were grown for eight weeks in top soil (30 cm) collected from an Oxisol in the University Teaching and Research Farm. Irrespective of incubation period and post-treatment type, maize seedling height, stem diameter, leaf production and total dry weight increased significantly ($p<0.05$) in all treatments having post-treated biochar materials over the non-treated control.The longer the incubation period, the more beneficial was the effect of NPK post-treated biochar on maize growth while the opposite was true for urea/bone ash-treated biochar sample NPK post-treatment of *Gliricidia* biochar was significantly superior to urea/bone ash post-treatment in terms of plant parameters.

Key words: biomass, *Gliricidia* biochar, post-treatment, incubation, plant parameters

INTRODUCTION

Biochar, at its most basic, is carbonized organic material. It can be produced using a wide variety of low- to high-tech thermochemical conversion technologies, and from a wide variety of feedstocks (Tomlinson and Draper, 2015). According to Lehmann and Joseph (2009a), biochar is a term used to designate a carbon-rich solid product obtained when a biomass (such as animal manures, municipal organic wastes, wood, lignocellulosic dedicated tree crops, agriculturally generated organic wastes or any sustainably obtained organic wastes) is heated in a closed container with little or no oxygen.

In addition to its many positive properties, biochar contains variable amount of plant nutrients, depending on the feedstock and processing temperature, and polymers such as humic substances. When used as a soil amendment and fertilizer, biochar has been reported to boost soil fertility, improve soil quality and enhance crop yield (Lehmann *et al.,* 2006; Lehmann, 2007). All these properties make biochar an effective organic soil conditioner and a driver of nutrient transformations in the soil (Glaser *et al,,* 2000a; Gundale and DeLuca, 2006). Biochar can also act as an effective carbon sink in the soil for several years because of its aromatic structure which makes it relatively recalcitrant in the soil system (McLaughlin *et al.,* 2009).

According to Tomlinson and Draper (2015), biochar can be used as a product itself or as an ingredient within a blended product, as an agent for soil improvement, improved resource use efficiency and so on. So over the past few years, there has been a large volume of data published on the application of biochar to soils. However, various studies on the ability of biochar to serve as an effective organic fertilizer have indicated the need to enhance its fertilizing properties by blending it with nutrient sources to meet soil and plant requirements (Joseph *et al.,* 2013). According to Joseph and others (2013), very little research has been carried out in this area.

In response to the above mentioned research gap, we separately post-treated *Gliricidia* biochar with urea/bone ash and 15:15:15 NPK inorganic fertilizer and these were incubated for 0, 14, 28 and 56 days.. The primary objective of this study was to investigate the effectiveness of untreated and incubated nutrient-enhanced *Gliricidia* biochar samples on the growth of maize seedlings. The stimulus to carry out this study comes from the reported beneficial effects of sole application of biochar and its complementary use with inorganic fertilizers on maize crop (Uzoma *et al.,* 2011; Arif *et al.*, 2012; Fagbenro *et al*., 2014b).

MATERIALS AND METHODS

Bulk surface soil (0-30 cm) was collected from an agricultural farm previously grown to maize and cowpea during last year planting season at Bowen University Teaching and Research Farm. The soil is grouped as Oxisol (Aubert and Tavenier, 1972; FAO/UNESCO, 1977). It was air-dried, ground and sieved through 2-mm sieve. The water holding capacity of the soil was determined to be 44.5 %.

Gliricidia feedstock for the production of biochar was from *Gliricidia sepium*, a nitrogen fixing tree species that grows widely on fallow lands in the southern and middle belt agro-ecological zones of Nigeria and which does not appear to have any other higher net resource value than to be converted to biochar.The feedstock was converted to biochar by heating using the traditional earthen mound kiln method in which earth is used as a shield against O_2. Average temperature within the kiln was 400 ^{0}C. A 50 kg bag of 15:15:15 NPK inorganic fertilizer and a 50 kg bag of urea fertilizer were purchased from Osun State Agricultural Development Project (OSADEP) in Iwo while cow bone was bought from a local abattoir within Iwo municipality and then burnt to ash. Apron plus-treated seeds of maize variety Oba Super-2 were purchased from Agbeloba Ventures also within Iwo municipality. The biochar was mixed (post-treated) separately with urea/bone ash (1:1) and with NPK 15:15:15 inorganic fertilizer at ratio 7:1 (biochar: nutrient source, w/w), moistened with a known quantity of water and mixed thoroughly.

Both the urea/bone ash mixture and NPK-biochar mixture was divided into four equal portions. Each portion was put in a polythene bag, covered with a white transparent sheet having 4 holes at the top for gaseous exchange, placed on the laboratory table and incubated aerobically at room temperature. Each of the four portions of each mixture was either incubated for 0 day, 14 days, 28 days or 56 days. At due days, the samples were air-dried for 72 hours and then oven-dried at 65 ^{0}C for 48 hours after which they were ground, mixed thoroughly and kept in bags pending time of use.

Key properties of the experimental soil are presented in Table 1 (Fagbenro *et al*., 2013) while Table 2 shows the selected properties of the untreated *Gliricidia* biochar (Fagbenro *et al.,* 2014). Some properties of the post-treated incubated *Gliricidia* biochar samples were determined using routine procedures (IITA, 1982) and are presented in Table 3.

The post-treated biochar samples, untreated biochar and poultry manure were applied at the rate of 10 t/hectare which was an equivalent of 4 g/kg soil while urea/bone ash and NPK inorganic fertilizer were applied at 90 kg N/hectare which was equivalent to 0.24 g/kg soil.The treatments used are presented in Table 4. Each organic or inorganic amendment was thoroughly mixed with 2 kg sample of soil and the mixture put in a 4-litre black polythene pot with drainage holes at the bottom. The holes were lightly plugged with non-absorbent cotton wool to prevent loss of soil and leaching of nutrients. The mixture in the pot was moistened to 50 % water holding capacity and left in the screenhouse for 7 days to equilibrate. The pots were then moved outside the screen house and lined up on black plastic sheet to prevent plant roots getting into the ground. Random numbers were used to determine the position of each pot on the plastic sheet. The experimental design was Completely Randomized Design (CRD) with three replicates. Four seeds of maize were sown per pot and thinned to one plant per pot two weeks after germination (WAG).The seedlings were grown outside the screen house and rain-fed to simulate nature but were watered once daily or as necessary when it did not rain.

At the end of eight weeks, the experiment was terminated. A day before harvesting , seedling height was measured with a long ruler from the soil surface to the seedling tip while the stem diameter was measured with a micrometer at the crown line to the nearest mm. The number of leaves produced was also recorded. The leaves, stems, and roots were harvested separately and their fresh weight recorded followed by oven-drying at 65 ^{0}C until constant dry weights were obtained. The weights of leaves, stems and roots were added together to obtain total dry weight.

Analysis of variance was carried out. Duncan's Multiple Range Test was used for means separation where significant effects were obtained according to Snedecor and Cochran (1967). Student's t-test analysis was used to compare effect of urea/bone ash post-treatment with that of NPK post-treatment on plant growth parameters.

RESULTS AND DISCUSSION

Effect of incubation on *Gliricidia* biochar post-treated with urea/bone ash.

Table 5 shows the height, stem diameter, number of leaves and dry matter yield of maize seedlings as affected by urea/bone ash post-treated *Gliricidia* biochar samples incubated for varying periods of time. The maize plant responded positively to the application of urea/bone ash-amended organic fertilizers. Plants grown in all treatments that had gliricidia biochar post-treated with urea/bone ash performed significantly better than those in the control.

Table 1: Key properties of soil (0-30cm) sample used for the pot experiment.

Property		Value
Particle size (g/kg)		
Sand		872
Silt		40
Clay		88
Texture	Sand	
pH (H_20)		6.2
Total N (g/kg)		2.3
Organic C (g/kg)		19.9
Available P (mg/kg)		16.5
Exchangeable Cations: (cmol/kg)		
Ca		13.50
Mg		1.35
K		0.24
Na		0.60
Extractable Micro nutrients: (mg/kg)		
Ca		2.36
Zn		5.69
Fe		78.30
Mn		79.60

Source: Fagbenro et al, 2013

The tallest plant (52.0 cm) was produced in the treatment that had post-treated biochar without incubation (GUA-0 and was closely followed by post- treated biochar incubated for 14 days (GUA-14). The shortest seedling (38.7 cm) was observed in the control. Maize seedling that was grown in the treatment that received biochar incubated for 28 days was not significantly taller than that produced in the control. Similar trend was observed for stem diameter. All treatments that received post-treated biochar samples, irrespective of incubation period, produced seedlings that were significantly bulkier than the one in the control. As for the number of leaves produced and the dry matter yield, there was no statistical difference between seedlings produced in all treatments that had post-treated biochar samples and the control. The data obtained appeared to indicate that the longer the incubation period of the urea/bone ash biochar, the lower the beneficial effects of the organic fertilizer.

The positive response of maize seedlings to the application of urea/bone ash post-treated *Gliricidia* biochar shows that combining urea/ bone ash with biochar can produce an effective organic fertilizer. The effectiveness of the urea/

Table 2:**Some selected properties of gliricidia feedstock and gliricidia biochar**

Property	Gliricidia Feedstock	Gliricidia Biochar
N%	2.26	1.09 (51.8%)
P%	0.25	0.17(32%)
K%	1.84	1.36 (26%)
Ca%	1.11	0.96 (13.5%)
Mg%	0.44	0.37 (15.9%)
Na (mg/kg)	24.95	54.48
Mn (mg/kg)	114.55	21.78
Fe (mg/kg)	71.755	115.48
Cu (mg/kg)	2.73	1.39
Zn (mg/kg)	9.33	13.05
pH (H_20)	ND	8.2
HA(g/kg)	ND	92.2
FA(g/kg)	ND	41.2
HA: FA Ratio	ND	2.24

Foot note: ND = Not determined
Figure in parenthesis is percentage loss of nutrient after conversion of feedstock to biochar.
HA = Humic acid, FA =Fulvic acid

bone ash treated biochar could be due to the presence of nitrogen in urea or to the biochar itself or to the combination of the two. This result confirms the positive effect of N on vigorous vegetative growth of plant (Khan *et al.,* 2008) and the stimulating effect of biochars on maize growth (Yamato *et al.,* 2006). Reasons for the reduction in plant parameters with increase in

Table 3:Selected properties of post-treated gliricidia biochar samples incubated for varying periods.

Biochar Sample	Property								
.	Ph(H_2O)	Total Ash	Total N	Total NH_4-N	Total NO_3 –N	Total K	Av. P	Total Org. C	C:N
Treatment		g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
1. GUA-0	7.1	100	15.4	0.3	1.3	0.65	3.5	378	24.5
2. GUA-14	7.1	114	15.7	0.5	1.7	0.67	3.6	276	23.9
3. GUA-28	7.4	114	16.2	0.5	1.8	0.67	3.5	376	23.2
4. GUA- 56	7.4	115	16.5	0.6	1.8	0.68	3.5	377	22.8
5. GMF-0	5.6	113	14.8	0.3	1.2	0.41	3.6	338	26.2
6. GMF-14	5.6	113	15.0	0.4	1.5	0.50	3.6	373	24.9
7. GMF-28	5.9	118	15.6	0.5	1.7	0.52	3.8	374	23.9
8. GMF-56	5.9	120	15.4	0.6	1.5	0.50	4.8	372	24.2

incubation period of urea/bone ash post-treated biochar were not apparent.

Effect of incubation on *Gliricidia* biochar post-treated with NPK fertilizer

Data on the performance of maize seedlings grown in treatment amended with incubated *Gliricidia* biochar post-treated with NPK 15:15:15 inorganic fertilizer are presented in Table 6. Irrespective of length of incubation period, maize seedlings produced in all treatments that had the post-treated biochar samples were significantly taller, bulkier, weightier and produced more leaves than those grown in the control. Unlike the urea/bone ash treated biochar, the longer the incubation period, the more beneficial the NPK post-treated biochar became. The tallest seedling (58.7 cm) with the heaviest dry weight

Table 4: Experimental treatments

No	Code	Description
1.	Gua-0	Urea/bone ash post treatment with no incubation (zero day)
2	Gua-14	Urea/bone ash post treatment incubated (14 days)
3.	Gua-28	Urea/bone ash post treatment incubated (28 days)
4.	Gua-56	Urea/bone ash post treatment incubated 56 days)
5.	GMF-0	15:15:15 post treatment with noincubation (Zero day)
6.	GMF-14	15:15:15 post treatment incubated (14 days)
7.	GMF-28	15:15:15 post treatment incubated for (28 days)
8.	GMF-56	15:15:15 post treatment incubated (56 days)
9.	UGB	Untreated Gliricidia biochar
10.	PM	Poultry manure
11.	MF	15:15:15 NPK
12.	UA	Urea/bone ash
13.	CO	Control

Table 5:Effect of incubated gliricidia biochar post treated with urea/bone ash on 8-weeks old maize seedlings.

Treatment	Heght (cm)	Stem Dm (mm)	Leaf no.	Total Dry Eight (g)
GUA-0	52a	11.7ab	9	12.3a
GUA-14	49a	13a	9	11.7ab
GUA-28	39.7c	13a	9	10.3ab
GUA-56	45b	12a	8	11.0ab
Control	38.7	10b	7	8.3b
LSD	3.8	2.0	2	4.0

Foot note: In this and other tables, means in one column followed by the same letter are not significantly different ($p<0.05$) according to Duncan's Multiple Range-Test.

Table 6: Effect of incubated gliricidia biochar post-treated with 15:15:15 inorganic fertilizer on 8-week old maize seedlings.

Treatment	Height (cm)	Stem Dm (mm)	No of Leaf	Total Dry Weight(g)
GMF-0	53a	15.7a	11a	20.3b
GMF-14	52a	16.3a	11a	20.7b
GMF-28	54.7a	18.0a	11a	22.7b
GMF-56	58.7a	15.7a	10b	26.3a
Control	38.7b	10.0b	7c	8.3c
LSD	10.7	2.4	1	3.6

yield (26.3 g) was produced in the treatment that had post-treated biochar incubated for 56 days. There was no significant difference in seedling height, stem diameter and number of leaves produced in all treatments that received post-treated biochar.

Again, the positive response of maize seedlings to the blending of NPK fertilizer with *Gliricidia* biochar further shows the effectiveness of the two as an organic amendment. This could be due to the presence of N, P and K contained in the inorganic fertilizer (Arif *et al.*, 2012) , the biochar itself (Chan *et al.*, 2008; Karhu *et al.,* 2011) or to the two. The fact that incubation enhanced the effectiveness of NPK post-treated biochar as an organic fertilizer indicates the desirability of incubation on biochar when post-treated with NPK inorganic fertilizer. This result could be due to NH_4-N and NO_3-N, available P and exchangeable K in the post-treated biochar which increased with incubation period as shown in Table 3.

Comparative effects of post-treated biochar samples, untreated biochar, poultry manure and inorganic fertilizers on 8-week old maize seedlings.

Comparative effects of urea/bone ash post-treated biochar with zero incubation (GUA-0),

Table 7: Comparative effects of unincubated organic and inorganic amendments on 8-week old maize seedlings.

Treatment	Height (cm)	Stem Dm (mm)	Leaf no	Total Dry Weight (g)
GUA -0	52.0ab	11.7b	9b	14.7b
GMF -0	53.0a	15.7a	11a	20.3a
UA	41.6b	13.7ab	9b	12bc
MF	45.0b	14.3ab	9a	14b
UGB	44.0b	13.3ab	9a	14b
PM	50.ab	14.3ab	10ab	15b
Control	38.7b	10b	7c	8.3c
LSD	7.2	2.8	2	5.2

Comparative effects of post-treated biochar samples, untreated biochar, poultry manure and inorganic fertilizers on 8-week old maize seedlings.

15:15:15 NPK post-treated biochar with zero incubation (GMF-0), untreated biochar (UGB), poultry manure (PM), urea/bone ash fertilizer (UA) and 15:15:15 NPK fertilizer (MF) on maize height, stem diameter, number of leaves and total dry matter yield are presented in Table 7. All treatments that received organic and inorganic amendments produced maize seedlings that were significantly superior to that of the control. Treatment that had GMF-0 amendment produced the heaviest seedling which was significantly different from the control and other treatments but was at par with GUA-0 and PM with respect to height and at par with UA, MF, UGB and PM with respect to stem diameter. Generally, treatments that had post-treated biochar samples (GUA-0, GMF-0) appeared to have greater beneficial effects on maize seedling than the untreated biochar sample (UGB) while all the organic amendments (GU-0, GMF-0, PM, UGB) also seemed to be superior to the inorganic (UA, MF) amendments in enhancing maize seedling growth.

Student's t-test showed that gliricidia biochar post-treated with NPK fertilizer significantly stimulated growth of maize seedlings more than did the urea/bone ash post-treated sample as presented in Table 8.

The positive response of maize seedlings to the application of both inorganic and organic fertilizers confirms the fact that all plants, whether arable or forest crops, require adequate supply of essential nutrients to grow well. Several workers have reported similar results (Nwoboshi, 1973; Arif *et al.,* 2012; Fagbenro *et al.*, 2012a; Fagbenro *et al.,* 2014). The response of maize plant to sole application of untreated *Gliricidia* biochar confirms the reported stimulating effect of biochars on maize growth (Yamato *et al.,* 2006; Chan *et al.*, 2008; Zhang *et al.*, 2011; Fagbenro, *et al.,* 2014). The positive effect of the biochar may be due to a number of factors which may include gradual abiotic and biotic oxidative release of nutrients and humic substances contained in the biochar (Fagbenro and Agboola,1993; Arif *et al.*, 2012), the high specific surface area, large amount of chemically reactive sites and high porosity of biochars, (Petter and Madari, 2012), the nutrient-transforming property of biochars in the soil system (Gundale and DeLuca, 2006) and the beneficial effect of biochars on a variety of agriculturally important soil micro-organisms (Ogawa *et al.,* 1983).The observation that maize seedlings grown in all treatments that received post-treated biochar samples were generally superior in growth to those produced in treatments that received sole application of untreated biochar sample indicates the desirability of post-treating biochars with sources of nutrient to improve their fertilizing quality as advocated by (Joseph *et al.,* 2013). The significant superiority of all treatments that received NPK post-treated biochar samples over those that had urea/bone ash post-treated biochar samples in stimulating

Table 8.T-test values for comparing plant parameters obtained from application of urea/bone ash post-treated biochar with those obtained from application ofNPK 15:15:15 post- treated biochar.

Height (cm)	Stem diameter (mm)	No of Leaf	Total Dry Weight
2.27NS	9.38**	8.49**	6.69**

NS= Not significant

** = Significant at 1% probability level.

plant growth could be attributed to the combined positive effect of P and K contained in NPK post-treated biochar samples and which were relatively in available form as compared to the P and K in the bone ash much of which were probably not in the available form within the short duration of the experiment.

CONCLUSION

The technology of post-treating biochars with sources of nutrients to enhance their quality is a promising and desired area of research in biochar technology. In this study, incubation enhanced the quality of NPK post-treated *Gliricidia* biochar while it suppressed the effectiveness of urea/bone ash post-treated biochar. Considering the data obtained, we concluded that incubated, 15:15:15 NPK post-treated *Gliricidia* biochar sample was significantly better in stimulating maize plant growth than poultry manure. However, there is the need for further studies on the best ratio of post-treating gliricidia biochar with 15:15:15 NPK, optimum incubation period and application rates of the products on maize plant growth in different soils.

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