UDS International Journal of Development [UDSIJD] ISSN: 2026-5336
Volume 5 No. 2, 2018
http://www.udsijd.org

EFFECT OF RICE HUSK BIOCHAR ON NITROGEN UPTAKE AND GRAIN YIELD OF MAIZE IN THE GUINEA SAVANNA ZONE OF GHANA

***Abukari, A.*, **Abunyewa, A.A., *Issifu, H.**
**Department of Forestry and Forest Resources Management, Faculty of Natural Resources and Environment, University for Development Studies, Nyankpala Campus.*
***Department of Agroforestry, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi*
**Corresponding author's email: ammalabukari@hotmail.com*

Abstract
The degradation of soils and the decrease of nutrients point to severe pressure to agriculture productivity in Africa. Soil fertility levels has declined and the amounts of nutrients required cannot support yield levels as they swiftly decline when cropping starts. The presently documented Integrated Nutrient Management (INM) methods promote the use of organic and inorganic fertilizer responses to restore nutrient depletion and sustain production. In this connection rice husk biochar was used in a split plot experimental design with 12 treatments and replicated thrice (3) to evaluate the effect of rice husk biochar on maize (Zea mays) yield in a field experiment at Savannah Agriculture Research Institute (SARI), Nyankpala-Tamale. The results revealed that the addition of 2t and 4t/ha biochar with 90 and 60 kg N recorded significantly higher yields of grain and stover. N uptake were also significant at 2t and 4t/ha with increased N application. Additionally, the research showed that for increased productivity of maize, application of biochar must be combined with either integrated nutrient management or the suggested quantity of N fertilizers.

Keywords: **Biochar, Maize grain yield, Soil fertility, Nitrogen uptake, Pyrolysis Introduction**

Introduction
The diminishing of soil fertility in Sub-Saharan African countries is recognized primarily by uninterrupted agriculture, combined with rapid mineralization of organic matter (Dovanan and Casey, 1998). Yet in Ghana, agrarian systems are characterized by trifling output, depending on low and unpredictable pattern of rainfall, old-fashioned agricultural approaches and little application of agricultural inputs. In Africa about 70% reside in rural areas, an array anticipated to remain for many years. Meanwhile agriculture is the main source of livelihood in the rural areas and thus increasing agricultural productivity is vital for substantial poverty reduction. The most pressing problems the continent faces is food insecurity which is an essential measure of poverty. While per capita food availability in the rest of the world has increased significantly over the past 45 years, the situation in sub-Saharan African has improved only slightly. For instance, the yield of cereals are averagely lower than one tonne per hectare in sub-Saharan African while the average yield of the continent has improved over the past 33 years by a meagre 5.2 kg/ha/y (Food and Agriculture Organization Corporate Statistical Database, 2005). The use of inorganic fertilizers still affords a possibility to overcome soil infertility, this option by smallholder farmers has become inaccessible owing to the elimination of subventions on fertilizers. Moreover, fertilizer transportation to the farmers' fields is a key problem as fields are generally far from the homestead. Improving crop yields on these marginal soils are vital for socio-economic reasons. A number of interventions have been considered in the past but with limited success. According to Marris (2006) and Renner (2007), the production of biochar from pyrolysis of plant residues has fine-grained charcoal, high in organic carbon and largely resistant to decomposition. Biochar generates an intractable soil carbon pool that is carbon-negative, which serves as a net withdrawal of atmospheric carbon dioxide and stored in highly intractable soil carbon stocks. Kwapinski and his associates (2010) suggest that feedstocks should be suitable for the production of biochar and use in agricultural soil and the development of strategies

should be ensured to adequately plan for the use of feedstocks. The encouragement for the addition of charcoal to soils is one of the prehistoric soil management practices and its application to agricultural soils may be economically feasible and advantageous. Biochar application to soil improves the physical, chemical and biological effects of soils (Chan et al., 2007; Novak et al., 2009; Laird et al., 2010; Van Zwieten et al., 2010; Peng et al., 2011). Globally biochar has been advocated for its ability to supply nutrients to inherently poor soils in the tropics.

Conversely, in recent years significant studies conducted on biochar showed positive results on grain yield and nutrient uptake (Shackley et al., 2009; Kookana et al., 2011; Yeboah et al., 2016).

This study however hypothesized that rice husk biochar has the potential to improve grain yields and N uptake by maize when applied solely or in combination with inorganic fertilizers.

Materials and Methods

Study area

The experiment was conducted at the research field of Savannah Agriculture Research Institute (SARI) in the Tolon/Kumbungu District of Northern Ghana. The site is located in the Guinea Savannah Agro-ecological Zone and lies between latitude 9o 25′ N and longitude 00o 58′ W. The rainfall pattern is unimodal, occurring between May and October which peaks in August and September. The average annual rainfall is about 93.9 mm and the season lasts for a period of six months mostly (April-September). Maximum temperatures are experienced during the months of March to April, whilst the lowest temperatures are experienced in December when the north east-trade winds push the Inter Tropical Convergence Zone further south. Mean monthly minimum and maximum temperatures are 26.6 °C and 35.6 °C respectively while the mean annual temperature is 29.7 °C (SARI, 2016).

Experimental design

The plots were demarcated with three (3) main plots and in each main plot four sub plots of 6.4 m x 6.4 m were demarcated and replicated three times in a Split plot experimental design. Main plots were pegged and separated from each other by two (2) m while the subplots were separated from each other by one (1) m. Three (3) treatments (0 t/ha, 2 t/ha and 4 t/ha) of rice husk biochar were applied to the main plots and four levels of inorganic nitrogen fertilizer (0, 30, 60 and 90kgN/ha) were also applied on sub plot and with each sub plot receiving a basal fertilizer application of 30 kg P/ha and 60 kg K/ ha to ensure adequate supply of these elements to the crop. In all, there were twelve (12) treatment combinations and three (3) replications. The biochar was applied to the soil by broadcasting and manually incorporated to the soil with a hoe to a depth of approximately 10 cm. The maize crop was grown to maturity and grain and stover yields were recorded according to plots. The plant and grain samples were collected, processed and analyzed for their N contents and uptake values were computed.

Biochar

The biochar used in the study was obtained from soil research institute Kumasi-Kwadaso, Ghana. It was produced from rice husk under a temperature of 500o C. Table 1 shows the chemical composition of the biochar.

Table 1: Chemical composition of biochar derived from rice husk.

pH (w/v) in H_2O	**Org C**	**N**	**Ash**	**P**	**Ca**	**Mg**	**K**	**Na**
	(%)			**(mg/kg)**				
6.51	**33.3**	**0.67**	**52.13**	**0.63**	**2.32**	**0.89**	**0.54**	**0.23**

Planting and fertilizer application

The maize variety ‘dorke’ was used as the test crop. Four seeds were planted per hole which was later thinned to two, two weeks after germination using a planting distance of 80 cm x 40 cm. Urea, Triple superphosphate and Muriate of Potash were the sources of N, P and K. The P and K were applied as basal to all treatments at the rate of 30 and 60 kg/ha respectively while the N was split applied; one third of the N was applied two weeks after planting and the remaining two thirds were applied six weeks after planting. Weeding of the field was done on the second, fifth and eighth week after planting.

Soil analysis

Soil pH was measured in soil to water ratio of 1:1 (McLean, 1982). The Walkley and Black (1934) procedure was used to determine soil organic carbon (OC), Total nitrogen (N) was determined using the Kjedahl digestion and distillation procedure. The cation exchange capacity (CEC) at pH 7 was determined by the NH_4OAc method. Calcium (Ca) and Magnesium (Mg) were determined by atomic absorption spectrophotometry while potassium (K) and sodium (Na) were determined by flame photometry.

Initial soil data

The soil was of sandy loam texture (% sand 63.24, % clay 2.41 and % silt 34.35). The chemical characteristics were: pH H_2O (1:1) 6.23; % Org. C 0.72, % N 0.16, Ca 2.42 Cmol/kg, Mg 0.65 Cmol/kg, K 0.15 Cmol/kg, Exchangeable acidity 0.13, Effective cation Exchange Capacity 3.82 Cmol/kg, Base saturation 97.10 Cmol/kg, Available Bray 1 Phosphorus 4.56 mg/kg. Generally, in tropical soil the chemical composition reveals low soil fertility due to continuous cropping. Low soil fertility in the tropics can be improved by the use of integrated soil fertility management to intensify agricultural production (Dovanan and Casey, 1998).

Data Analysis

The data collected were subjected to a two-way split plot ANOVA using GenStat statistical software and the test treatments were differentiated using Least Significant Differences at 5% probability level.

Results and Discussion

Grain and stover yield

The grain yield of maize (Figure 1) ranged from 10.93 kg/ha at 0t/ha biochar+0kgN to 65.70 kg/ha in 4t/ha at biochar+90kgN respectively. Maize grain yield was influenced significantly (p = 0.05) among treatments by the application of biochar and inorganic nitrogen. The control of 0t/ha biochar recorded low yields of 10.93 and 23.43 kg/ha. An increase in grain yield of 56.4 and 65.7 was recorded at 2t/ha biochar and 4t/ha biochar respectively but were significantly different (p = 0.05). However, 4t/ha biochar+90kgN was in similarity with 4t/ha biochar+60kgN which recorded a yield of 62.81kg/ha indicating a significant increase over 2t/ha biochar+ 60kgN (Figure 1) which clearly shows that maize responded to biochar application when applied under integrated nutrient management. These findings corroborate the results of Coumaravel *et al.* (2015) and Igarashi (1996).

The conceivable clarification for the increase in maize grain yield with biochar and inorganic N include the effect of biochar on soil physio-chemical properties such as enhanced water holding capacity, increased cation exchange capacity (CEC), and providing a medium for adsorption of plant nutrients and improved conditions for soil micro-organisms. This may be due to the fact that the biochar used for the experiment were rich in organic carbon (33.3%) and ash (52.13%) contents. Also, maize grain yield may have been improved due to the increased soil moisture contents at the biochar treatments.

The application of biochar with N increased maize grain significantly and this may be due to the enriched nutrient availability of biochar. These results corroborate the findings of Igarashi (1996), Yamato *et al.* (2006), Coumaravel *et al.* (2015) and Yeboah *et al.* (2016). Maize stover yield at (Figure 2) showed similar trend as recorded in the maize grain yield.

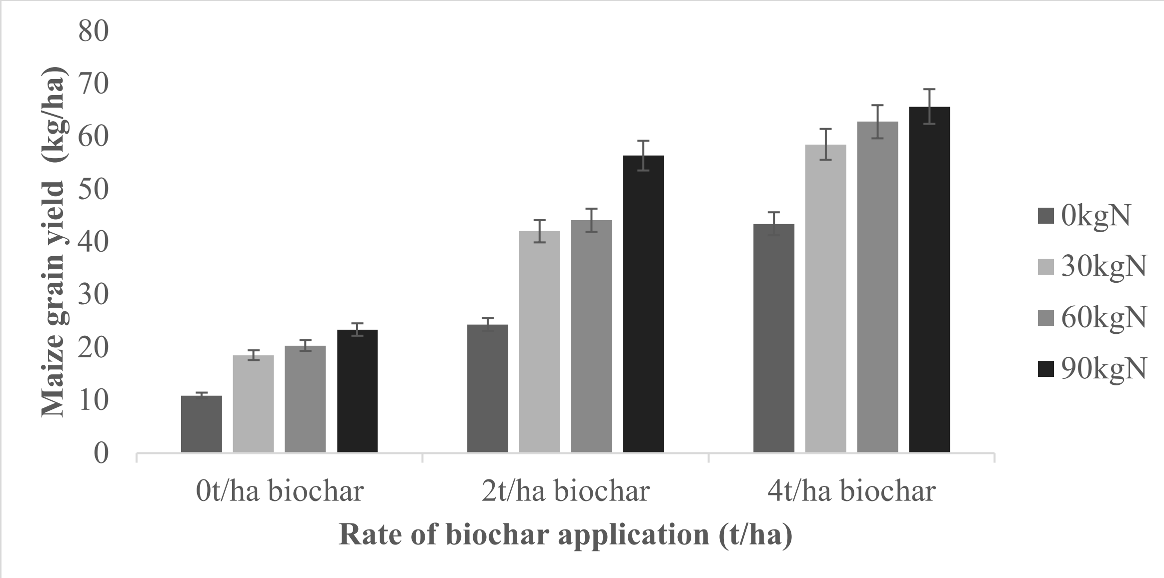

Fig 1: Maize grain yield as influenced by different N application rates at three different biochar application rates LSD (p = 0.05). Error bars represent ±1 SE

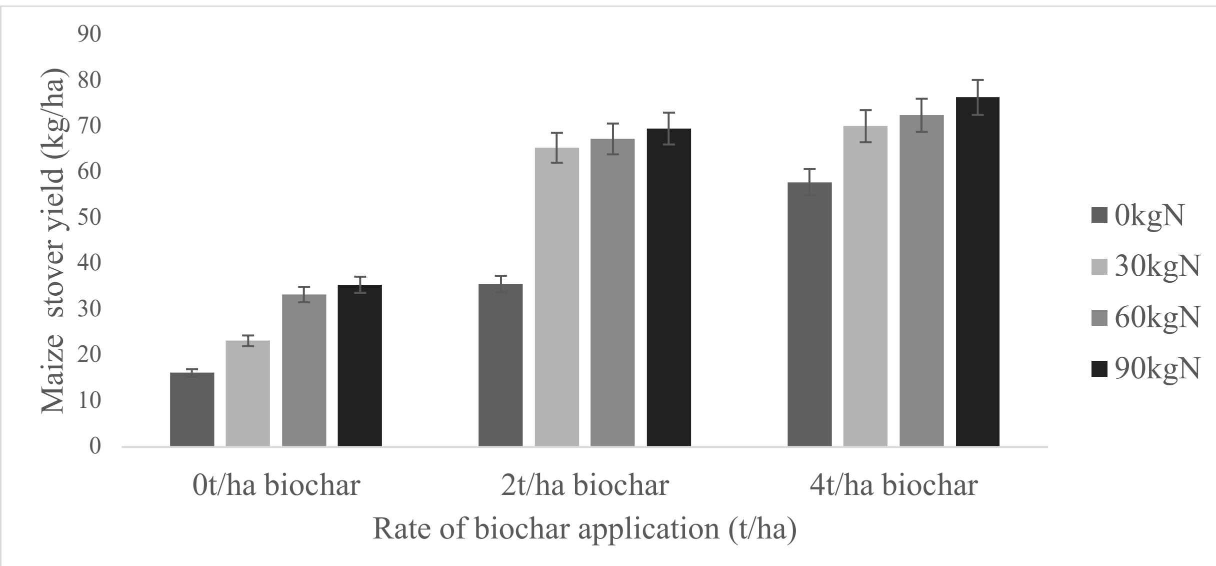

Fig 2: Maize stover yield as influenced by different N application rates at three different biochar application rates LSD (p = 0.05). Error bars represent ±1 SE

Nutrient uptake

Uptake of N by maize stover yield revealed that, N uptake ranged from 16.2 kg/ha to 76.4 kg/ha (Figure 2). The results showed that the effect of biochar on nitrogen fertilizer uptake by maize were influenced significantly (p = 0.05) among treatments. It was found that though the highest N uptake was recorded in 4t/ha biochar+90kgN, it was in similarity with 4t/ha biochar+60kgN and 2t/ha biochar+90kgN which may be due to the fact that N was not lost through leaching or runoffs due to the binding effect of biochar. The lowest N uptake by maize stover yield was recorded in the control treatment of 0t/ha biochar but were higher in 2t/ha biochar and 4t/ha biochar which were significantly different (p = 0.05) from each other (Figure 2). The improved nutrient retention capacity of biochar incorporated to soils has beneficial effect and enhances dry matter production showing higher nutrient uptake (Coumaravel *et al.,* 2015). These results are in agreement with Singh *et al.* (2010) who recommended that the timely availability of N could be assured and corn productivity can be positively increased by combined use of mineral N and organic manures. This observation might be due to the information that the combined treatments enhanced the soil which was efficiently exploited by the maize plants as compared to the sole organic or inorganic treatment. Conversely this observation corroborates the findings of DeLuca *et al.* (2009) who documented that the application of biochar increases N uptake by plants. Plant N uptake increases through the amendment of biochar which has the ability to improve N fertilizer use efficiency.

Conclusion

This study concludes that application of biochar at 4t/ha biochar+90kgN and 2t/ha biochar+90kgN was the best for attaining significant higher yields. N uptake by maize were highest at 4t/ha biochar+90kgN and 2t/ha biochar+90kgN. The application of biochar must be combined with the recommended amounts of N fertilizers or integrated nutrient management approaches for realizing better productivity of maize with sustained soil fertility.

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