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Modelling Effects of Residual Organic Materials on Productivity of Maize (*Zea mays* L.) for Sustainable Soil Fertility Restoration in the Guinea Savannah Zone

Israel K. Dzomeku[1], Osman Illiasu[1], Peter T. Birteeb[2], Stella Obanyi[3], Tara Wood[3]

[1]University for Development Studies, Department of Agronomy, Tamale, Ghana, [2]University for Development Studies, Department of Animal Science, Tamale, Ghana, [3]International Fertilizer Development Center (IFDC), Tamale, Ghana.

Corresponding Author's email: ikdzomeku2009@yahoo.com

Abstract

A field experiment was conducted at Nyankpala, near Tamale during the 2014 cropping season and continued during 2015, to investigate one year residual effects of indigenous organic materials (biochar, groundnut shell, rice husk and rice straw) on yield components and yield of maize. It was a 4×3×3 factorial experiment consisting of 4 organic materials at 3 levels (2.5, 5 and 7.5 t ha^{-1} on dry matter basis) and 3 N levels (0, 45 and 90 kg/ha N) laid out in a Randomized Complete Block Design with four replications. The study revealed that integrated management of one year residuals of the organic materials with inorganic N supported increased grain yield and was maximised with 7 5 t/ha biochar + 90 kg N/ha, 5 t/ha groundnut shell + 45 kg N/ha, 7.5 t/ha groundnut shell + 90 kg N/ha and 7.5 t/ha rice husk + 90 kg N/ha in the range of 3000 - 3600 kg/ha. Pearson correlation coefficients of grain yield with other traits exhibited robust relationships signifying strong impact of integrated soil fertility management of one year residual organic materials and N on maize production in the Guinea savannah. Grain yield prediction indicated treatments were best fitted in polynomials with 7.5 t/ha biochar + 90 kg N/ha for optimum grain yield.

Keywords: Residual effects, Indigenous organic materials, Biochar, Wang Dataa, Grain yield.

Introduction

Maize (*Zea mays* L.) is the most important cultivated cereal crop in tropical sub-Saharan Africa and mostly grown under rain-fed conditions. Maize has become one of the most important cereals that have added great value to man, as it serves as food and livelihood for millions of people (Enujeke, 2013). In developed countries, maize is a source of industrial products such as corn oil, syrup, corn flour, sugar, brewers' grit and alcohol (Dutt, 2005). It is the most important cereal crop produced and consumed staple food in Ghana with yearly increased production since 1965 (Morris et al., 1999; FAO, 2008).

However, maize yield in Africa has continuously declined to as low as 1 t/ha due to such factors as rapid reduction in soil fertility and negligence in use of soil amendment materials (DIPA, 2006; Enujeke, 2013). Low inherent soil fertility has been identified as a major cause for low cereal yield in Ghana (Buri et al., 2009; Abe et al., 2010). The soils of maize growing areas in

Ghana are generally low in organic carbon (<1.5%), total nitrogen (<0.2%), exchangeable potassium (<100 mg/kg) and available phosphorus (<10 mg/kg) (Adu, 1995).

Combination of organic and mineral fertilizer nutrients sources have been shown to result in synergistic effects and improved synchronization of nutrient release and uptake by crop leading to higher yields. Nambiar (1991) indicated that integrated use of organic manures and chemical NPK fertilizers would be quite promising not only in providing stability in production, but also in maintaining higher soil microbial and fertility status. Studies fall short of elucidating the residual effects of the organic materials used. Therefore, the main objective of this research was to evaluate the residual effects of the organic materials of biochar, groundnut shell, rice husk and rice straw, with and without nitrogen supplement on the yield and yield components of maize in the Guinea savannah zone of Ghana.

Materials and Methods

Experimental site

A field experiment was carried out in 2014 and continued during 2015 cropping season at the University for Development Studies, Nyankpala Campus near Tamale, in the Guinea savannah zone of Ghana. Nyankpala is located at latitude 9°25' 14'N, longitude 0° 58' 42'W and at an altitude 183 m above sea level (NAES, 1992).

Experimental Design and Treatments

The experiment was a 4×3×3 factorial experiment made up of 4 organic materials (biochar, groundnut shell, rice husk and rice straw) at 3 levels (2.5, 5 and 7.5 t ha^{-1} dry matter basis) and 3 nitrogen levels, 45 and 90 kg N/ha). The experiment was laid in a Randomized Complete Block Design (RCBD) with four (4) replications.

Agronomic Practices

In 2015, the glyphosate herbicide was applied at 1.0 kg a.i./ha to kill regrowth vegetation followed by hoe-tillage to loosen the soil and make bonds to prevent spillage of water and nutrients between neighbourhood plots. Planting of 'Wang Dataa' maize variety was done on July 7, 2015. Nitrogen was applied in the form of ammonium sulphate in split doses at 14 and 35 days after planting (DAP) at the rate of 0, 45 and 90 kg/ha. Atrazine (80 WP) was applied 7 DAP. Hoe weed control was carried out thrice at 14 DAP and 35 DAP and 56 DAP.

Data Collection

Grain yield: At physiological maturity, maize cobs were harvested from a net plot of 4 m × 4 m and processed for grain yield determination. Grain yield was adjusted at 14% grain moisture using equation 1:

$$\text{Adjusted grain yield (kg/ha)} = \frac{\text{Grain yield}*10000m^2*(100\%\text{-grain moisture content}\%)}{16m^2*(100\%-14\%)} \ldots \text{Eqn.1.}$$

Statistical Analysis

The data were subjected to analyses of variance using GenStat statistical package. Count data were transformed using square root transformation ($\sqrt{n} + 0.5$) to homogenize the variance before subjecting them to analysis of variance. Treatment means were separated using Least Significant Difference at 5% significant level. Correlation and regression analysis were examined.

Results and Discussion

Grain Yield

Integration of residual organic material and nitrogen significantly ($p<0.05$) equally increased grain yield of maize with 7.5 t/ha biochar + 90 kg N/ha, 5 t/ha groundnut shell + 45 kg N/ha, 7.5 t/ha groundnut shell + 90 kg N/ha and 7.5 t/ha rice husk + 90 kg N/ha with high yield in the range of 3000 - 3600 kg/ha (Fig. 1). Residual organic materials and N effects on soil physico-chemical properties such as enhancement of water holding capacity, cation exchange capacity might have provided a medium of adequate fertility for adsorption of crop nutrients and improved conditions for soil micro-organisms. Organic manure efficiently adsorbs ammonia and acts as a binder for ammonia in soil, therefore having the potential to decrease ammonia volatilization from soil surfaces. Singh et al. (2010) observed timely availability of nitrogen increased maize productivity through the increase use of a combination of mineral nitrogen and organic manures. Similarly, Boateng et al. (2006) reported 35% increment in grain yield through integrated organic manure and nitrogen soil fertility management.

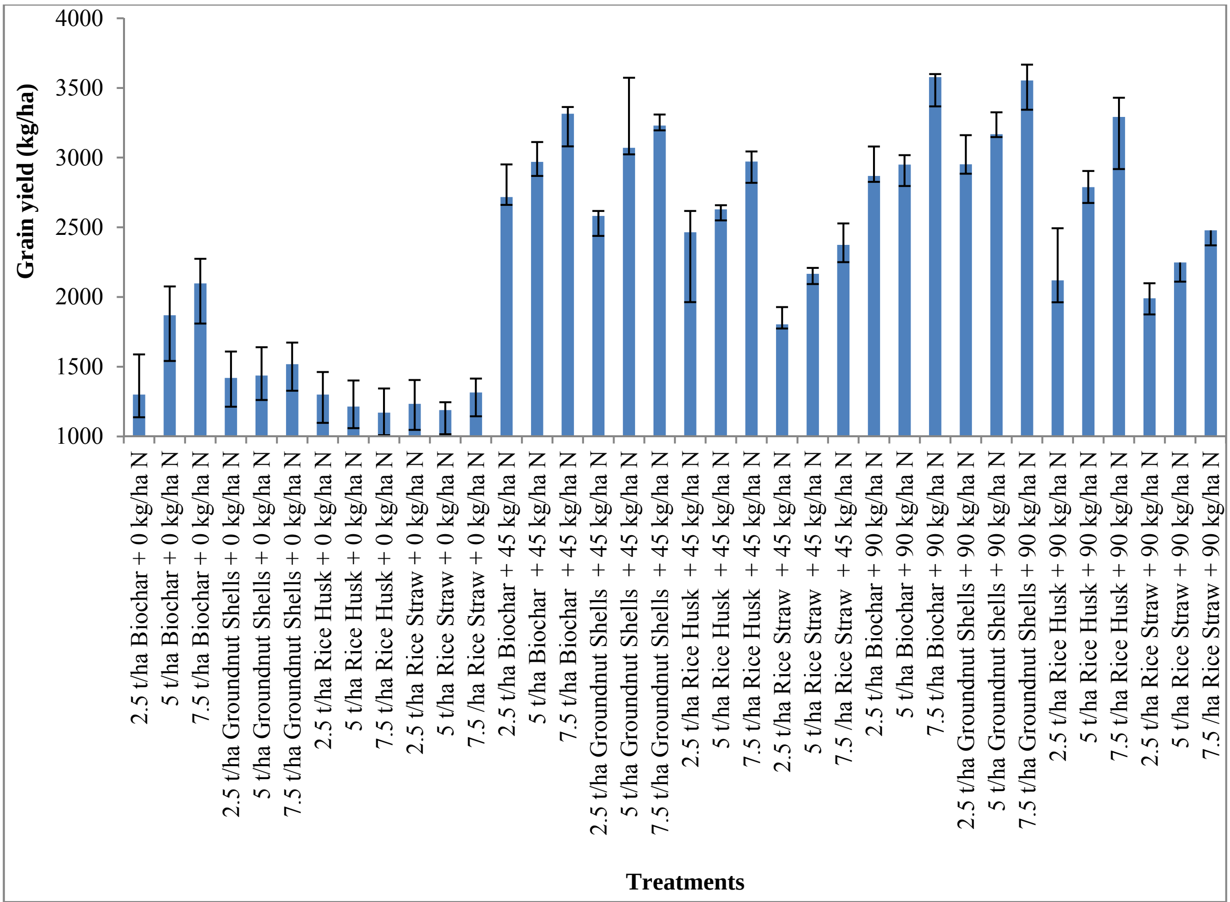

Fig. 1. Effects of the interaction between residual organic materials and nitrogen fertilizer on grain yield of maize during the 2015 cropping season. Bars represent SEM.

Table 1. Pearson correlation coefficients (n=144) between grain yield and other agronomic traits of maize under residual organic matter and N fertilization in 2015 cropping season.

	PH	LAI at 6WAP	LAI at 9WAP	DFF	HTCOB	Cob Wt	Seed wt	GY	Straw wt
PH	1								
LAI at 6WAP	0.66**	1							
LAI at 9WAP	0.59**	0.59**	1						
DFF	-0.74**	-0.57**	-0.48**	1					
HTCOB	0.74**	0.52**	0.62**	-0.58**	1				
COBW	0.58**	0.48**	0.36**	-0.54**	0.60**	1			
Seed wt	0.67**	0.58**	0.50**	-0.55**	0.70**	0.67**	1		
GY	0.49**	0.42**	0.38**	-0.45**	0.51**	0.43**	0.38**	1	
Straw wt	0.67**	0.60**	0.51**	-0.59**	0.52**	0.50**	0.66**	0.44**	1

† PH = Plant height; LAI = Leaf area index; WAP = weeks after planting; DFF = days to 50% flowering; HTCOB = height of cob attachment; COBW = Cob weight and GY = grain yield; straw wt = straw weight. **- significant at ($p<0.001$) probability level

Regression Analysis

The results from multiple regression analysis for mixed models indicated grain yield (GY) could be determined from the combination of continuous and dummy variables, which accounted for 48.4% of variance in gain yield. The best prediction model was developed as:

BC3 + Full N, GY = 2192 + 168.3 (LC 9) + 16.32 (Pt ht 9) – 82.3 (50% F) [Eqn. 2]

The use of treatment BC3 + Full N increased grain yield by 783 kg/ha [Eqn. 2]. Evaluating the performance of each treatment in grain yield prediction indicated the treatments were best fitted in polynomial (Fig. 2).

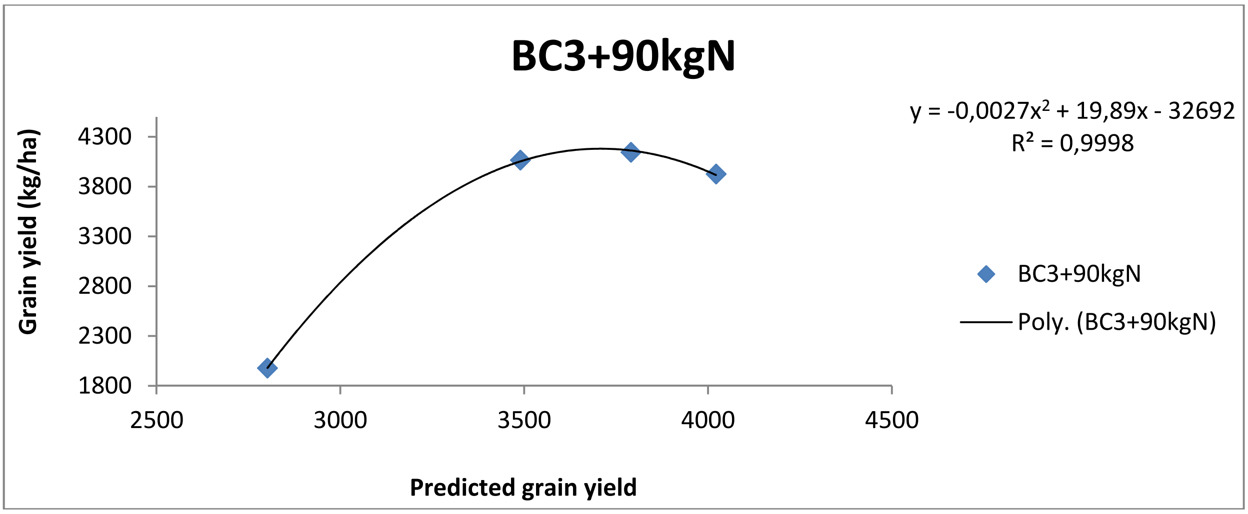

Fig. 2. The polynomial for BC3 + 90 kg N.

Conclusion

The study revealed that integrated management of one year residual effects of organic materials of biochar, groundnut shell, rice husk and rice straw with inorganic N supported increased grain yield of maize; maximised with 7 5 t/ha biochar + 90 kg N/ha, 5 t/ha groundnut shell + 45 kg N/ha, 7.5 t/ha groundnut shell + 90 kg N/ha and 7.5 t/ha rice husk + 90 kg N/ha with high yield range of 3000 - 3600 kg/ha; thereby providing options for selection based on amount of organic matter available and the finance resource base of the farmer. Pearson correlation coefficients of grain yield with both growth and yield components exhibited very robust relationship signifying the strong production impact of one year residual organic materials in combination with N on maize production in the Guinea savannah.

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