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Research Article

Effects of Groundnut Shell, Rice Husk and Rice Straw on the Productivity of Maize (*Zea mays* L.) and Soil Fertility in the Guinea Savannah Zone of Ghana

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Abstract

A field experiment was conducted at Nyankpala, near Tamale during the 2014 cropping season to investigate the effects of indigenous organic materials (groundnut shell, rice husk and rice straw) on yield components and yield of maize. The study was a 3 × 3 × 3 factorial experiment consisting of the three organic materials at three levels (2.5, 5 and 7.5 t ha^{-1} on dry matter basis) and three NPK rate (zero control, 45-30-30 kg/ha and 90-60-60 kg/ha) laid out in a randomized complete block design with four replications. Best grain yield of 4781 kg/ha was obtained with 7.5 t/ha groundnut shell plus 90-60-60 kg NPK/ha but 5 t/ha of groundnut shell plus 90-60-60 kg NPK/ha, 7.5 t/ha groundnut shell plus 45-30-30 kg NPK/ha, 7.5 t/ha of rice husk or rice straw plus 90-60-60 kg NPK/ha gave equal yields. Longest cob was obtained with 5 to 7.5 t/ha groundnut shell (18.9 cm) or 7.5 t/ha rice husk (17.9 cm) or 7.5 t/ha rice straw (17.9 cm), each plus at least 45-30-30 kg NPK/ha. However, sole application of 5 to 7.5 t/ha groundnut shell notably determined cob weight (116.4 g/cob), 100 seed weight (24.9g) and stover weight (4822 kg/ha). Similarly, sole application of NPK at 45-30-30 kg/ha was adequate to enhance cob length (16.8 cm), cob weight (127.4 g/cob) and stover weight (4514 kg/ha). Grain yield correlated positively with stover weight (r = 0.851**) and cob length (r = 0.601**).

Keywords: Soil Fertility; Organic Matter; Groundnut Shell; Rice Husk; Rice Straw

Introduction

Maize (*Zea mays* L.) is one of the major important cereal crops that provide staple food to a large number of the rapidly growing human population in the world especially sub-Saharan Africa. It is a rich source of food for human population, fodder for animals (especially ruminants), and feed for poultry and provides raw material for industrial use. Maize has a carbohydrate content of about 71%, but low in protein. It is processed into a wide range of foods and beverages and consumed as breakfast, main meals, or snacks.

Despite the importance of maize as a food security crop, many factors militate against attainment of its grain yield potential in Ghana. Low soil fertility has been identified as a major factor reducing crop yields in Ghana [1]. A quantum of literature is available on a similar cereal crop rice, to prove low inherent soil fertility as a major cause of poor crop productivity [2,3]. Nyalemegbe., *et al.* [4] attributed the low inherent soil fertility partly to low levels of soil organic matter and observed that rice yields in continuously cropped fields declined with time, even with the application of mineral fertilizers.

Issaka., *et al.* [5] reported abundance of indigenous organic materials available in Ghana that could be used to improve soil fertility. JIRCAS [6] also reported on the quantity, quality and distribution of various organic materials in Ghana. According to this report, rice straw, cow dung and human excreta were evaluated in Northern region as chiefly effective materials applied at 3 t/ha, could improve soil fertility and soil physical properties and its buffer capacity. Samy., *et al.* [7] observed noted good potential for organic based farming with a combination of organic fertilizers to attain maximum yields. There is growing interest of plant materials grown in situ to provide litter fall, root decay, green manure incorporation, crop residue returns and animal excreta and its subsequent decomposition to enhance soil fertility [8]. Research to date has predominantly focused on inorganic fertilizers and organic materials from animal waste, solid waste and compost, with least attention on indigenous raw materials. The use of indigenous organic materials (such as rice straw, rice husk, and grounded groundnut shell) as soil amendments for agricultural practices is limited in Ghana. The objectives of the study were to determine the best promising indigenous organic materials for maize production in Northern Ghana using rice straw, rice husk and groundnut shell with and without inorganic NPK fertilizer on yield components and grain yield of maize.

Materials and Methods

Study Site Description

The experiment was conducted at the University for Development Studies at Nyankpala, near Tamale, in the Guinea savannah zone of Ghana, at latitude 9° 25’14’N, longitude 0° 58’ 42’W and at an altitude of 183 m above sea level [9]. The area experiences unimodal rainfall with an annual mean rainfall of 1000 to 1022 mm. Temperature distribution is fairly uniform with mean monthly minimum of 21.9^{0}C and a maximum of 34.1^{0}C. It has a minimum relative humidity of 46% and maximum of 76.8%. The soil of the study site is a typical upland soil, developed from iron stone gravel and ferruginized ironstone brash [10]. The soil is classified as a Haplic Lixisol [11] and locally referred to as the Tingoli series [12].

Experimental Design and Treatments

The experiment was a 3 × 3 × 3 factorial experiment made up of four indigenous organic materials (groundnut shell, rice husk and rice straw) at three levels (2.5, 5 and 7.5 t ha^{-1} dry matter basis) and three NPK rate (0-0-0 kg NPK ha-1, 45-30-30 kg NPK ha^{-1} and 90-60-60 kg NPK ha^{-1}), laid in a randomized complete block design with four (4) replications. Plots measured 5m × 5m with 1m and 2m alleys between plots replications respectively.

Agronomic Practices

The experimental field was tractor ploughed and two weeks after harrowed and laid-out after which the organic materials were applied and manually incorporated into the soil with a hoe. The experimental field was left undisturbed for 21 days before planting. Planting of 'Wang Data' maize variety was done by sowing two seeds per hill at a spacing of 80 cm x 45 cm. NPK 15-15-15 was applied at 0-0-0 kg NPK ha^{-1}, 45-30-30 kg NPK ha^{-1} and 90-60-60 kg NPK ha^{-1}. Atrazine (80 WP) was applied seven days after planting (DAP) and supplemented with hoe weeding at 35 DAP and 56 DAP.

Soil Analysis

Before planting, three soil samples were randomly collected at 0 - 20 cm soil depth from each replicate by using an auger and the samples bulked together to get one composite sample to determine the initial soil physio-chemical properties (Table 1). After harvesting soil samples were collected in the same manner, as before planting, but replicates of each treatment were mixed with each other and analysis was done with samples for each treatment (Table 2), with the results being prepared for a second paper.

Table 1: Initial Soil Analysis, July, 2014.

	pH	% OC	% N	Mg/kg P	Mg/kg K	Mg/kg Ca	Mg/kg Mg
Initial soil	5.5	0.12	0.01	3.6	51.8	64.7	27.9

Table 2: Soil Chemical Analysis after Harvesting, November, 2014.

Treatment	Soil pH	% OC	% N	Mg/Kg P	Mg/Kg K	Mg/Kg Ca	Mg/Kg Mg
2.5 t/ha Groundnut shells	5.5	0.8	0.1	8.9	98.5	64.7	47.3
2.5 t/ha Groundnut shells + 45-30-30 kg/ha NPK	5.4	1.7	0.2	12.8	61.3	186.8	65.6
2.5 t/ha Groundnut shells + 90-60-60 kg/ha NPK	5.0	0.8	0.07	8.4	52.7	122.6	47.8
5 t/ha Groundnut shells	5.1	2.9	0.3	8.7	55.0	178.9	72.5
5 t/ha Groundnut shells + 45-30-30 kg/ha NPK	4.5	3.0	0.3	10.6	58.6	164.7	88.7
5 t/ha Groundnut shells + 90-60-60 kg/ha NPK	4.8	3.2	0.3	14.9	59.4	188.6	97.9
7.5 t/ha Groundnut shells	5.1	2.8	0.3	8.0	151.8	245.8	87.6
7.5 t/ha Groundnut shells + 45-30-30 kg/ha NPK	5.1	2.8	0.3	6.8	114.3	214.4	71.9
7.5 t/ha Groundnut shells + 90-60-60 kg/ha NPK	5.0	3.0	0.3	8.7	198.5	267.0	92.7
2.5 t/ha Rice Husk	4.7	0.8	0.04	3.8	74.8	98.7	58.4
2.5 t/ha Rice Husk + 45-30-30 kg/ha NPK	4.6	1.0	0.1	5.5	74.0	136.9	64.3
2.5 t/ha Rice Husk + 90-60-60 kg/ha NPK	5.1	0.8	0.1	5.8	75.0	118.5	72.2
5 t/ha Rice Husk	4.7	0.8	0.1	3.9	72.3	83.2	52.1
5 t/ha Rice Husk + 45-30-30 kg/ha NPK	4.8	1.0	0.1	5.7	68.8	96.9	81.2
5 t/ha Rice Husk + 90-60-60 kg/ha NPK	5.1	0.8	0.1	4.9	84.4	114.8	52.5
7.5 t/ha Rice Husk	4.6	0.8	0.1	5.7	76.6	92.7	57.2
7.5 t/ha Rice Husk + 45-30-30 kg/ha NPK	4.9	0.8	0.1	5.5	86.4	124.2	48.8
7.5 t/ha Rice Husk + 90-60-60 kg/ha NPK	5.1	1.3	0.2	7.8	92.6	132.1	82.5
2.5 t/ha Rice Straw	4.9	1.9	0.2	4.5	64.4	98.3	58.6
2.5 t/ha Rice Straw + 45-30-30 kg/ha NPK	4.7	2.8	0.3	9.0	86.5	196.8	64.9
2.5 t/ha Rice Straw + 90-60-60 kg/ha NPK	4.9	2.4	0.3	8.7	73.9	175.7	74.4
5 t/ha Rice Straw	5.0	1.7	0.3	6.5	56.5	118.3	58.8
5 t/ha Rice Straw + 45-30-30 kg/ha NPK	4.9	3.3	0.3	11.6	78.6	226.4	84.2
5 t/ha Rice Straw + 90-60-60 kg/ha NPK	4.9	3.4	0.4	12.8	98.9	218.8	78.7
7.5 t/ha Rice Straw	5.1	1.9	0.3	10.0	64.3	114.3	57.0
7.5 t/ha Rice Straw + 45-30-30 kg/ha NPK	4.8	3.4	0.3	12.7	76.9	198.7	77.5
7.5 t/ha Rice Straw + 90-60-60 kg/ha NPK	4.9	3.3	0.4	11.9	112.7	228.3	65.0

Data Collection

Five plants were randomly selected per plot and tagged for the measurement of growth and yield characteristics such as plant height, leaf area index, days to 50% flowering and height of cob attachment, cob weight, cob length, stover weight, 100 seed weight and grain yield.

Statistical Analysis

The data were subjected to analyses of variance using GenStat statistical package. Treatment means were separated using Least Significant Difference at 5% significant level. Correlation and regression analysis were also examined.

Results and Discussions

Days to 50% Flowering

Organic materials supplemented with inorganic NPK fertilizer enhanced early flowering in maize with 2.5 to 7.5 t/ha of groundnut shell or rice husk or rice straw supplemented with at least 45-30-30 kg/ha NPK took the shortest days of 47 to 50 days to 50% flowering (Figure 1). Timely availability of nutrients mainly nitrogen from the organic source and NPK fertilizer could have provided adequate availability of the required crop growth conditions which positively supported the physiological functions of the crop to early flowering as reported by Khan., *et al* [13].

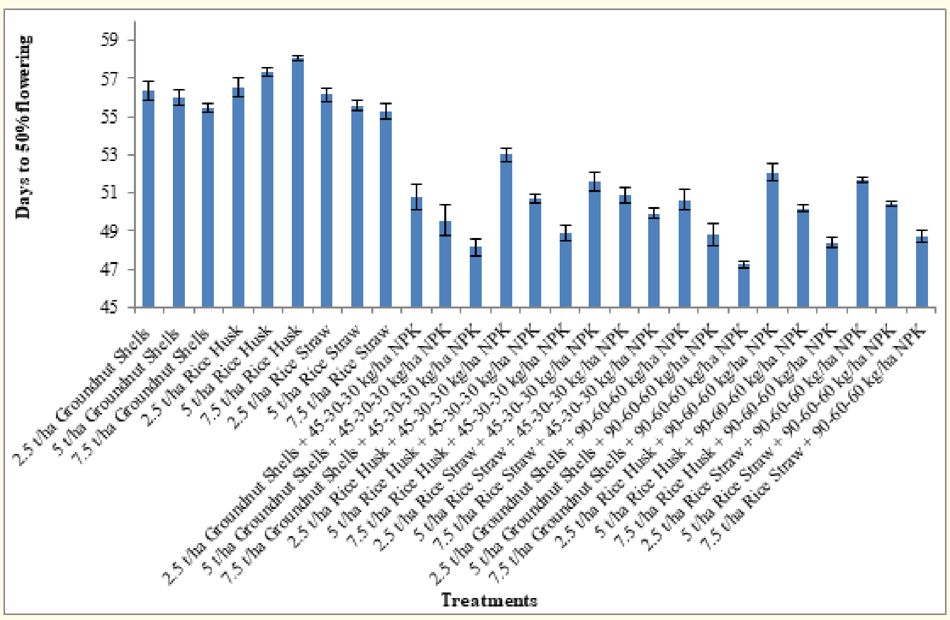

Figure 1: Effects of organic material by NPK fertilizer on days to 50% flowering of maize. Bars represent SEMs.

Cob Length

Combination of organic materials and NPK amended soil significantly ($p < 0.01$) increased cob length. Entries of 5 to 7.5 t/ha groundnut shell or rice husk or rice straw plus at least 45-30-30 kg/ha NPK maximise cob length (Figure 2). Lengthy cobs supported by the synergy of organic and NPK amended entries could be attributed to high growth rate attained by the crop due to timely availability of adequate nutrients from both sources of soil fertility amendments with consequential increased dry matter accumulation. In a previous study, Uzoma., *et al.* [14] reported combined application of organic and inorganic fertilizers positively affected maize ear characteristics and ascribed it to incorporation of organic material that improved soil physical properties and the increase in mineralization as a result of the addition of synthetic fertilizers. Bilalis., *et al.* [15] observed that sustainable yield index and agronomic efficiency was more stable under combined organic and inorganic fertilization in maize production.

Cob Weight

Cob weight as influenced by organic materials was in the range of 118 to 127 g/cob with 5 to 7.5 t/ha groundnut shell supporting the highest weight followed by 7.5 t/ha rice straw similar to 5 -7.5 t/ha of rice husk (Figure 3). Inorganic fertilizer application increased cob weight in the range of 127 to 135 g/cob maximised at 90-60-60 kg/ha NPK but similar to 45-30-30 kg/ha NPK (Figure 4). The maximum maize cob weight observed with organic matter could be attributed to improved nutrient availability to crop through enhanced organic matter decomposition and mineralization processes and directly from applied N which improved maize root and shoot development, as previously reported [15,16].

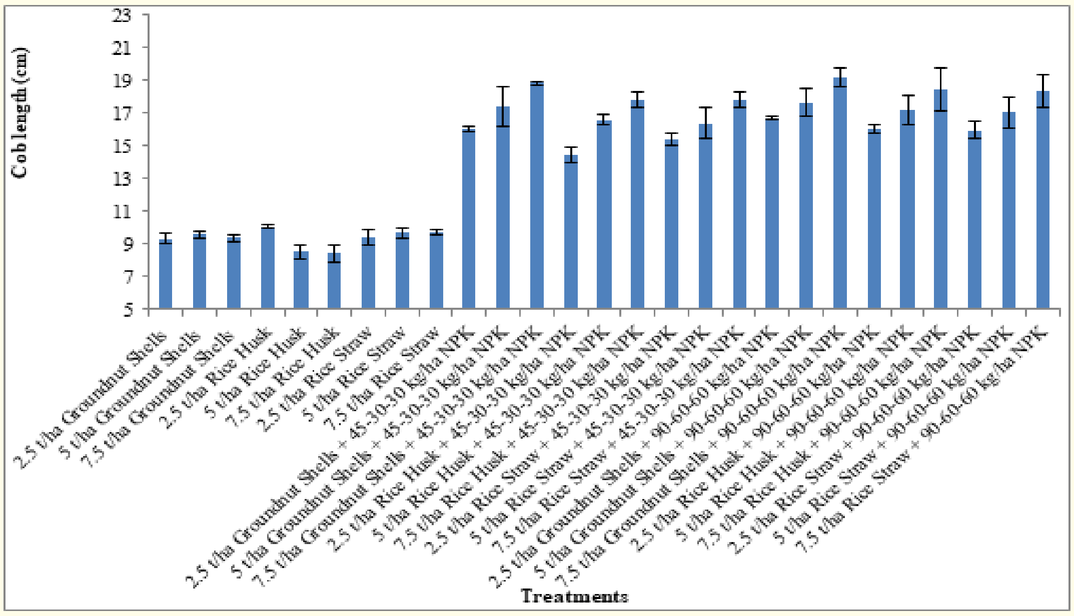

Figure 2: Effects of organic material by NPK fertilizer on cob length of maize. Bars represent SEMs.

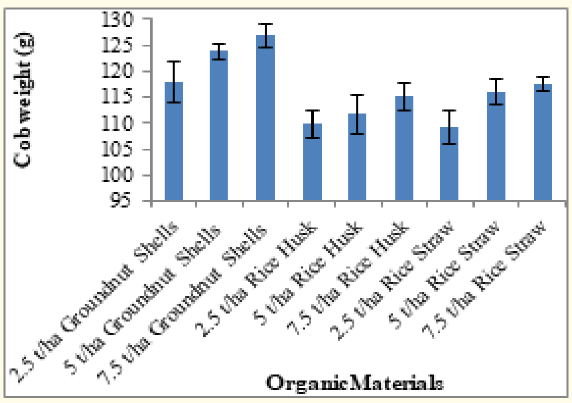

Figure 3: Effects of the organic materials on cob weight of maize. Bars represent SEMs.

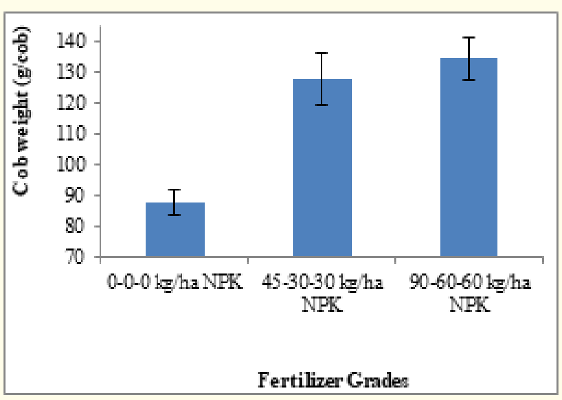

Figure 4: Effects of NPK fertilizer on cob weight of maize. Bars represent SEMs.

Grain Yield

Integration of organic material and NPK fertilizer significantly ($p < 0.001$) increased the parameter with maximum grain yield of maize (4781 kg/ha) at 7.5 t/ha groundnut shell plus 90-60-60 kg/ha NPK (Figure 5). However, four other entries of 5 t/ha of groundnut shell plus 90-60-60 kg/ha NPK, 7.5 t/ha groundnut shell plus 45-30-30 kg/ha, 7.5 t/ha of either rice husk or rice straw plus 90-60-60 kg/ha NPK gave similar grain yields. Combined organic and nitrogen fertilization promoted maize yield in comparison to the organic materials alone and agreed with findings of Sadeghi and Bahrani [17] who observed optimum crop growth with the highest crop residues and nitrogen. The results could be attributed to the overall improvement in soil chemical, physical and biological properties [18]. The observations confirm findings of Asai., et al. [19] who observed that integrated nitrogen strategies convincingly enhance maize yield. Continuous application of smaller amount of manure plus fertilizer increased grain yield and sustained soil fertility in the sub-humid zone of Ghana and was noted to reduce nutrient mining and environmental degradation [16].

100 Seed Weight

Hundred seed weight varied due to the effects of applied organic materials ($p < 0.001$) and mineral nitrogen ($p < 0.05$), with application of 7.5 t/ha groundnut shells supporting highest size of 27.7g (Figure 6). Whilst 90-60-60 kg NPK/ha optimised seed weight (28.6g), 45-30-30 kg NPK/ha gave similar size (Figure 7). Khan., *et al*. [13] observed that lower nitrogen level in the soil resulted in lighter seeds. Similar to our results maize yield and yield components was reported to increase with organic matter application [20].

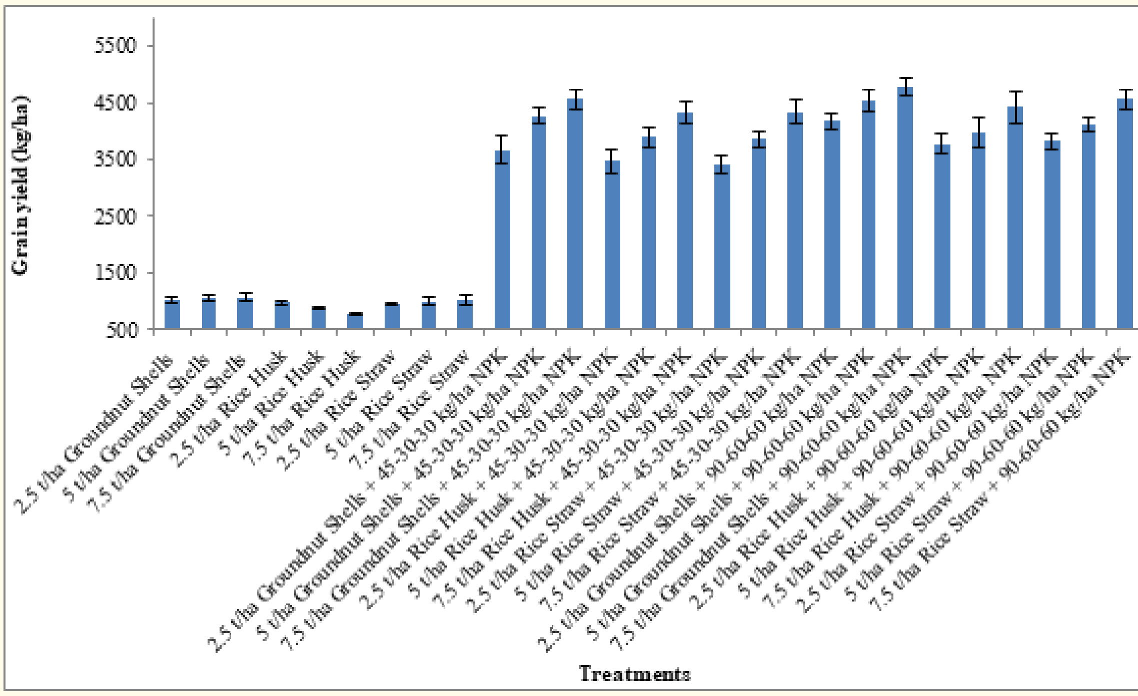

Figure 5: The synergistic effect of organic materials and NPK fertilizer on grain yield of maize after harvesting during the 2014 cropping season. Bars represent SEMs.

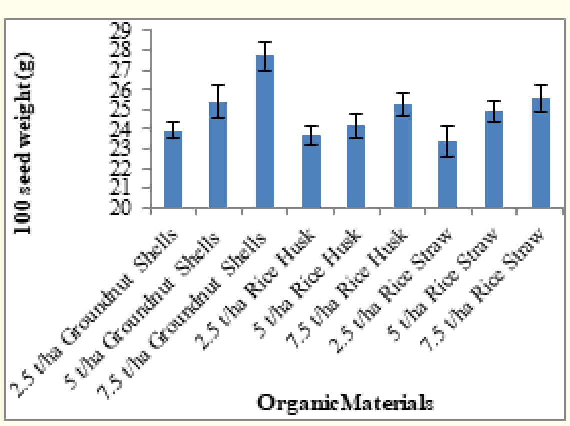

Figure 6: Effects of the organic materials on 100 seed weight of maize. Bars represent SEMs.

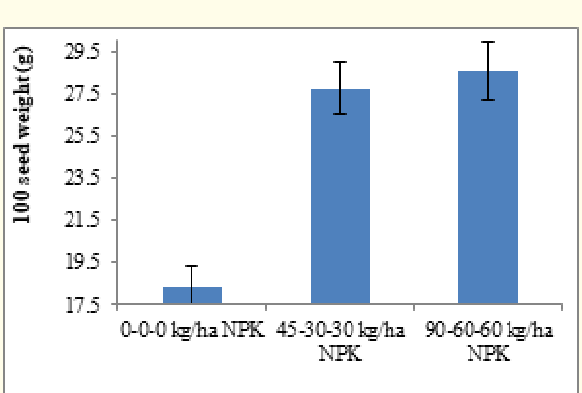

Figure 7: Effects of NPK fertilizer on 100 seed weight of maize. Bars represent SEMs.

Stover Weight

Stover weight was both highly significantly determined by effects of organic materials and mineral nitrogen. The highest stover weight obtained with the applications of 5 t/ha - 7.5 t/ha groundnut shell and 7.5 t/ha rice straw (Figure 8) could be due to continues slow release and adequate availability of crop nutrients from the organic materials buried in the soil, which were less subjected to leaching loses. NPK fertilizer application at 90-60-60 kg/ha maximized stover weight of 4792 kg/ha but was similar to 45-30-30 kg NPK/ha (Figure 9). It was reported organic amendments positively increased crop growth and net assimilation rates with consequential high maize productivity [14].

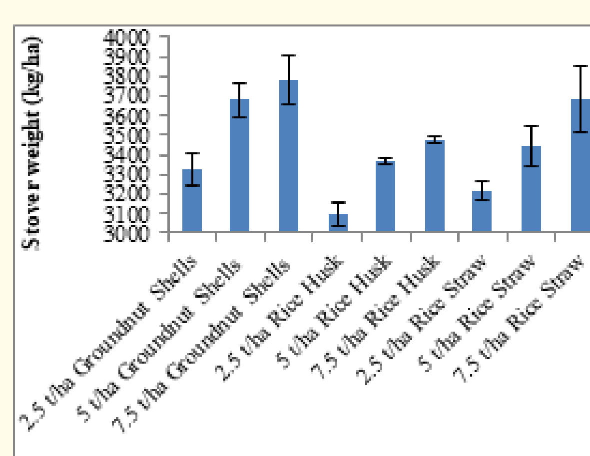

Figure 8: Effects of the organic materials on stover weight of maize. Bars represent SEMs.

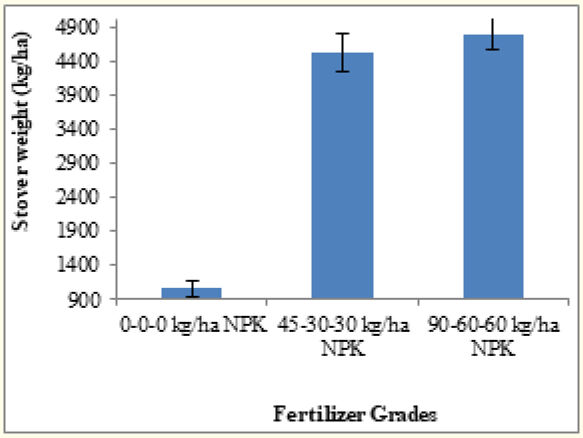

Figure 9: Effects of NPK fertilizer on stover weight of maize. Bars represent SEMs.

Correlation Analysis

Stover weight highly correlated (r = 0.851) with grain yield followed by cob length (r = 0.601). This indicates that grain yield at harvest was determined by the length of the cob and stover weight (Table 3).

Table 3: Correlation between cob length, cob weight, stover Weight, 100 seed weight and grain yield.

	Grain Yield	Cob Length	Cob Weight	100 Seed Weight	Stover Weight
Grain Yield	1.000				
Cob Length	0.601	1.000			
Cob Weight	0.313	0.173	1.000		
100 Seed Weight	0.499	0.091	0.323	1.000	
Stover Weight	0.851	0.733	0.149	0.369	1.000

Soil Analysis after Harvesting

Soil analysis after harvesting showed treatments had affected the chemical properties of the soil over the initial. The soil amendments slightly affected the pH of the soil. The soil amendments also positively increased the organic carbon content and the major plant nutrient elements (nitrogen, phosphorus, potassium, calcium and magnesium) of the soil (Table 2). Masulili., *et al.* [21] reported on the improvement of soil properties with organic soil amendments. Saha., *et al.* [22] reported that rice straw incorporation increased soil organic matter content. Notably, Tualar., *et al.* [23] observed that the interaction between the application of organic fertilizers and inorganic fertilizers (nitrogen, phosphorus and potassium) affected organic carbon content and soil cation exchange capacity.

Conclusion

The results showed integrated use of organic amendments of groundnut shells, rice husk and rice straw with NPK fertilizer at 45-30-30 kg/ha increased maize grain and yield components.

Grain yield of maize was maximised by 7.5 t/ha groundnut shell plus 90-60-60 kg/ha NPK, being 4781 kg/ha. However, the lower amount of organic matter required in 5 t/ha of groundnut shell plus 90-60-60 kg/ha NPK, and lower input of NPK in 7.5 t/ha groundnut shell plus 45-30-30 kg/ha which equalled the maximum could be preferred by farmers who can only afford lower quantities of organic material or NPK. Application of 7.5 t/ha of either rice husk or rice straw plus 90-60-60 kg/ha NPK also preformed similar to the maximum in grain yield. The application of 2.5 to 7.5 t/ha of groundnut shell or rice husk or rice straw plus at least 45-30-30 kg NPK/ha enhanced days to 50% flowering and cob length. Generally 5 to 7.5 t/ha of groundnut shell alone were outstanding in enhancing cob weight, 100 seed weight and stover weight. The application of NPK fertilizer alone at 45-30-30 kg NPK/ha promoted cob weight, 100 seed weight and stover weight. Overall implication showed combination of organic matter and inorganic NPK fertilizer could play a more significant role in enhancing and replenishing soil nutrients and sustained maize production.

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