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Effects of groundnut shells on soil properties, growth and yield of maize

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ABSTRACT

The aim of the study was to assess the effects of groundnut shells on soil properties, growth and yield of maize. The study was carried out in Jalingo, Taraba State, North-Eastern Nigeria in July, 2019. Treatments in the study were four doses of groundnut shells (0.0, 2.5, 5.0 and 7.5 t ha^{-1}); arranged in a randomized complete block design, replicated four times. Each plot was 2.0 m × 2.0 m with 0.5 m gap between the plots and replicates. Crushed groundnut shells were applied on a dry matter basis at the rates of 0, 2.5, 5.0 and 7.5 t ha^{-1} 28 days before planting maize. Seeds were planted on prepared land treated with crushed groundnut shells. Soil properties were determined at harvest, maize growth parameters were determined at 50% flowering and maize yield parameters were determined at maturity. The results showed that groundnut shells application increased soil porosity, water holding capacity, soil pH, organic matter, nitrogen, phosphorus, calcium, magnesium, potassium, sodium and total exchangeable bases and decreased soil bulk density to favorable levels. Groundnut shells application also increased plant height, stem girth, number of leaves per plant, leave area, leave area index, cob length, number of seeds per cob, seed weight per plant, hundred (100) seed weight, stover yield, grain yield and harvest index and decreased number of days to 50% tasseling. The result suggests that the 7.5 t ha^{-1} of groundnut shell application rate be utilized, as a more appropriate and profitable groundnut shell incorporation method in order to achieve better performance of maize plants.

Keywords: Groundnut shell, incorporation rates, maize, organic.

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INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal crop of the world, grown in irrigated and rain-fed areas (Hussan et al., 2003). It is a rich source of food for human population, fodder for animals, and feed for poultry and provides raw material for industrial utilization. Maize is processed into a wide range of foods and beverages, which are consumed as breakfast, main meals or snacks. It is also a main source of carbohydrates for poultry industries in Nigeria. It is also used in the manufacturing of alcohol, maize starch, and maize oil and the stalk is turned to paper cardboard. It provides valuable roughages for dairy and beef cattle and constitutes a high proportion of the concentrate in livestock feeds.

Despite the importance of maize as a food security crop, many factors militate against attainment of its grain yield potential in Nigeria. Low soil fertility has been identified as a major factor reducing crop yields in Nigeria. Maobe et al. (2010) reported that maize grain yield is constrained by inadequate nitrogen supply caused by insufficient application of fertilizers that are costly and unaffordable in smallholder farming. Mineral fertilizers to boost crop production are expensive and sometimes unavailable. In Nigeria, the soils of the Guinea savanna zone are inherently low in soil fertility, especially of nitrogen and organic matter with resultant low crop yields (Nottidge et al., 2005). In this zone, inorganic materials are widely used to improve soil and crop productivity. These fertilizers are scarce and beyond the reach of resource poor farmers. In addition, their application produces detrimental effects on the soil (enhancement of soil acidity and degradation of soil properties) and pollution of water bodies (Nottidge et al., 2005).

The expected yield increase on the application of inorganic fertilizer is not obtained since these fertilizers are readily lost to leaching due to high rainfall coupled with low activity clays in these soils (Ano and Agwu, 2005).

However, there are various organic materials such as groundnut shells that have the potential of effective agronomical use in Nigeria. Fening et al. (2005) reported that there is an increasing interest in using crop residues for improving soil productivity which can reduce the use of external inputs of inorganic fertilizer. These crop residues are in sufficient abundance in farmers' fields at the end of a growing season and play an important role in soil fertility management through their short term effects on nutrient supply and longer term contribution to soil organic matter (Karanja et al., 2006). In Nigeria and other developing countries, the groundnut shell is used as soil amendment, manure and mulch.

Groundnut is the third most abundantly cultivated oilseed in the world and plays an important role in the economy of these West African countries, including the Gambia, Nigeria, Ghana and Senegal (Nwanosike, 2011). In Africa, groundnut is grown mainly in these countries, Nigeria, Gambia, Sudan, Senegal, Chad, Ghana Congo and Niger (Prasad et al, 2010). In 2007, the total harvested area for groundnut in Africa was 9.04 million ha with a total production of 8.7 million metric tonnes. The average productivity index for Nigeria was reported to be 1720 kg/ha, 500 kg/ha was reported for Sudan and 700 kg/ha was given for Senegal. From the several million tonnes of groundnuts produced each year, hulls constitute about 25 percent of the total mass produced and are not being utilized.

Groundnut shells are an agricultural by-product from an oilseed leguminous crop groundnut. Significant waste disposal problems are created around areas where agricultural wastes, such as groundnuts shells are generated. The common methods of handling the disposal of oilseed harvest residue such as groundnut shell is mostly either by incineration, incorporation in soil on land dumping. At present in the developing countries the majority of groundnut hulls are either burned, dumped in forest areas or left to degrade naturally. However, incineration method will emit smoke and particulate matter, which causes air pollution. Incorporation of agricultural waste into soil influences physical, biological and chemical properties of soil (Sim, 2011). Therefore, it is necessary to develop improved methods of managing the huge amount of peanut shells, which poses no critical problem in waste management systems and subsequently causes no environmental pollution (Sim, 2011). Transforming groundnut shells into a valuable raw material, ingredient or product would be the better method to utilize them (Dongmezaet et al., 2009; El-hagger et al., 2010; Sim, 2011).

The shells are the dry pericarp of the mature pods contains moisture content, crude fibre, lipids, crude protein, carbohydrate, oxalate, phytate, cyanogenic glycosides and trypsin inhibitors of 8.0%, 2.50%, 59%, 0.50%, 4.43%, 25.57%, 220 mg/100 mg, 362.1 mg/100 kg, 1.60 mg/100 g and 25 TUI/mg, respectively (Bansal et al., 1993). Groundnut shell contains calcium, phosphorus, potassium, magnesium, zinc and more than 10 kinds of other trace elements, small amount of fat and protein (Nirmala and Vasavi, 2018). It is used as cattle feed and as a carrier of insecticide, in the manufacture of logs and production of pulp and can also be used for preparing activated carbon (Nirmala and Vasavi, 2018). Groundnut shells are used as fuel when pelletized and made as smokeless briquette (Harrell et al., 2010) as a soil conditioner, filler in fertilizer and feeds, or is processed as substitutes for cork and hardboard, or composting with the aid of lignin composting bacteria (Nautiyal, 2002). Folagbade and George (2010) categorized *Arachis hypogaea* shell ash with about 8.66% calcium oxide (CaO), 1.93% Iron oxide (Fe_2O_3), 6.12% magnesium oxide (MgO), 15.92% silicon oxide (SiO_2) and 6.73% Aluminium Oxide (Al_2O_3) under pozzolana. This composition makes it suitable for application in concrete as a partial replacement for cement with a measure of success achieved.

Groundnut shells are traditionally used as organic matter by farmers to restore their paddy fields affected by salinity. Unfortunately, their effects have not been scientifically reported for the recycling and sustainable use. Their effects on soil physical, chemical, and biological characteristics remained up to now less prioritize. The addition of peanut shells as organic amendment increases nutrient levels such as carbon, nitrogen, phosphorus, and calcium structure and reduces soil salinity (Mojiri et al., 2011). Soil microorganisms such as nitrogen-fixing bacteria (rhizobia) and arbuscular mycorrhizal fungi establish triple association, capable of supplying N and P contents to the plants, particularly in poor soils (Silveira and Cardoso, 2004). So the addition of peanut shells leading to improve soil fertility could affect microbial symbiosis (nodulation and mycorrhization). Thus, the study of the effect of groundnuts shell amendment on the growth and yield of maize is necessary.

The problem of low soil fertility amidst scarcity of mineral fertilizers around Taraba State have triggered attempts to use organic fertilizer sources to replenish soil nutrients at low cost. Besides, the high cost of inorganic materials and its frequent adulteration, makes the product to have adverse effects on soils, water and plants. There exists the need to find other fertilizer sources for maintaining soil fertility to enhance optimum maize yields. Lucas (1986) reported that sometimes, the application of organic manure might be more important than the addition of chemical fertilizers to some crops. Consequently, Maize yields very well in a continuously cropped field, but declines with time, even with the application of certain mineral fertilizers.

Groundnut shell has dual effects; firstly, by providing required nutrients to growing plants, and secondly, by feeding soil organisms. A balanced blend of groundnut shell fertilizer provides food sources for important micro-organisms, which in turn help plants ability to uptake more nutrients from the soil. The use of groundnut waste in agriculture can reduce the need for chemical fertilizers and it restores organic carbon deficiency in soils (Surekha, 2013). As chemical fertilizers are causing ecological damage, an alternative method is required to replace the use of chemical fertilizers for the growth of maize plants. Groundnut shell produced during processing is used as a natural fertilizer for cultivation. According to Pietraszko and De-Clereq (1982), application of groundnut shell fertilizer has less effect on invertebrate animals in the soil. At present, there is no scientific data on the effects of groundnut shell fertilizer materials on maize production in Taraba State, thereby making its incorporation rates to be without precision. Thus, there is lack of information on recommendable groundnut shell incorporation rates for maize production around Taraba state and its environs. The present research therefore intends to determine the effect of groundnut shell incorporation rate on the soil properties, growth and yield of maize in Taraba State, north-eastern Nigeria.

Objectives of the study

General objective

The main objective of the study is to determine the effect of groundnut shell on soil properties, growth and yield components of maize.

Specific objectives

The specific objectives are:

i. To determine the effects of groundnut shell on soil physical properties,
ii. To determine the effects of groundnut shell on soil chemical properties,
iii. To determine the effects of groundnut shell on maize growth parameters,
iv. To determine the effects of groundnut shell on maize yield parameters.

Justification of the study

The soils of Taraba State are fragile due to their Kaolinite clay-based constitution; as such there is the need to build the buffer capacity of these soils through increasing the level of organic matter. Adequate soil organic matter buffers the soil against drastic changes in soil pH, increases the exchange sites for storage and release of nutrients, moderates soil temperature, improves the physical base of the soil by increasing its resilience to soil structure deterioration and soil degradation. Organic matter is the source of about 90-95% of the nitrogen in unfertilized soils. Organic matter can be the major source of both available phosphorus and available sulphur when soil humus is presented in appreciable amounts.

The use of locally available materials for crop improvement is an option that can be fully exploited to improve crop production. The use of organic materials (such as rice straw, rice husk, biochar and groundnut shell) as soil amendments for agricultural practices is rarely used in Nigeria. Large amounts of plant residues that can be used as soil amendments are annually generated through farming. These residues include groundnut shells, maize stover, rice husk, rice straw, millet or sorghum straw resulting from annual production of these crops.

The study is relevant in terms of information provision on the suitable organic fertilizer recommendation for maize production in Taraba State. Hence, the results of the research are expected to be of great benefit to maize producers in Taraba State. The study is expected to provide suitable information on groundnut shell incorporation rate on soil properties, growth and yield of maize in Taraba State and its environs.

MATERIALS AND METHODS

The study was conducted during 2019 farming seasons in Jalingo, Taraba State, North-Eastern Nigeria. Jalingo is located between latitude 8° 47′ N to 9° 01′ N and longitude 11° 09′ E to 11° 30′ E. The field trial location was selected on the basis of common practices of maize cropping among farmers at the selected location. The groundnut shells for this study were obtained from a groundnut shelling machine in Jalingo. The groundnut shells were grounded into small sized particles for easy incorporation.

Research design and treatments

The experiment was conducted in randomized complete blocks design (RCBD) in four replications with each experimental unit measuring 2 m × 2 m (4 m^2). The experiment consisted of four treatments which consist of four levels of groundnut shells incorporation rates at 0.0, 2.5, 5.0 and 7.5 t ha^{-1} dry matter basis. This gave a total of sixteen experimental plots. A 0.5 m alley was left between plots within a replication and a 0.5 m alley between replications.

Agronomic practices

Land preparation and groundnut shell application

The experimental field was demarcated prior to experimental setup and was cleared using a cutlass and a hoe while ploughing was done using a tractor. The total land area used was 9.5 m × 9.5 m (90.25 m^2). After laying-out, the various organic materials were then applied on their respective plots. Incorporation of organic materials and levelling were done manually using human labour. The organic materials were applied on a dry matter basis at the rates of 0, 2.5, 5.0 and 7.5 t ha^{-1} 28 days before planting maize.

Planting

Prior to planting, the experiment field was sprayed with glyphosate a non-selective herbicide to kill all weeds to avoid competition. Hybrid maize (Oba Super 1 Premier seeds, commercial hybrid-white) that has a maturity period of 90 to 95 days (3 month) was planted. Planting method used was that use locally by the famers in the area by the use of manual dibbler and a garden line to help get the crops in straight lines. At least three seed were planted per hole and later thinned to one per hole after the crop germinated and emerged from the soil. The seeds were planted on at a spacing of 80 cm between rows and 40 cm within rows, which gave 31,250 plants ha^{-1}.

Weed management

Prior to planting, glyphosate (non-selective) herbicide was applied to kill all weeds to avoid early competition. The first hand weeding was done 18 Days After Planting (DAP) and the second hand weeding was done 40 DAP. Third hand weeding was done after 75 DAP.

Harvesting

Harvesting of 18 plants per the net plot (2×2 m size) was carried out after the maize was fully matured on the field. The entire plants on the plots were harvested by cutting at the ground level. The harvested maize was dried, bagged and labelled according to treatments, replications and plot numbers.

Soil sampling and analysis

Surface soil samples (0 to 15 cm in depth) were taken randomly using the zig-zag method (Brady and Weil, 2008) on plot basis before planting and at crop maturity. The soil samples were air-dried for a period of one week in a clean well ventilated laboratory, homogenized by grinding, passed through a 2 mm (10 mesh) stainless sieve and were analyzed for physical and chemical properties using standard procedures.

Soil dry bulk density was determined using the core method. The soil particle density and total porosity were determined according to Aikins and Afuakwa, 2012. Water holding capacity was determined using porous cup method.

Soil pH was measured in a 1:1 soil-water ratio using a glass electrode (H19017 Microprocessor) pH meter. Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method and organic matter was calculated by multiplying organic carbon by 1.724 (Burt, 2014). Total nitrogen of the samples was determined by the regular macro kjeldahl method. Available phosphorous was extracted using Bray-1 solution and determined by molybdenum blue colorimetry (Burt, 2014). Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determined using method described in Burt (2014).

Plant data collection

Determination of maize plant growth parameters

The plant growth data were collected at 50% flowering stage. The plant growth data collected were days to 50% flowering, plant height, plant girth, number of leaves, leaf area and leaf area index. Six maize plants were selected at random from each plot and tagged for growth measurements.

The days to 50% flowering was done by counting the number of days from planting to when half (50%) of the maize plants on each plot produces tassels or start tasselling. Plant height was measured using a measuring tape. Tape measure was used to measure the heights from the base of the plant to the tip of the flag leaf and their averages recorded. Data on stem diameter of representative maize plants on each plot was measured using venire calipers. The number of leaves per plant was determined by physical counting and data from the tagged plants was used to compute the score for each plot (Masarirambi et al., 2012). The leaf area was measured using a measuring tape. The leaf length and breadth were measured to obtain the leaf area. The leaf area was estimated as its length multiplied by its maximum width multiplied by maize leaf calibration factor, 0.75 (Elings, 2000). The leaf area index (LAI) was computed according to Msibi et al. (2014).

$$\text{LAI} = \frac{\text{Y} \times \text{N} \times \text{LA}}{\text{AP}} \qquad (1)$$

Where; Y = Population of plants per plot, N = Average number of leaves, LA = Leaf area (cm^2), AP = Area of plot (cm^2).

Determination of maize yield and yield components

The entire plants on the plots were harvested by cutting at the ground level. The plants were then separated into ears (cob + grains) and stover (stem, leaves and husks). The plant parts; ears and stover were weighed and their weights recorded as fresh weights. The ears were further separated into cobs and grains by shelling. The various plant parts were put in brown paper envelopes and then oven dried at 70 °C for 48 h to obtain their dry weights.

The lengths of maize cobs from each treatment were measured using the meter rule and their averages were recorded. The number of seeds per cob was determined by counting. The weight of seeds per plant was measured using an electronic scale. Samples of grains were taken from the produce of each treatment plot and then 100 grains were separated by counting from each sample and weighed using an electronic balance. The stover (stem, leaves and husks) obtained after harvest from the net plot area of each plot were weighed on an electronic balance. After this, the stover yield (kg) per plot was converted into stover yields (kg) per hectare by multiplying with an appropriate conversion factor (367.65). The clean grains obtained after threshing from the net plot area of each plot were weighed on an electronic balance. After this, the grain yield (kg) per plot was converted into grain yields (kg) per hectare by multiplying with an appropriate conversion factor (367.65). Harvest index (HI) was computed using Equation 2.

$$\text{Harvest Index (HI)} = \frac{\text{Dry grain weight}}{\text{(Dry weight of ears + dry weight of stover)}} \qquad (2)$$

Statistical analysis

All the data that were collected from the field experiments on soil properties, growth and yield characteristics of maize were subjected to ANOVA test at P ≤ 0.05. Treatment means were compared using the least significant difference (LSD) at P ≤ 0.05.

RESULTS AND DISCUSSION

Soil properties of the experimental site before the experiment

The properties of the soil at the experimental site before the experiment are presented in Table 1. The soils were slightly acidic with a relatively high bulk density, moderate porosity and water holding capacity. The organic matter, total nitrogen, available phosphorus, exchangeable calcium, magnesium, potassium and sodium were low.

Effects of application of groundnut shells on soil physical properties

The results of the effect of application of groundnut shell on soil physical properties are presented in Table 2. The groundnut shells treatment had a significant ($P < 0.05$) effect on soil bulk density, soil porosity and water holding capacity. Soil bulk density was found to decrease with increase in groundnut shell application rate while soil porosity and water holding capacity were found to increase with increase in groundnut shell application rate. Physical characteristics of soil were improved by the application of groundnut shells.

Effects of application of groundnut shells on soil chemical properties

The results of the effect of application of groundnut shell on soil chemical properties are presented in Table 3. The results show that the application of groundnut shells had a significant ($P < 0.05$) positive effect on soil pH, organic matter, nitrogen, phosphorus, calcium, magnesium, potassium, sodium and total exchangeable bases. The soil chemical properties investigated were found to increase with increase in groundnut shell application rate. Chemical characteristics of soil were improved by the application of groundnut shells

Effects of application of groundnut shells on maize growth characteristics

The results (Table 4) of the field experiments show that the effects of application of groundnut shell were pronounced on the growth characteristics of maize. The effects of the treatment varied on the growth characteristics of maize.

Days to 50% flowering

The results showed that groundnut shells treatment had a significant ($P < 0.05$) negative effect on days to 50% flowering. Groundnut shell application significantly reduced days to 50% tasselling in maize. Application of groundnut shell enhanced early flowering in maize with 7.5 t ha^{-1} of groundnut shell taking the shortest days of 49 days to 50% flowering while 0.0 t ha^{-1} of groundnut shell taking the longest days of 54 days to 50% flowering (Table 4). Timely availability of nutrients mainly nitrogen from the organic source 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. (2008).

Plant height

Plant height indicates the influence of various nutrients on plant metabolism. The results showed that groundnut shells treatment had a significant ($P < 0.05$) positive effect on the plant height. Increasing the rates of groundnut shell incorporation resulted to an increase in plant height. Groundnut shells application improved plant height significantly. Groundnut shells promoted fast maize growth and development of the plants. Highest plants were obtained with 7.5 t ha^{-1} groundnut shell incorporation treatment and the lowest plant height was produced by the 0.0 t ha^{-1} groundnut shell incorporation treatment (Table 4). The observed increment in height with groundnut shell application is attributed to nutrients availability especially nitrogen (Khan et al., 2008) which promoted fast growth and development of the maize plants.

Stem girth

The groundnut shell incorporation had significant ($P < 0.05$) effect on the stem diameter of maize plants. Plant girth increased with increasing rates of groundnut shell incorporation. The highest stem girth was recorded in the 7.5 t ha^{-1} groundnut shell incorporation rate and the lowest was in the 0.0 t ha^{-1} groundnut shell incorporation rate (Table 4). This agrees with the findings of Anon (2002), who opined that groundnut shell is an excellent fertilizer material because of its high nitrogen, phosphorus and potassium content and it is readily available than the mineral fertilizer. In addition, its effect on the soil is stable and with slow nutrition to maize plants. This shows that a high rate of application has a positive effect on the maize stem girth.

Number of leaves

The number of leaves was influenced ($P < 0.05$) by the groundnut shell applications. The number of leaves increased with increasing rates of groundnut shell incorporation. Groundnut shells incorporation rate of 7.5 t ha^{-1} produced the maximum number of leaves and groundnut shells incorporation rate of 0.0 t ha^{-1} recorded the least number of leaves (Table 4). The significant variation in maize leaf count is attributed to the organic material source levels. The increased number of leaves observed with groundnut shells is attributed to nutrients

Table 1. Physical and chemical properties of soil before the experiment.

Properties	Value
Bulk density (g cm^{-3})	1.42
Soil porosity (%)	43.43
Water holding capacity (%)	80.4
pH (H_2O)	5.7
Organic matter (%)	1.84
Total N (%)	0.16
Available P (%)	12.24
Exchangeable Ca (cmol (+) kg^{-1})	2.38
Exchangeable Mg (cmol (+) kg^{-1})	1.80
Exchangeable K (cmol (+) kg^{-1})	0.28
Exchangeable Na (cmol (+) kg^{-1})	0.22
Total Exchangeable Bases, TEB (cmol (+) kg^{-1})	4.68

Table 2. Effects of application of groundnut shells on soil physical properties.

Treatment	Soil physical properties		
	Bulk density (g cm^{-3})	Porosity (%)	Water holding capacity (%)
0.0 t ha^{-1}	1.44	42.63	81.0
2.5 t ha^{-1}	1.35	45.56	83.6
5.0 t ha^{-1}	1.33	45.71	84.8
7.5 t ha^{-1}	1.28	47.76	87.3
F-LSD $_{0.05}$	0.024	0.020	0.189

Table 3. Effects of application of groundnut shells on soil chemical properties.

Treatment	Soil chemical properties								
	pH	OM	Total N	Avail. P	Ca	Mg	K	Na	TEB
	(H_2O)	(%)	(%)	(%)	[cmol (+) kg^{-1}]				
0.0 t ha^{-1}	5.5	1.82	0.13	11.55	1.91	1.61	0.27	0.23	4.02
2.5 t ha^{-1}	5.8	2.76	0.24	15.62	2.53	1.78	0.44	0.26	5.01
5.0 t ha^{-1}	5.9	2.90	0.28	17.06	2.74	1.88	0.44	0.28	5.34
7.5 t ha^{-1}	6.3	3.10	0.29	18.74	2.82	1.90	0.47	0.31	5.50
F-LSD $_{0.05}$	0.069	0.014	0.020	0.031	0.024	0.049	0.024	0.020	0.014

Table 4. Effects of groundnut shells on maize growth characteristics at 50% flowering stage.

Treatment	Maize growth parameters					
	Days to 50% tasseling	Plant height (cm)	Stem girth (cm)	Number of leaves	Leaf area (cm^2)	Leaf area index
0.0 t ha^{-1}	54.0	93.5	2.3	6.0	32.0	0.0864
2.5 t ha^{-1}	53.0	142.4	2.7	7.0	35.8	0.1128
5.0 t ha^{-1}	50.0	156.9	3.3	7.0	40.2	0.1266
7.5 t ha^{-1}	49.0	178.3	3.5	8.0	41.5	0.1494
F-LSD $_{0.05}$	2.516	0.316	0.189	0.316	1.258	0.020

availability especially nitrogen (Khan et al., 2008) provided by the organic materials which promoted fast growth and development of the maize plants. This is in line with Efthimiadou et al. (2010) who observed that organic soil amendments recorded the highest number of leaves. An increase in the number of leaves could positively affect the photosynthetic activity of the plant since leaf number is a growth index that could enhance crop yields.

Leaf area

The results showed that groundnut shells treatment had a significant ($P < 0.05$) positive effect on the leaf area. Leaf area increased with increasing rates of groundnut shell incorporation. Plot treated with groundnut shells at 7.5 t ha^{-1} produced the highest value of leaf area while the least leaf area was observed with the plot treated with groundnut shells at 0.0 t ha^{-1} (Table 4).

Leaf area index

Leaf area index was significantly ($P < 0.05$) influenced by different doses of applied groundnut shells. The highest leaf area index was recorded in the 7.5 t ha^{-1} groundnut shell incorporation rate and the lowest was in the 0.0 t ha^{-1} groundnut shell incorporation rate (Table 4). The significant increase in leaf area index with the application of groundnut shell indicated the effectiveness of applied groundnut shell in improving the growth of maize crop.

Effects of application of groundnut shells on maize yield characteristics

The results (Table 5) of the field experiments show that the effects of application of groundnut shell were pronounced on the yield characteristics of maize. The effects of the treatment varied on the yield characteristics of maize.

Cob length

Cob length is a yield component and a determinant of overall maize yield. Application of groundnut shell significantly ($P \leq 0.05$) increased cob length. Entries of 0.0 to 7.5 t ha^{-1} groundnut shell maximize cob length. Lengthy cobs supported by the groundnut shell application could be attributed to high growth rate attained by the crop due to timely availability of nutrients from the source of soil fertility amendments with consequential increased dry matter accumulation. In a previous study, Uzoma et al. (2011) reported combined application of organic and inorganic materials 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.

Number of seeds per cob

Application of groundnut shell significantly ($P \leq 0.05$) increased the number of seeds per cob. The 0.0 t ha^{-1} groundnut shell application treatment gave the lowest mean number of seeds per cob of maize while 7.5 t ha^{-1} groundnut shell application treatment gave the highest mean number of seeds per cob.

Seed weight per plant

The result shows significant ($P \leq 0.05$) differences among the treatment effects on the maize seed weight per plant. The treatment effects were proportional to the treatment rates. The seed weight per plant increased with increasing rate of groundnut shell application. The 7.5 t ha^{-1} treatment rate produced the heaviest maize seed weight per plant (68.98 g) while the 0.0 t ha^{-1} treatment rate produced the lightest maize seed weight per plant (48.57 g). The increase in seed weight per plant with increasing rate of groundnut shell application is attributed to improved nitrogen uptake by maize through enhanced organic matter decomposition-mineralization process or indirectly maize root development. High nitrogen level and other nutrients obtained from the organic material resulted in heavy cobs. Similar trend was observed by Khan et al. (2008) who detected that lower nitrogen level in the soil resulted in lighter grain weight due to less available nitrogen for the optimum plant growth. Anon (2002) similarly found that higher application rates of groundnut shell produced heavier maize cob weights, than with lower application rates.

Hundred (100) seed weight

Hundred seed weight varied significantly ($P < 0.05$) due to the effects of applied groundnut shells, with application of 7.5 t ha^{-1} groundnut shells giving the highest hundred seed weight of 27.90 g and application of 0.0 t ha^{-1} groundnut shells giving the lowest hundred seed weight of 21.22 g. The increase in hundred seed weight with groundnut shell application rates is attributed to higher nitrogen level in the soil which resulted in heavier grain weight due to nitrogen availability for optimum maize growth and formation of assimilates for healthy grains (Khan et al., 2008). Khan et al. (2008) 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 (Steiner et al., 2007).

Stover yield

The stover weight of maize plant was significantly

Table 5. Effects of groundnut shells on yield and yield component of maize.

Treatment	Maize yield parameters						
	Cob length (cm)	Number of seeds per cob	Seed weight per plant (g)	100-seed weight (g)	Stover yield (t/ha)	Grain yield (t/ha)	Harvest index
0.0 t ha^{-1}	13.50	312	48.57	21.22	6.52	3.11	0.32
2.5 t ha^{-1}	14.75	362	59.82	24.68	6.98	4.28	0.38
5.0 t ha^{-1}	16.00	418	63.54	25.75	7.35	5.10	0.41
7.5 t ha^{-1}	17.40	474	68.98	27.90	8.10	5.78	0.42
F-LSD $_{0.05}$	0.316	7.548	0.049	0.138	0.327	0.069	0.014

($P < 0.05$) determined by effects of groundnut shell application. The groundnut shell application rate of 7.5 t ha^{-1} had the highest stover weight while the groundnut shell application rate of 0.0 t ha^{-1} had the lowest stover weight. The highest stover weight obtained with the application of 7.5 t ha^{-1} groundnut shell 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. It was reported organic amendments positively increased crop growth and net assimilation rates with consequential high maize productivity (Uzoma et al., 2011).

Grain yield

Application of groundnut shell significantly ($P < 0.05$) increased the parameter with maximum grain yield of maize (5.78 t ha^{-1}) at 7.5 t ha^{-1} groundnut shell application rate and minimum grain yield of maize (3.11 t ha^{-1}) at 0.0 t ha^{-1} groundnut shell application rate. This agreed with findings of Sadeghi and Bahrani (2009) 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. The observations confirm findings of Asai et al. (2009) who observed that integrated nitrogen strategies convincingly enhance maize yield.

Harvest index

Application of groundnut shell significantly ($P < 0.05$) increased the harvest index with maximum harvest index of 0.42 at 7.5 t ha^{-1} groundnut shell application rate and minimum harvest index of 0.32 at 0.0 t ha^{-1} groundnut shell application rate.

CONCLUSIONS

From the results it may be concluded that growth and yield of maize variety were significantly influenced by different levels of groundnut shell incorporation. The plant growth was increased by application of groundnut shell at different levels. Consecutively, the variety produced the highest yield with 7.5 t ha^{-1} groundnut shell, with the highest nutrient use efficiency. Groundnut shell application increased soil porosity, water holding capacity, soil pH, organic matter, nitrogen, phosphorus, calcium, magnesium, potassium, sodium and total exchangeable bases and decreased soil bulk density and particle density to favorable levels.

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