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

Tanko Bako[1*], Ezekiel Ambo Mamai[2], Akila Bardey Istifanus[1]

(1. Department of Agricultural and Bio-Resources Engineering, Taraba State University, P.M.B. 1167, Jalingo, Nigeria;
2. Department of Soil Science and Land Resource Management, Federal University, P.M.B. 1020, Wukari, Nigeria)

Abstract: The study aimed to assess the effects of groundnut shells on soil properties, growth and yield of maize. The study was carried out at Lamurde floodplain in Jalingo, Taraba State, North-Eastern Nigeria in July, 2019. Treatments in the study were four doses of groundnut shells (0, 2.5, 5.0 and 7.5 t ha^{-1}); arranged in a randomized complete block design with four replications per experimental unit. 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 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 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 to favourable levels. Groundnut shell 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 seed weight, stover yield, corn ear yield, grain yield and harvest index and decreased number of days to 50% tea selling. 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: Peanut shell, Incorporation Rates, Fertilizer, Organic

Citation: Bako, T., E. A. Mamai, and A. B. Istifanus. 2022. Effects of groundnut shells on soil properties, growth and yield of maize. Agricultural Engineering International: CIGR Journal, 24(1): 1-12.

1 Introduction

Maize (*Zea mays L.*) is the most important cereal crop of the world, grown in irrigated and rain-fed areas (Okoroafor et al., 2013). It is a rich source of food for human population, fodder for animals, and feed for poultry and provides raw material for industrial utilization (Efthimiadou et al., 2010). 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

Received date: 2020-11-10 **Accepted date:** 2021-04-06

***Corresponding author: Tanko Bako,** Ph.D., Department of Agricultural and Bio-Resources Engineering, Taraba State University, P.M.B. 1167, Jalingo, Nigeria. Tel: +234 7064190523. Email: engbako@gmail.com.

inherently low in soil fertility, especially of nitrogen and organic matter with resultant low crop yields (Nottfige 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 (Nottfige 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 (*Arachis hypogaea*) 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 (*Arachis hypogaea*) 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 (Vara Prasad et al., 2010). In 2007, the total harvested area for groundnut in Africa was 9.04 Mha with a total production of 8.7 Mt. The average productivity index for Nigeria was reported to be 1720kg ha^{-1}; 500kg ha^{-1} was reported for Sudan and 700kg ha^{-1} was given for Senegal (Vara Prasad et al., 2010). Hulls constitute about 25% of the total mass of groundnuts produced but they are not being utilized (Nwanosike, 2011).

Peanut shells are an agricultural by-product from an oilseed leguminous crop peanut. Significant waste disposal problems are created around areas where agricultural wastes, such as peanuts shells are generated. The common methods of handling the disposal of oilseed harvest residue such as peanut shell is mostly either by incineration, incorporation in soil on land dumping. At present in the developing countries the majority of peanut 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 peanut shells into a valuable raw material, ingredient or product would be the better method to utilize them (Dongmeza et al., 2009; El-Haggar 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^{-1}, respectively (Bansal et al.1993). Peanut shell contains Ca, P, K, Mg, Zn and more than 10 kinds of other trace elements, small amount of fat and protein (Nalluri and Karri, 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 (Nalluri and Karri, 2018). Groundnut shells are used as fuel when pelletized and made as smokeless briquette (Lubwama and Yiga, 2017) 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). Oriola and Moses (2010) categorized *Arachis hypogaea* shell ash with about 8.66% CaO, 1.93% Fe_2O_3, 6.12% MgO, 15.92% SiO_2 and 6.73% 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 of C, N, P and Ca 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.

Peanut shell has dual effects; firstly, by providing required nutrients to growing plants, and secondly, by feeding soil organisms. A balanced blend of peanut 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 peanut waste in agriculture can reduce the need for chemical fertilizers and it restores organic carbon deficiency in soils (Nirmala and Vasavi, 2018). 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. Peanut shell produced during processing is used as a natural fertilizer for cultivation. According to Olowoake and Ojo (2014), application of peanut shell fertilizer has less effect on invertebrate animals in the soil. At present, there is no scientific data on the effects of peanut 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 peanut 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.

2 Materials and methods

2.1 Study area

The study was conducted during 2019 farming seasons at Lamurde floodplain in Jalingo, Taraba State, North-Eastern Nigeria. Jalingo is located between latitude 8^o 47′ N to 9^o 01′ N and longitude 11^o 09′ E to 11^o 30′ E. Jalingo area has tropical continental type of climate characterized by well-marked wet and dry season. The wet season usually begins around April and ends in October. Jalingo has a mean annual rainfall of about 1,200 mm. In the rainy season, the relative humidity is much higher and ranges between 60% -70%. The dry season begins in November and ends in March. The dry season is characterized by the prevalence of the northeast trade winds, which are usually dry and dusty. During the dry season, relative humidity is low and falls between 35% - 45%. This low relative humidity coupled with high afternoon temperatures account for the desiccating effects of the dry season. The average minimum recorded temperature is 15.2^{o}C while the average maximum temperature is 39.7^{o}C (Umeh et al., 2019). 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.

2.2 Research design and treatments

The experiment was conducted in randomized complete blocks design (RCBD) in four replications with each experimental unit measuring 2×2 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 bases. 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. Figure 1 shows the experimental design field layouts.

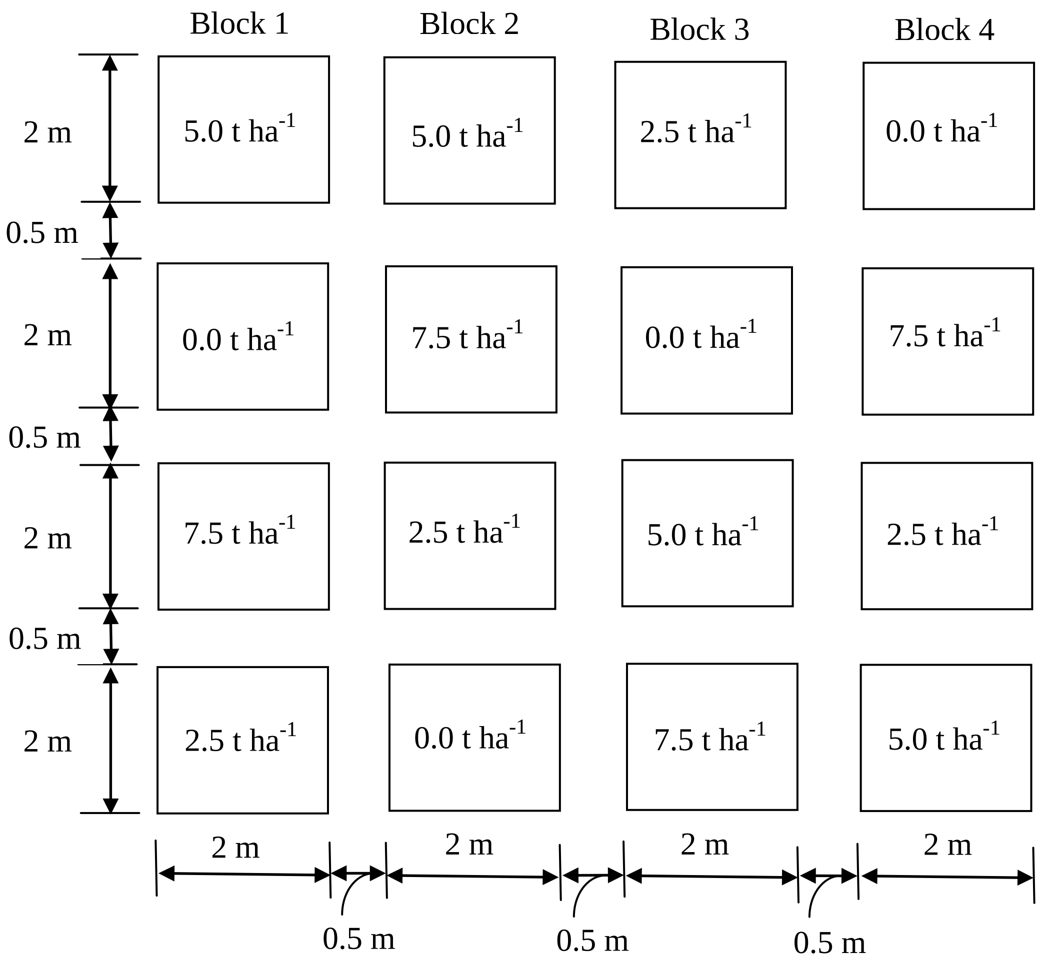

Figure 1 Experimental design field layouts

2.3 Agronomic practices

2.3.1 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 9.5×9.5 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.

2.3.2 Planting

Hybrid maize (Oba Super 1 Premier seeds, commercial hybrid-white) that has a maturity period of 90-95 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}.

2.3.3 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.

2.3.4 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.

2.4 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 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 (Ca, Mg, K and Na) in the soil were determined using method described in Burt (2014).

2.5 Plant data collection

2.5.1 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 tea selling. 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).

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

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

2.5.2 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 and 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^{o}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 ears (cob and grains) and 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 corn ear yield (kg) per plot and the stover yield (kg) per plot were converted into corn ear yield (kg) per ha and stover yields (kg) per ha 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 also converted into grain yields (kg) per ha by multiplying it by 367.65. Harvest index (HI) was computed using Equation 2.

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

2.6 Statistical analysis

All the data that were collected from the field experiments on soil properties, growth and yield characteristics of maize were subjected to analysis of variance (ANOVA) test at $p \leq 0.05$. Treatment means were compared using the least significant difference (LSD) at $p \leq 0.05$. Two statistical packages, SPSS 16 and Mini-tab 20 for windows, were used for the statistical analysis.

3 Results and discussions

3.1 Soil properties of the experimental site before the experiment

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

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 (OM), total nitrogen (N), available phosphorus (P), exchangeable calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) were low.

3.2 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 ($p \leq 0.05$) effect on soil bulk density, soil porosity and water holding capacity. Soil bulk density was found to significantly decrease ($p \leq 0.05$) with increase in groundnut shell application rate while soil porosity and water holding capacity were found to significantly increase ($p \leq 0.05$) with increase in groundnut shell application rate. However, there was no significant statistical difference in bulk densities between 2.5 t ha^{-1} and 5.0 t ha^{-1} groundnut shell incorporation rates treated plots. So, physical characteristics of soil were improved by the application of groundnut shells. This is in line with Gani et al. (2020) who observed that organic fertilizer improved soil biological and physical properties.

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^a	42.63^d	81.0^d
2.5 t ha^{-1}	1.35^b	45.56^c	83.6^c
5.0 t ha^{-1}	1.33^b	45.71^b	84.8^b
7.5 t ha^{-1}	1.28^c	47.76^a	87.3^a
P-value	0.000	0.000	0.000
F-LSD $_{0.05}$	0.024	0.020	0.189

Note: Means having the same letter in the same columns are not significantly different at $p \leq 0.05$

3.3 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 ($p \leq 0.05$) positive effect on soil pH, organic matter, N, P, Ca, Mg, K, Na and total exchangeable bases (TEB). The soil chemical properties investigated were found to increase with increase in groundnut shell application rate. The highest soil pH (6.3), organic matter (3.10%), N (0.29%), P (18.74%), Ca (2.82 cmol (+) kg^{-1}), Mg (1.90 cmol (+) kg^{-1}), K (0.47 cmol (+) kg^{-1}), Na (0.31 cmol (+) kg^{-1}) and TEB (5.50 cmol (+) kg^{-1}) were observed in plots treated with 7.5 t ha^{-1} groundnut shell application rate while the lowest soil pH (5.5), organic matter (1.82%), N (0.13%), P (11.55%), Ca (1.91 cmol (+) kg^{-1}), Mg (1.61 cmol (+) kg^{-1}), K (0.27 cmol (+) kg^{-1}), Na (0.23 cmol (+) kg^{-1}) and TEB (4.02 cmol (+) kg^{-1}) were observed in plots treated with 0.0 t ha^{-1} groundnut shell application rate (control plots). The multiple comparison of means indicated that the mean soil pH, organic matter, N, P, Ca, Mg, K, Na and TEB were statistically ($p \leq 0.05$) different among the treatments. However, there were no significant differences between 5.0 t ha^{-1} and 7.5 t ha^{-1} groundnut shell treated plots for total N and Mg contents. There were also no significant differences between 2.5 t ha^{-1} and 5.0 t ha^{-1} groundnut shell treated plots for K and Na contents. Chemical characteristics of soil were improved by the application of groundnut shells. This agrees with Gani et al. (2020) who observed that organic fertilizer improved mineral nutrient status as well as soil biological and physical properties.

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

Treatment	Soil chemical properties								
	pH (H_2O)	OM (%)	Total N (%)	Avail. P (%)	Ca ←	Mg	K [cmol (+) kg^{-1}]	Na	TEB →
0.0 t ha^{-1}	5.5^d	1.82^d	0.13^c	11.55^d	1.91^d	1.61^c	0.27^c	0.23^c	4.02^d
2.5 t ha^{-1}	5.8^c	2.76^c	0.24^b	15.62^c	2.53^c	1.78^b	0.44^b	0.26^b	5.01^c
5.0 t ha^{-1}	5.9^b	2.90^b	0.28^a	17.06^b	2.74^b	1.88^a	0.44^b	0.28^b	5.34^b
7.5 t ha^{-1}	6.3^a	3.10^a	0.29^a	18.74^a	2.82^a	1.90^a	0.47^a	0.31^a	5.50^a
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F-LSD $_{0.05}$	0.069	0.014	0.020	0.031	0.024	0.049	0.024	0.020	0.014

Note: Means having the same letter in the same columns are not significantly different at $p \leq 0.05$

3.4 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.

3.4.1 Days to 50% flowering

The results showed that groundnut shell treatment had a significant ($p \leq 0.05$) positive effect on number of days to 50% flowering. Groundnut shell application significantly reduced the number of days to 50% tea selling 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 and were statistically significant at $p \leq 0.05$ (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).

3.4.2 Plant height

Plant height indicates the influence of various nutrients on plant metabolism. The results showed that groundnut shells treatments had a significant and different ($p \leq 0.05$) positive effect on the plant height. Increasing the rates of groundnut shell incorporation resulted to a significant increase in plant height. 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 N (Khan et al., 2008) which promoted fast growth and development of the maize plants.

3.4.3 Stem girth

The groundnut shell incorporation had significant ($p \leq 0.05$) effect on the stem diameter of maize plants. Plant girth significantly 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 found that groundnut shell is an excellent fertilizer material because of its high N, P and K 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.

3.4.4 Number of leaves

The number of leaves significantly increased ($p \le 0.05$) with increasing rates of groundnut shell incorporation. Groundnut shells incorporation rate of 7.5 t ha^{-1} produced the maximum number of leaves while groundnut shells incorporation rate of 0.0 t ha^{-1} recorded the least number of leaves and were statistically significant at $p \le 0.05$ (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 availability especially N (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.

3.4.5 Leaf area

The results showed that groundnut shells treatments significantly increased ($p \le 0.05$) the leaf area (Table 4) with increasing rates of groundnut shell. 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} (control or no-treatment plot). The multiple comparison of means showed that the mean leaf areas were statistically ($p \le 0.05$) different among all the treatments.

3.4.6 Leaf area index

Leaf area index was significantly ($p \le 0.05$) 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). However, there was no significant statistical difference in the mean leaf area indexes between 2.5 t ha^{-1} and 5.0 t ha^{-1} groundnut shell incorporation rates. 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.

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

Treatment	Maize growth parameters					
	Days to 50% teaselling	Plant height (cm)	Stem girth (cm)	Number of leaves	Leaf area (cm^2)	Leaf area index
0.0 t ha^{-1}	54.0^a	93.5^d	2.3^d	6.0^c	32.0^d	0.0864^c
2.5 t ha^{-1}	53.0^a	142.4^c	2.7^c	7.0^b	35.8^c	0.1128^b
5.0 t ha^{-1}	50.0^b	156.9^b	3.3^b	7.0^b	40.2^b	0.1266^b
7.5 t ha^{-1}	49.0^b	178.3^a	3.5^a	8.0^a	41.5^a	0.1494^a
P-value	0.000	0.000	0.000	0.000	0.000	0.000
F-LSD $_{0.05}$	2.516	0.316	0.189	0.316	1.258	0.020

Note: Means having the same letter in the same columns are not significantly different at $p \le 0.05$

3.5 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.

3.5.1 Cob length

Cob length is a yield component and a determinant of overall maize yield. Application rates of groundnut shell significantly ($p \le 0.05$) increased cob length. Entries of 0.0 to 7.5 t ha^{-1} groundnut shell maximize cob length. The multiple comparison of means showed that the mean cobs lengths were statistically ($p \le 0.05$) different among all the treatments. 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.

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

3.5.3 Seed weight per plant

The results showed significant ($p \leq 0.05$) differences that increased with higher treatment rates 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 significantly ($p \leq 0.05$) heaviest maize seed weight per plant (68.98 g) while the 0.0 t ha^{-1} treatment rate produced the significantly ($p \leq 0.05$) 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.

3.5.4 Hundred seed weight

Hundred seed weight varied significantly ($p \leq 0.05$) 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).

3.5.5 Stover yield

The stover weight of maize plant was significantly ($p \leq 0.05$) affected by groundnut shell application. The groundnut shell application rate of 7.5 t ha^{-1} had the significantly highest stover weight while the groundnut shell application rate of 0.0 t ha^{-1} had the significantly 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).

3.5.6 Corn ear yield

Application of groundnut shell significantly ($p \leq 0.05$) increased the corn ear yield with a significantly maximum value of 7.16 t ha^{-1} at 7.5 t ha^{-1} groundnut shell application rate and a significantly minimum value of 5.12 t ha^{-1} at 0.0 t ha^{-1} groundnut shell application rate. This agreed with findings of Uzoma et al. (2011) who reported that 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.

3.5.7 Grain yield

Application of groundnut shell significantly ($p \leq 0.05$) increased the parameter with a significantly maximum grain yield of maize (5.78 t ha^{-1}) at 7.5 t ha^{-1} groundnut shell application rate and a significantly 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.

3.5.8 Harvest index

Application of groundnut shell significantly ($p \le 0.05$) increased the harvest index with a significantly maximum harvest index of 0.38 at 7.5 t ha^{-1} groundnut shell application rate and a significantly minimum harvest index of 0.27 at 0.0 t ha^{-1} application rate. The multiple comparison of means showed that the mean harvest indexes were statistically ($p \le 0.05$) different among all the treatments.

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^{-1})	Corn ear yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index
0.0 t ha^{-1}	13.50^{d}	312^{d}	48.57^{d}	21.22^{d}	6.52^{d}	5.12^{d}	3.11^{d}	0.27^{d}
2.5 t ha^{-1}	14.75^{c}	362^{c}	59.82^{c}	24.68^{c}	6.98^{c}	5.74^{c}	4.28^{c}	0.34^{c}
5.0 t ha^{-1}	16.00^{b}	418^{b}	63.54^{b}	25.75^{b}	7.35^{b}	6.80^{b}	5.10^{b}	0.36^{b}
7.5 t ha^{-1}	17.40^{a}	474^{a}	68.98^{a}	27.90^{a}	8.10^{a}	7.16^{a}	5.78^{a}	0.38^{a}
P-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F-LSD $_{0.05}$	0.316	7.548	0.049	0.138	0.327	0.014	0.069	0.014

Note: Means having the same letter in the same columns are not significantly different at $p \le 0.05$

4 Conclusions

From the results it may be concluded that growth and yield of maize variety were significantly ($p \le 0.05$) influenced by different levels of groundnut shell incorporation. The plant growth was significantly increased by application of groundnut shell at different levels. Consecutively, the variety produced the significantly 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 favourable levels. Dosage of the fertilizers (concentration levels) had an increment effect on the plant height, average number of leaves, stem girth, leaf area and leaf area index, this implies the higher the dosage the higher the growth performance which can be attributed to the increased amount of nutrients in higher dosage of fertilizers. Hence, the higher nutrients in higher dosage were used for the development of important parts of the plants such as higher foliage and longer shoot. The reason behind this increment is because in higher dosage of fertilizers, there are more nutrients for the synthesis of various other nutrients, chemicals and anti-nutrients in the maize plant.

References

Aikins, S. H. M., and J. J. Afuakwa. 2012. Effect of four different tillage practices on soil physical properties under cowpea. *Agriculture and Biology Journal of North America*, 3(1): 17-24.

Ano, A. O., and J. A. Agwu. 2005. Effect of animal manures on selected soil chemical properties, organic matter, pH, exchangeable Ca, and Mg. *Nigerian Journal of Soil Science*, 15: 14-19.

Anon. 2002. Agricultural issue on compost controversy. Acres U. S. A, June, pp. 20.

Asai, H., B. K. Samson, H. M. Stephan, K. Songyikhangsuthor, K. Homma, Y. Kiyono, Y. Inoue, T. Shiraiwa, and T. Horie. 2009. Biochar amendment techniques for upland rice production in Northern Lagos: 1. Soil physical properties, leaf SPAD and grain yield. *Field Crops Research*, 111(1-2): 81-84.

Bansal, U. K., D. R. Satija, and K. L. Ahula. 1993. Oil composition of diverse groundnut (*Arachis hypogaea* L.) genotype relation to different environment. *Journal of the Science of Food Agriculture*, 63(1): 17-19.

Brady, N. C., and R. R. Weil. 2008. *The Nature and Properties of Soils*. 14th ed. Upper Saddle River, N.J.: Pearson Education Inc.

Burt, R. 2014. Soil survey field and laboratory methods manual. *Soil Survey Investigations Report*, 2(51): 181-387.

Dongmeza, E., S. Steinbronn, G. Francis, U. Focken, and K. Becker. 2009. Investigations on the nutrient and antinutrient content of typical plants used as fish feed in small scale aquaculture in the mountainous regions of Northern Vietnam. *Animal Feed Science and Technology*, 149(1-2): 162-178.

Efthimiadou, A., D. Bilalis, A. Karkanis, and B. Froud-Williams. 2010. Combined organic/inorganic fertilization enhance soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. *Australian Journal of Crop Science*, 4(9): 722-729.

El-Haggar, S. M., G. Mounir, and L. Gennaro. 2010. Agricultural waste as energy source in developing countries: a case study in Egypt on the utilization of agricultural waste through complexes. Available at: http://www2.hcmuaf.edu.vn/data/quoctuan/Agricultural%20waste%20as%20an%20energy%20source%20in%20developing%20countries(1).pdf. Accessed: 14-08-2020.

Elings, A. 2000. Estimation of leaf area in tropical maize. *Agronomy Journal*, 92(3): 436-444.

Fening, J. O., T. Adjei-Gyapong, E. Yeboah, E. O. Ampontuah, G. Quansah, and S. K. A. Danso. 2005. Soil fertility status and potential organic inputs for improving small holder crop production in the interior savannah zone of Ghana. *Journal of Sustainable Agriculture*, 25(4): 69-92.

Gani, A. T., C. A. Odey, and A. Christopher. 2020. Effects of compost tea application on soil properties, growth and yield of amaranthus (*Amaranthus caudatus* L) in Wukari, Northern Guinea Savanna, Nigeria. *Asian Soil Research Journal*, 4(1): 34-42.

Karanja, N.K., F.O. Ajuke and M.J. Swift. 2006. Organic resources quality and soil fauna: their role on the microbial biomass, decomposition and nutrient release patterns in Kenyan soils. Tropical and Subtropical Agroecosystems, 6(2): 73-86.

Khan, H. Z., M. A. Malik, and M. F. Saleem. 2008. Effect of rate and source of organic material on the production potential of spring maize (*Zea mays* L.). *Pakistan Journal of Agricultural Science*, 45(1): 40-43.

Lubwama, M., and V. Yiga. 2017. Development of groundnut shells and bagasse briquettes as sustainable fuel sources for domestic cooking applications in Uganda. *Renewable Energy*, 111: 532-542.

Lucas, E. O. 1986. The effect of density and nitrogen fertilizer on the growth and yield of maize (*Zea mays* L.) in Nigeria. *The Journal of Agricultural Science*, 107(3): 573-578.

Maobe, S. N., M. W. K. Mburu, L. S. M. Akundabweni, J. K. Ndufa, J. G. Mureithi, C. K. K. Gaehene, F. W. Makini, and J. J. Okello. 2010. Residual effect of *Macuna pruriens* green manure application rate on maize (*Zea mays* L.) grain yield. *World Journal of Agricultural Sciences*, 6(6): 720-727.

Masarirambi, M. T., M. B. Mbokazi, P. K. Wahome, and T. O. Oseni. 2012. Effect of kraal manure, chicken manure and inorganic fertilizer on growth and yield of lettuce (*Lactuca sativa* L. var Commander) in a semi-arid environment. *Asian Journal of Agricultural Sciences*, 4(1): 58-64.

Mojiri, A., A. Jalalian, and H. Radnezhad. 2011. Effects of urban waste water treatments on chemical properties of saline and alkaline soil. *Journal of Applied Science Research*, 7: 222-228.

Msibi, B. M., W. O. Mukabwe, A. M. Manyatsi, N. Mhazo, and M. T. Masarirambi. 2014. Effects of liquid manure on growth and yield of spinach (*Beta vulgaris var cicla*) in a sub-tropical environment in Swaziland. *Asian Journal of Agricultural Sciences*, 6(2): 40-47.

Nalluri, N., and V. R. Karri. 2018. Use of groundnut shell compost as a natural fertilizer for the cultivation of vegetable plants. *International Journal of Advance Research in Science and Engineering*, 7(1): 97-104.

Nautiyal, P. C. 2002. Groundnut: post-harvest operation. Available at: http://www.fao.org/fileadmin/user_upload/inpho/docs /Post_Harvest_ Compendium_-_Groundnut.pdf. Accessed: 14-08-2020.

Nirmala, N., and R. K. Vasavi. 2018. Use of groundnut shell compost as a natural fertilizer for the cultivation of vegetable plants. *International Journal of Advance Research in Science and Engineering*, 7(1): 97-104.

Nottfige, D. O., S. O. Ojeniyi, and D. O. Asawalam. 2005. Comparative effect of plant residues and NPK fertilizer on nutrient status and yield of maize (*Zea mays* L.) in a humid ultisol. *Nigerian Journal of Soil Science*, 15: 1-8.

Nwanosike, M. R. O. 2011. Economic analysis of groundnut enterprises in Rafi local government area of Niger state, Nigeria. *International Research Journal of Applied and Basic Science*, 2(4): 155-162.

Okoroafor, I. B, E. O. Okelola, O. N. Edeh, V. C. Emehute, C. N. Onu, T. C. Nwaneri, and G. I. Chinaka. 2013. Effect of organic manure on the growth and yield performance of maize in Ishiagu, Ebonyi State, Nigeria. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 5(4): 28-31.

Olowoake, A. A., and J. A. Ojo. 2014. Effect of fertilizer types on the growth and yield of *Amaranthus caudatus* in Ilorin, Southern guinea, savanna zone of Nigeria. *Advances in Agriculture*, Volume 2014, pp 1-5.

Oriola, F., and G. Moses. 2010. Groundnut shell ash stabilization of black cotton soil. *Electronic Journal of Geotechnical*

Engineering, 15(1): 415-428.

Sadeghi, H., and M. J. Bahrani. 2009. Effects of crop residue a nitrogen rates on yield and yield components of two dry land wheat (*Triticum aestivum* L.) cultivars. *Plant Production Science*, 12(4): 497-502.

Silveira, A. P. D., and E. J. B. N. Cardoso. 2004. Arbuscular mycorrhiza and kinetic parameters of phosphorus absorption by bean plants. *Agricultural Science*, 61(2): 203-209.

Sim, E. W. 2011. Isolation and determination of anti-nutritional compounds from roots and shells of peanut (*Arachis hypogaea*). Unpublished Bachelor of Science (B.Sc) Project, Department of Chemical Science, Faculty of Science, Universiti Tunku Abdul Rahman, Malaysia. 90 pp.

Steiner, C., W. G. Teixeira, J. Lehmann, T. Nehls, J. L. V. de Macêdo, W. E. H. Blum, and W. Zech. 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and Soil*, 292(1): 275-290.

Umeh, P. P., K. F. Nkwocha, and S. O. Iheukwumere. 2019. Geographical analysis of household waste generation and disposal in Taraba state, northeast Nigeria. *International Journal of Geography and Geology*, 8(2): 58-68.

Uzoma, K. C., M. Inoue, H. Andry, H. Fujimaki, A. Zahoor, and E. Nishihara. 2011. Effect of cow manure biochar on maize productivity under sandy soil condition. *Soil Use and Management*, 27(2): 205-212.

Vara Prasad, P. V., V. G. Kakani, and H. D. Upadhyaya. 2010. Growth and production of groundnuts. In *Soil, Plant Growth and Crop Production*, *vol. II*. Oxford, UK: Encyclopedia of Life Support Systems (EOLSS).