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Organic amendment of an ultisol: effects on soil properties, growth, and yield of maize in Southern Guinea savanna zone of Nigeria

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Abstract

Background: The Southern Guinea savanna zone of Nigeria is characterized by inherently low soil fertility status and rapid nutrient depletion especially soil organic matter. However, this zone is characterized by abundant agricultural land and is a potential for crop production. Field experiments were conducted in order to evaluate the effects of integrated use of agricultural waste materials and compound mineral fertilizer on soil and plant nutrient status, growth, and yield of maize in ultisol in the Southern Guinea savanna zone of Nigeria.

Results: Application of organic waste alone and in combination with mineral fertilizer enhanced root and shoot biomass, leaf area development, and yield and components of maize. Treatment effects were significant on growth characteristics of maize (stem girth, leaf area, plant height and days to 50% tasselling, root and shoot biomass). Sole application of NPK fertilizer (400 kg/ha) was not significant over the combined use of poultry manure and NPK on girth, leaf area, and plant height. Mean values of stem girth, leaf area, and plant height ranged between 2.05 and 3.8 cm, 0.26 and 0.54 m², and 84.7 and 209.4 cm, respectively. Root and shoot dry weights were highest under sole NPK application compared with plots where either sole wastes or wastes in combination with reduced NPK were applied. Integrated use of agricultural wastes and NPK also enhanced root and shoot dry weights compared with sole application of wastes as well as seed weight per plant, 100-seed weight, and number of seeds per cob and grain yield. Among the agricultural wastes applied, poultry manure enhanced the growth and seed yield characteristics of maize. This treatment increased the seed weight per plant, number of seeds per cob, 100-seed weight and seed yield by 55.6%, 66.5%, and 55.4%, respectively over *Chromolaena* and neem seed cake. *Chromolaena* and neem seed cake produced similar grain weight per plant, 100-seed weight, number of seed per cob, and seed yield. Poultry manure significantly enhanced the growth and seed yield characteristics of maize over *Chromolaena* and neem seed cake.

Conclusions: Integrated use of organic wastes and mineral NPK fertilizer showed promising potential for improving soil fertility, growth, and yield of maize in the Southern Guinea savanna agroecological zone of Nigeria. It is recommended that poultry manure at 7 t/ha plus NPK fertilizer at 200 kg/ha be adopted for maize cultivation in the study area.

Keywords: Tropics, Savanna, Soil, Organic, Amendment, Maize

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Background

Maize (*Zea mays* L) is an important cereal crop in the humid and subhumid tropics; the crop which is an important source of carbohydrate (70.4%) is consumed by man as cornflakes and maize meal. 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. In Nigeria, the soils of the Southern 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 fertilizers 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; Ano and Agwu 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).

In circumstances of the problems associated with the use of chemical fertilizers, (Ano and Agwu 2005) recommended the combined use of organic and inorganic manures as soil amendment for increasing crop productivity in the Southern Guinea savanna agroecology. The merits of organic over inorganic fertilizers include better crop establishment and improved efficiency of the utilization of applied materials (Odu and Mba 1991). However, the use of organic fertilizer alone is faced with limitations, such as slow decomposition and mineralization rates, bulkiness, and dirt. Integrated use of inorganic and organic fertilizers is therefore required for sustainable soil and crop productivity. Integrated use of organic wastes and mineral fertilizer is reported to reduce the cost and amount of fertilizer required by crops (IAEA 2003; Krupnik et al. 2004; Dobermann and Cassmann 2004). Also, Bair (1990) reported that proper soil fertility management and sustainable agriculture can be achieved with the use of both mineral fertilizer and organic manure. Paul and Mannan (2006) suggested that integrated nutrient management through combined use of organic wastes and chemical fertilizers can be an effective approach to combat nutrient depletion and promote sustainable crop productivity. Practices which focus on recycling agricultural wastes into the soil would contribute to the improvement in the quality of the environment and soil health.

There is a dearth of information on the effect of integrated soil fertility management using agricultural wastes and mineral fertilizer on physical and chemical properties

of the ultisols of the Southern Guinea savanna zone of Nigeria, an agroecological that is characterized by inherently low soil fertility status, and rapid nutrient depletion especially on soil organic matter. However, the Southern Guinea savanna is also characterized by abundant agricultural land and is a high potential for crop production. This study examines the effects of integrated management of some agricultural waste materials and mineral fertilizer (commercially available compound fertilizer containing nitrogen, phosphorus, and potassium (NPK)) on the growth and yield of maize in the Southern Guinea savanna zone of Nigeria.

Methods

Experimental site and conditions

Field experiments were conducted at the Lower Niger River Basin Development Authority farm located in Ejiba, Agba, West Local Government Area, Kogi State, Nigeria. Ejiba is located on latitude 8°0, 18'N and longitude 5°0, 39'E in the Southern Guinea savanna agroecological zone of Nigeria. The soil in Ejiba is an ultisol. In the study area, rainfall is monomodal from April to September.

Field experiments and treatments

The experiments were conducted in 2008 and 2009, and involved the sole application of six agricultural wastes and in combination with reduced rate of NPK (120 kg/ha). The treatments were arranged using randomized complete block design in three replicates.

Crop establishment

Each year, an experiment was conducted using a 35 × 29-m field plots which was laid out into three blocks with a 1-m guard row between blocks. Each block consisted of 14 plots (5 × 4 m) and a 0.5-m guard row between plots.

Chemical analysis of organic materials

Poultry manure was obtained from Speedy Farms, Isanlu, Nigeria. Melon shell was obtained from a melon shelling plant, and shoots (foliage) of *Parkia* and *Chromolaena odorata* were obtained from the ADP office of Isanlu. Samples from these agricultural wastes were analyzed in the laboratory for their chemical composition.

Soil sampling and analysis

Surface soil samples (0 to 15 cm in depth) were taken randomly on plot basis before planting and at crop maturity. The samples were bulked, air-dried, and sieved using a 2-mm sieve and were analyzed for physical and chemical properties using standard procedure (AOAC International 2005).

Leaf nutrient analysis

The three topmost leaves of maize plant and from five plants per plot were collected for laboratory analysis (N, P, K, Ca, and Mg). The samples were oven-dried at 80°C for 48 h before grinding using a Willey mill before they were subjected to a routine chemical analysis.

Determination of growth and yield parameters

Ten plants were randomly selected at the center of each plot for the determination of growth and yield characteristics. Measurements were made on plant height, stem girth (using Vernier calliper) and leaf area while 147 days to 50% tasselling was noted. At plant harvest (90 days after planting (DAP)), tagged plants were carefully uprooted, and soil particles were washed off the plant using moderate jets of water. Root and shoot fresh biomass were oven-dried at 80°C for 48 h to obtain their dry weights. Shelled seeds were air-dried to 14% moisture content.

All the data that were collected from the field experiments on soil properties, growth, and seed yield characteristics of maize were subjected to ANOVA test. Treatment means were compared using Duncan's multiple range test (Steel and Torrie 1987).

Results and discussion

Soil properties of the experimental site before planting and at crop harvest

The properties of the soil at the site of the experiment is presented in Table 1. The soils are predominantly sandy and slightly acidic with a relatively high bulk density. The organic matter, total nitrogen, available phosphorus, exchangeable potassium, and calcium were low.

Table 1 Physical and chemical properties of soil (0 to 15 cm) before the experiment

Properties	2008	2009	Mean
Sand (%)	54.8	60.4	57.6
Clay (%)	27.2	24.0	25.2
Silt (%)	18.0	15.6	16.8
Soil texture	Sandy clay loam	Sandy clay loam	
pH (H ₂ O)	5.9	5.5	5.7
Bulk density (gcm ⁻³)	1.31	1.47	1.39
Total porosity (%)	41.1	43.3	42.2
Organic matter (%)	1.93	1.83	1.88
Total N (%)	0.18	0.09	0.14
Available P (mg kg ⁻¹)	2.34	2.74	2.54
Exchangeable K (cmol kg ⁻¹)	0.22	0.16	0.19
Exchangeable Ca (cmol kg ⁻¹)	2.60	1.91	2.26
Exchangeable Mg (cmol kg ⁻¹)	3.39	1.80	2.60

The results of the effect of application of agricultural wastes and mineral fertilizer on soil chemical properties are presented in Table 2. The results show that the application of agricultural waste alone or in combination with NPK fertilizer did not significantly affect the soil pH in 2008 and 2009. However, a reduction in soil pH was observed in 2009 as compared with the soil pH in 2008. Soil organic matter, N, available P, K, Ca, and Mg, were all significantly affected by organic amendments alone or in combination with the NPK fertilizer. Plots where agricultural wastes and reduced level of NPK were applied had higher soil organic matter, nitrogen, available P, and Mg except in plots treated with melon shell. Poultry manure (7 t/ha) plus NPK (120 kg/ha) recorded the highest values of soil organic matter (SOM), N, and P, in 2008, and SOM and P in the 2009 cropping season. In 2009, unamended plots (control) recorded the least value of SOM, N, and P. It was observed in this study that combined applications of organic residues and NPK fertilizer produced a greater increase in soil chemical properties when compared with organic residues alone.

Effects of agricultural wastes and mineral fertilizer on the growth and yield characteristics of maize

The results of the field experiments show that the effects of sole application of agricultural wastes and in combination with a compound mineral fertilizer were pronounced on the growth and yield characteristics of maize. The effects of the treatment varied on the growth (stem girth, leaf area, plant height, days to 50% tasselling, root and shoot biomass) and seed yield (seed weight per plant, 100-seed weight, and number of seeds per cob and grain yield) characteristics of maize. Generally, the seed weight per plant, 100-seed weight, number of seeds per cob, and grain yield increased under sole application of agricultural wastes or in combination with NPK as compared with the unamended (control) plot (Tables 3 and 4). The combined application of poultry manure and NPK fertilizer produced the highest values of root and shoot biomass and seed yield of maize. Interaction effects of agricultural wastes and NPK fertilizer were not significant ($P = 0.05$) on the soil's physical and chemical properties and on the growth and seed yield of maize.

The result shows that there were significant treatment effects on stem girth, leaf area, plant height, and days to 50% tasselling of maize. Plot treated with poultry manure at 7 t/ha and 120 kg/ha NPK produced the highest value of stem girth, leaf area, and plant height. Sole application of NPK fertilizer (400 kg/ha) was not statistically better than the combined use of poultry manure and NPK in terms of stem girth, leaf area, and plant height (Table 3). However, least stem girth, leaf area, and

Table 2 Effect of application of agricultural waste and mineral fertilizer on soil chemical properties at crop harvest

Treatment	Soil pH (H ₂ O)		SOM (%)		N (%)		P (mg/kg)		K (cmol/kg soil)		Ca (cmol/kg soil)		Mg (cmol/kg soil)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
NPK	5.5	5.9	1.8 ^c	2.1 ^f	0.13 ^{ab}	0.19 ^{cde}	3.47 ^{bcd}	5.63 ^b	0.17 ^b	0.53 ^a	1.0 ^d	3.2 ^a	0.4 ^e	1.6 ^{abc}
Chr	5.7	6.1	2.7 ^b	3.2 ^{bc}	0.11 ^{bc}	0.21 ^{bcd}	2.18 ^e	6.63 ^a	0.25 ^a	0.48 ^{ab}	1.8 ^{ab}	2.0 ^{ef}	0.8 ^{bdd}	1.3 ^{cd}
Chr + NPK	5.8	6.1	2.9 ^{ab}	3.8 ^a	0.15 ^a	0.24 ^{abc}	3.41 ^{bcd}	6.62 ^a	0.23 ^{ab}	0.44 ^{ab}	1.2 ^{cd}	2.4 ^{cd}	0.5 ^d	1.6 ^{abc}
Nm	5.6	6.0	2.1 ^c	2.9 ^{cd}	0.08 ^c	0.15 ^{ef}	3.26 ^{bcd}	5.09 ^{bc}	0.27 ^{ab}	0.18 ^c	1.1 ^d	2.1 ^{df}	0.5 ^d	1.5 ^{bc}
Nm + NPK	5.6	6.3	2.6 ^b	3.0 ^c	0.10 ^c	0.18 ^{de}	3.32 ^{bcd}	5.63 ^b	0.25 ^{ab}	0.25 ^c	1.8 ^{ab}	1.8 ^f	0.7 ^{bcd}	1.8 ^{ab}
Pak	5.7	6.0	2.0 ^c	2.7 ^{de}	0.09 ^c	0.26 ^{ab}	2.88 ^{cde}	6.16 ^{ab}	0.16 ^b	0.43 ^{ab}	1.0 ^d	2.1 ^{df}	0.6 ^{cd}	0.9 ^{de}
Pak + NPK	5.6	6.1	2.4 ^c	2.9 ^{cd}	0.11 ^{bc}	0.27 ^a	3.52 ^{bcd}	6.85 ^a	0.26 ^{ab}	0.36 ^{abc}	2.0 ^a	2.3 ^{ce}	1.2 ^a	1.3 ^{cd}
Cwd	5.6	6.2	3.0 ^{bc}	3.1 ^c	0.10 ^c	0.26 ^{ab}	1.71 ^e	5.63 ^{ab}	0.22 ^{ab}	0.24 ^c	1.2 ^{cd}	1.8 ^f	0.6 ^{cd}	0.8 ^e
Cwd + NPK	5.5	6.2	3.2 ^{ab}	3.2 ^{bc}	0.13 ^{ab}	0.27 ^a	2.78 ^{cde}	6.36 ^{ab}	0.21 ^{ab}	0.21 ^c	1.5 ^{bc}	2.0 ^{ef}	1.0 ^{ab}	0.9 ^{de}
Ptr	5.8	6.3	3.0 ^{bc}	4.0 ^a	0.14 ^{ab}	0.26 ^{ab}	4.03 ^{abc}	6.86 ^a	0.36 ^a	0.34 ^{abc}	1.2 ^{cd}	2.7 ^{bc}	0.9 ^{abc}	0.9 ^{de}
Ptr + NPK	5.8	6.1	3.7 ^a	4.2 ^a	0.16 ^a	0.24 ^{abc}	4.98 ^a	7.52 ^a	0.20 ^b	0.35 ^{abc}	1.6 ^{ab}	2.9 ^{ab}	0.8 ^{bcd}	2.0 ^a
Mel	5.6	6.2	2.6 ^b	2.5 ^{df}	0.08 ^c	0.15 ^{ef}	2.63 ^{de}	3.89 ^c	0.21 ^{ab}	0.33 ^{bc}	1.8 ^{ab}	3.2 ^a	0.8 ^{bcd}	1.6 ^{abc}
Mel + NPK	5.6	6.2	2.8 ^b	2.1 ^f	0.09 ^c	0.16 ^{ef}	3.37 ^{ab}	6.24 ^{ab}	0.22 ^{ab}	0.31 ^{bc}	1.2 ^{cd}	1.8 ^f	0.8 ^{bcd}	1.3 ^{cd}
Control	5.6	6.0	2.0 ^c	2.0 ^f	0.10 ^c	0.11 ^f	2.74 ^{cde}	2.94 ^d	0.13 ^b	0.26 ^c	1.1 ^d	2.6 ^{bc}	0.9 ^{abc}	1.5 ^{bc}
LSD (0.05)	NS	NS	0.7	0.5	0.04	0.06	0.81	1.54	0.16	0.19	0.48	0.42	0.38	0.38

NPK nitrogen, phosphorus, and potassium fertilizer; Chr *Chromolaena*, Nm *Neem*, Pak *Parkia* leaf; Cwd cow dung; Ptr poultry manure; Mel melon shell, NS not significant. Means followed by the same letter in the same column are not significantly different at $P < 0.05$.

plant height were observed in unamended control. The mean values of stem girth, leaf area, and plant height for 2008 and 2009 experiments ranged between 2.05 and 3.75 cm, 0.26 and 0.54 m², and 84.7 and 209.4 cm, respectively.

Agricultural wastes and mineral fertilizer application significantly reduced days to 50% tasselling in maize. Days to 50% tasselling was earlier (46 DAP) in plots where poultry manure was combined with NPK fertilizer. Plots with NPK fertilizer at optimum rate (400 kg/ha) attained 50% tasselling later (47 DAP), while

unamended control plot had the longest delay in attaining 50% tasselling (54 DAP). Root and shoot dry weights were highest in plots with NPK fertilizer application alone compared with plots treated with either agricultural waste alone or in combination with reduced level of NPK. Plots which had combined application of wastes and NPK fertilizer had the highest values of root and shoot dry weights compared with those with sole application of agricultural wastes.

Table 4 shows results of the effect of application of agricultural wastes and NPK fertilizer on seed weight

Table 3 Effects agricultural waste and mineral fertilizer on growth characteristics of maize

Treatments	Stem girth (cm)		Leaf area (m ²)		Plant height (cm)		Days to 50% tasselling		Root dry weight (g)		Shoot dry weight (g)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
NPK	3.2 ^{bc}	3.1 ^{abc}	0.5 ^a	0.4 ^a	175.1 ^{abc}	191.7 ^{abc}	49.0 ^{cd}	46.0 ^c	49.3 ^a	53.4 ^{ab}	152.2 ^a	136.1 ^a
Chr	3.0 ^{bc}	2.7 ^{cde}	0.4 ^b	0.3 ^b	133.1 ^c	163.7 ^{cd}	51.0 ^{bc}	49.0 ^b	40.0 ^{abc}	44.4 ^{ab}	83.0 ^{bc}	89.8 ^c
Chr + NPK	3.3 ^b	2.9 ^{bcd}	0.4 ^b	0.4 ^a	151.9 ^c	170.5 ^{abcd}	49.0 ^{cd}	49.0 ^b	31.0 ^{bcd}	33.7 ^b	82.0 ^{bc}	84.6 ^c
Nm	2.9 ^c	2.1 ^f	0.2 ^c	0.3 ^b	153.7 ^c	161.0 ^{cd}	51.0 ^{bc}	51.0 ^{ab}	25.1 ^{cd}	30.8 ^b	75.4 ^{bc}	72.4 ^{cd}
Nm + NPK	3.0 ^{bc}	2.6 ^{ef}	0.3 ^b	0.4 ^a	169.9 ^{bc}	166.4 ^{bcd}	50.0 ^c	50.0 ^{ab}	39.1 ^{abc}	41.4 ^{ab}	75.1 ^{bc}	76.3 ^{cd}
Pak	2.9 ^c	2.2 ^f	0.2 ^c	0.3 ^b	149.9 ^c	135.3 ^{de}	51.0 ^{bc}	53.0 ^a	26.0 ^{cd}	36.3 ^b	50.0 ^c	60.9 ^{cd}
Pak + NPK	3.3 ^b	2.7 ^{cde}	0.4 ^b	0.3 ^b	176.5 ^{abc}	152.4 ^{cd}	49.0 ^{cd}	48.0 ^{bc}	32.2 ^{bcd}	34.2 ^b	87.0 ^{bc}	85.4 ^c
Cwd	3.0 ^{bc}	2.1 ^f	0.3 ^c	0.3 ^b	146.4 ^c	144.5 ^{de}	53.0 ^{ab}	50.0 ^{ab}	31.0 ^{bcd}	30.9 ^b	75.0 ^{bc}	79.3 ^{cd}
Cwd + NPK	2.9 ^c	3.3 ^{ab}	0.4 ^b	0.4 ^a	170.3 ^{bc}	191.9 ^{abc}	51.0 ^{bc}	49.0 ^b	35.1 ^{ab}	36.3 ^b	100.2 ^b	94.8 ^{bc}
Ptr	3.9 ^a	3.3 ^{ab}	0.5 ^a	0.4 ^a	206.4 ^{ab}	203.9 ^{ab}	47.0 ^d	46.0 ^c	46.3 ^{ab}	63.4 ^a	185.7 ^a	134.2 ^a
Ptr + NPK	4.0 ^a	3.5 ^a	0.6 ^a	0.5 ^a	213.0 ^a	205.7 ^a	46.0 ^d	46.0 ^c	45.2 ^{ab}	63.8 ^a	150.4 ^a	128.6 ^{ab}
Mel	2.5 ^d	2.3 ^{ef}	0.3 ^b	0.3 ^b	141.5 ^c	141.9 ^{de}	54.0 ^a	53.0 ^a	30.1 ^{bcd}	43.1 ^{ab}	75.1 ^{bc}	63.3 ^{cd}
Mel + NPK	3.2 ^{bc}	2.6 ^{ef}	0.4 ^b	0.4 ^a	167.7 ^{bc}	173.1 ^{abcd}	50.0 ^c	50.0 ^{ab}	37.0 ^{abc}	37.6 ^b	77.4 ^{bc}	70.8 ^{cd}
Control	2.2 ^d	1.9 ^f	0.3 ^c	0.3 ^b	82.7 ^d	109.1 ^e	55.0 ^a	53.0 ^a	18.4 ^d	28.3 ^b	30.3 ^c	42.4 ^d

NPK nitrogen, phosphorus, and potassium fertilizer; Chr *Chromolaena*; Nm *Neem*; Pak *Parkia* leaf; Cwd cow dung; Ptr poultry manure; Mel melon shell. Means followed by the same letter in the same column are not significantly different at $P < 0.05$.

Table 4 Effect of application of agricultural waste and mineral fertilizer on yield and yield component of maize

Treatments	Seed weight per plant (g)		100-seed weight (g)		Number of seeds/cob		Seed yield (t/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009
NPK	778.5 ^{abc}	71.1 ^{bc}	25.91 ^b	21.42 ^{cd}	493 ^{bc}	456 ^b	4.63 ^a	4.19 ^{bc}
Chr	62.4 ^{cd}	64.3 ^c	25.14 ^{bc}	20.98 ^{def}	421 ^d	452 ^b	3.68 ^c	3.79 ^{de}
Chr + NPK	80.1 ^{ab}	70.4 ^{bc}	26.19 ^{ab}	21.10 ^{cde}	503 ^{bc}	585 ^a	4.73 ^a	4.15 ^{ab}
Nm	61.1 ^{cd}	56.7 ^c	25.17 ^{bc}	20.73 ^{def}	401 ^d	356 ^{cd}	3.60 ^c	3.34 ^{de}
Nm + NPK	84.9 ^{ab}	68.0 ^{bc}	25.21 ^b	21.94 ^{bcd}	426 ^d	392 ^{bc}	5.01 ^a	4.01 ^{cd}
Pak	54.9 ^d	59.4 ^c	24.40 ^c	19.40 ^f	398 ^d	331 ^{de}	3.24 ^c	3.50 ^e
Pak + NPK	64.3 ^{cd}	64.8 ^c	25.13 ^{bc}	19.36 ^f	417 ^d	386 ^{cd}	3.79 ^b	3.82 ^d
Cwd	68.1 ^{bc}	68.3 ^{bc}	23.92 ^{bc}	21.92 ^{bcd}	378 ^{de}	392 ^{bc}	4.02 ^b	4.03 ^{bc}
Cwd + NPK	80.1 ^{ab}	86.4 ^{ab}	25.13 ^{bc}	23.92 ^a	464 ^c	571 ^a	4.75 ^a	5.10 ^{ab}
Ptr	81.2 ^{ab}	88.7 ^{ab}	27.62 ^a	22.51 ^{abc}	548 ^{ab}	437 ^b	4.79 ^a	5.23 ^a
Ptr + NPK	88.1 ^a	96.9 ^a	28.73 ^a	23.14 ^{ab}	603 ^a	589 ^a	5.20 ^a	5.72 ^a
Mel	59.8 ^d	34.9 ^d	24.66 ^a	20.33 ^{ef}	368 ^{de}	394 ^{bc}	3.53 ^c	2.06 ^{de}
Mel + NPK	63.4 ^{cd}	63.2 ^c	24.71 ^c	21.94 ^{bcd}	374 ^{de}	345 ^{cde}	3.74 ^b	3.73 ^{de}
Control	49.9 ^d	33.3 ^d	21.24 ^d	16.97 ^f	314 ^e	321 ^e	2.94 ^d	1.96 ^e
LSD (0.05)	18.55	19.42	2.54	1.44	66.12	57.11	0.74	0.62

NPK nitrogen, phosphorus, and potassium fertilizer; Chr *Chromolaena*; Nm Neem; Pak *Parkia* leaf; Cwd cow dung; Ptr poultry manure; Mel melon shell. Means followed by the same letter in the same column are not significantly different at $P < 0.05$.

per plant, 100-seed weight, number of seeds per cob, and grain yield. The results show that there were significant differences in the values of these parameters under combined application of agricultural wastes and NPK fertilizer. Generally, grain weight per plant, 100-seed weight, number of seeds per cob, and grain yield increased in organically amended plots (treated with *Chromolaena*, *Parkia*, neem seed cake, cow dung, poultry manure, and melon shell) and wastes combined with reduce level of NPK compared with the unamended (control) plot. In Table 3, it is also shown that the plots treated with combined application of organic residues (7 t/ha) + NPK 120 kg/ha produced highest seed weight per plant, 100-seed weight, and number of seeds per cob when compared with plots where agricultural wastes alone (10 t/ha) were applied. Combined use of poultry manure and NPK fertilizer recorded the highest seed weight and number of seed per cob which were statistically better than when NPK fertilizer was applied at a recommended rate (400 kg/ha). The unamended (control) plot, however, produced the least value of seed weight, 100-seed weight, number of seed per cob, and grain yield. The combined application of agricultural wastes and NPK fertilizer improved the grain yield of maize as indicated by the increase in seed weight per plant, 100-seed weight, number of seed per cob, and seed yield.

Effect of agricultural wastes and NPK fertilizer on leaf nutrient contents

Table 5 presents the results of the effects of agricultural wastes and NPK fertilizer on leaf nutrient (N, P, K, Ca,

and Mg) contents of maize. Leaf N, K, and Ca were significantly affected by the applied organic residues and NPK fertilizer. However, P and Mg were not significantly affected. All amended plots were slightly higher in leaf N, P, and K when compared with the unamended control. Application NPK alone produced the greatest percentage of leaf N (1.78%) and P (0.61%) when compared with soil amendment with agricultural wastes combined

Table 5 Effect of agricultural wastes and NPK fertilizer application on leaf nutrient contents

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
NPK	1.78 ^b	0.61	1.24 ^b	1.65 ^a	0.38
Chr	1.61 ^{cd}	0.64	1.40 ^{ab}	1.51 ^a	0.40
Chr + NPK	1.50 ^d	0.61	1.58 ^a	1.38 ^b	0.41
Nm	1.82 ^{ab}	0.66	1.36 ^{ab}	1.53 ^b	0.39
Nm + NPK	1.89 ^a	0.55	1.46 ^a	1.39 ^b	0.38
Pak	1.41 ^e	0.55	1.54 ^a	1.48 ^b	0.41
Pak + NPK	1.62 ^{cd}	0.54	1.62 ^a	1.45 ^b	0.38
Cwd	1.54 ^d	0.61	1.53 ^a	1.36 ^b	0.41
Cwd + NPK	1.82 ^{ab}	0.60	1.21 ^b	1.62 ^a	0.39
Ptr	1.64 ^c	0.56	1.16 ^b	1.52 ^a	0.39
Ptr + NPK	1.60 ^{cd}	0.61	1.60 ^a	1.45 ^b	0.41
Mel	1.85 ^a	0.56	1.44 ^{ab}	1.51 ^b	0.38
Mel + NPK	1.79 ^b	0.54	1.38 ^{ab}	1.44 ^b	0.42
Control	1.31 ^f	0.53	1.41 ^{ab}	1.72 ^a	0.40
LSD (0.05)	0.17	NS	1.24	0.23	NS

NPK nitrogen, phosphorus, and potassium fertilizer; Chr *Chromolaena*; Nm Neem; Pak *Parkia* leaf; Cwd cow dung; Ptr poultry manure; Mel melon shell. Means followed by the same letter in the same column are not significantly different at $P < 0.05$.

with NPK fertilizer (Table 4). The unamended control recorded the highest percentage of leaf Ca (1.72%) and Mg (0.45%) contents which were slightly higher than the plots treated with NPK alone or integrated use of agricultural wastes and NPK fertilizer. Application of agricultural wastes and mineral fertilizer improved the nutrient uptake of maize, as shown from the observed slight increases in N, P, and K contents of maize leaves.

The integrated use of agricultural wastes and NPK improved the soil chemical status and the growth and yield characteristics of maize. These observations were consistent with earlier reports of Agele et al. (2011). Improvements in the soil properties in the cited reports were attributed to the enhancement of soil organic matter by the residues applied. Soil chemical properties in organically amended soil were improved over the unamended plots. Soil organic matter, N, P, Ca, and Mg, and pH increased with the application of agricultural wastes or in combination with NPK over the unamended plots. Adeniyani and Ojeniyi (2005) indicated that the application of poultry manure alone or in combination with reduced rates of NPK fertilizer significantly improved the soil chemical properties and nutrient uptake. Soils of the experimental site were deficient in organic matter, N and P. Following the organic amendment, there were improvements in soil chemical properties, and they can be attributed to the mineralization of SOM from decomposing agricultural wastes. Combined application of agricultural wastes and NPK fertilizer irrespective of the types of waste and levels of NPK fertilizer application has improved soil chemical properties. Agricultural waste has been found to increase the contents of nutrients in the soil and its uptake by maize (Adeniyani and Ojeniyi 2005) and tomato (Agele et al. 2011). Seed yield increased under combined use of poultry manure and NPK fertilizer which was significantly higher than the sole application of NPK or agricultural wastes and the unamended control. Percentage increases in yield of NPK fertilizer plus agricultural wastes alone were 25.8% and 29.4%, respectively, in 2008 and 2009. This result implies that integrated application of both agricultural wastes and NPK fertilizer would enhance maize yields over sole NPK and organic wastes.

Conclusions

The study area is located in the Southern Guinea savanna agroecological zone of Nigeria where soils are inherently low in fertility and rapid nutrient depletion especially organic matter. However, the Southern Guinea savanna agroecology is endowed with abundant agricultural land and high potential for crop production. Application of agricultural wastes alone and in combination with reduced rates of NPK fertilizer improved soil properties and significantly increased the growth and yield components of maize. The effects of agricultural waste

alone and in combination with NPK fertilizer were significant on the growth and yield characteristics of maize. Generally, seed weight per plant, 100-seed weight, number of seeds per cob, and grain yield increased under the sole application of agricultural wastes or in combination with NPK compared with unamended treatment. Among the agricultural wastes tested, poultry manure increased the growth and yield characteristics of maize better than *Chromolaena*, *Parkia*, neem seed cake, and melon shell. The integrated use of organic wastes and mineral NPK fertilizer showed a promising potential for improving soil fertility and growth and yield performance of maize in the Southern Guinea savanna agroecology. It is recommended that poultry manure at 7 t/ha plus NPK fertilizer at 200 kg/ha be adopted for maize cultivation in the study area.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KSO carried out the field study, soil and plant analysis, and statistical analysis and helped draft the manuscript. SOA conceived the study, participated in its design and coordination, and helped draft the manuscript. POA participated in the design of the study, performed statistical analysis, and helped draft the manuscript. All authors read and approved the final manuscript.

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