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EFFECT OF TILLAGE, POULTRY MANURE AND NPK FERTILIZER ON SOIL CHEMICAL PROPERTIES AND MAIZE YIELD ON AN ALFISOL AT ABEOKUTA, SOUTH-WESTERN NIGERIA

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ABSTRACT

Tillage is a basic soil management tool which significantly affects soil characteristics and plant development. This study examined 2-year effects of tillage, poultry manure (PM) and NPK 20:10:10 fertilizer on soil chemical properties and maize yield. The experiment was a split-split-plot design with three replications. Tillage (zero tillage (ZT), minimum tillage (MT) and conventional tillage (CT)) was the main plot, the sub-plot comprised three PM treatments (0, 10 and 20 Mg ha^{-1}) while the sub-sub-plot was NPK 20:10:10 fertilizer (applied at 0, 90, 120 and 150 kg N ha^{-1}). At harvest, routine soil chemical properties, maize grain yield and yield parameters were measured. Soil chemical qualities were significantly higher under conservation tillage (ZT and MT) than CT with or without PM treatment and such increments were higher with NPK plus PM than their separate use. The soil organic carbon was higher by 28% and 20% under ZT and MT, respectively compared with CT in 2008 and 79% (ZT) and 65% (MT) compared with CT in 2009. Maize grain yield of 1.61 Mg ha^{-1} (2008) and 2.28 Mg ha^{-1} (2009) under MT were significantly higher than the yields from ZT and CT. Application of NPK plus PM resulted in 18-53% grain yield increments compared with their separate use under the three tillage systems. Therefore, improved soil chemical qualities and higher maize production can be achieved when organic and inorganic fertilizers are jointly applied than their separate use.

Keywords: Alfisol; conservation tillage; maize yield; soil chemical quality

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INTRODUCTION

Selection of tillage to suit crop type, soil and climatic condition is very important to ensure optimum crop productivity. The significance of tillage in relation to soil chemical properties has long been recognised. For instance, manual tillage systems including heaps, ridges or beds have been reported to degrade soil quality, reduce chemical and biological qualities especially in case of Alfisols located in the rain forest areas of south-western Nigeria (Ojeniyi, 1991). Similarly, Lal (1989) reported that soil chemical properties of the surface layer are more favourable under the no-till than the plough-till method. Conversely, tillage operations and its attendant soil surface disturbance generally can cause an increase in soil aeration, residue decomposition, organic N mineralization and the availability of N for plant use (Sainju and Singh, 2001). This suggests that there are conflicting research reports on the influence of tillage on soil chemical properties. Likewise, contradictory reports as to the superiority of crop grown on tilled plots to those of no-tilled plots have been documented. Some researchers reported either no significant differences between tilled and zero-tilled plots or the superiority of no-tilled to tilled plots (Lawrence *et al*., 1994; Merrill *et al*., 1996). Other investigators found significant superiority of tilled plots over no-tilled plots particularly where there was soil moisture stress (Ike, 1989; Jalota *et al*., 2010). Therefore, tillage related research alongside various soil amendments will continue to be relevant in different regions of the world.

The increasing cost of fertilizers and growing concern about deterioration of soil health and environmental quality (Hati *et al*., 2007), calls for effective management strategies capable of reducing input costs and damage to soil environment. Consequently, integrated use of both organic manures and chemical fertilizers has emerged as a promising option, because complimentary use of both fertilizers enhances better nutrient release from organic fertilizer and satisfies crop requirement during the initial stage of crop growth and development. Thus, neither sole chemical fertilizer nor organic manure alone can achieve stability in crop production (Huang *et al*., 2010), whereas integrated application of organic and inorganic manures can significantly raise soil productivity (Busari *et al*., 2008).

Although, there are many reported research findings on tillage and use of organic and inorganic manures, such researches have not been well documented on the interactive effects between tillage and manures and how this interaction relates to crop yield. Therefore, the objective of this study was to determine the interactive effects of tillage, poultry manure and NPK 20:10:10 fertilizer on soil chemical properties and maize yield.

MATERIALS AND METHODS

Location of the study

The study was carried out at the University of Agriculture, Abeokuta, south-western Nigeria in 2008 and 2009. The study site lies between Latitude 7^{o}14' N and Longitude 3^{o}26' E and is located within a forest–savanna transition zone with two distinct seasons - the wet season, which extends from March to October, and the dry season which is usually from November to February. The average annual rainfall of the study area, based on a ten-year record, is 1058.48 mm. The rainfall is bimodal in distribution- usually Mach to July and September to October, with characteristic August break. The mean monthly temperature ranged from 30.0 to 37.0^{o}C in 2008 and 23.5 to 34.4^{o}C in 2009. The mean relative humidity was 68.3%. The soil of the study site is gravelly loamy sand and is underlain by undifferentiated basement complex of an alluvio-colluvial parent material.

Experimental design

The experiment was a split-plot-split factorial design with three replications where the main plot was tillage (zero, minimum and conventional tillage), the sub-plot was poultry manure (PM) (applied at 0, 10 and 20 Mg ha^{-1}) while the sub-sub plot comprised NPK 20:10:10 fertilizer (applied at 0, 90, 120 and 150 kg N ha^{-1}). Under zero tillage (ZT), no ploughing was done and weeds were controlled using herbicide (paraquat). In the minimum tillage (MT), ploughing was done once using tractor coupled with plough while conventional tillage (CT) involved ploughing followed by harrowing mechanically. The tillage operations were not carried out before application of poultry manure in year 2009 but weeds were cleared manually under MT and CT and with the aid of paraquat under ZT. Each plot was 4 m x 5 m with each plot separated by 1 m border. About 4 m margins were left on both sides of each main plot for the tractor to manoeuver without entering into an adjacent plot.

Application of poultry manure

The poultry manure (PM) used for the experiment was collected from a poultry house operating a battery cage system. The PM was applied at 10 Mg ha^{-1} (PM_{10}) and 20 Mg ha^{-1} (PM_{20}) and was incorporated manually into the soil two weeks before planting. Application of PM was done in June 2008 for the first cropping year and was repeated in May 2009 for the second cropping year. Furrow dikes were made manually round each plot to prevent nutrient drifting among plots.

Maize planting and harvesting

Maize (DMR-ESR-Y) was planted two weeks after application of PM at a spacing of 50 cm x 75 cm at 2 seeds per hole. The maize was harvested at 12 weeks after planting (WAP) in both years of cropping.

Soil chemical analysis

Surface soil (0-20 cm) samples were collected after harvest and subjected to routine soil chemical analysis (Carter, 1993). Soil pH was measured in 1:2 soil: water suspension using digital pH meter. Soil organic carbon was determined by the wet combustion method and the soil total nitrogen (TN) by the Kjeldahl method. Exchangeable cations were extracted using 1M Ammonium Acetate pH 7.0 and the cations in the extract were determined by atomic absorption spectrophotometer (AAS). The effective cation exchange capacity (ECEC) was obtained by summation methods. Available phosphorus (Avail P.) was analysed using Bray-1 P extractant and determined colorimetrically by the molybdenum blue procedure.

Yield parameters

Plant height, dry matter, cob and grain yields were measured at maize harvest (12 WAP).

Statistical analysis

Data collected were analyzed using analysis of variance (ANOVA) MIXED MODEL procedure in Statistical Analysis System (SAS, 1999). The significance of the main and interaction effects was determined and significant means were separated using least significant difference (LSD) at 5% level of probability.

RESULTS

Soil texture and chemical characteristics at the onset of the study

At the commencement of the study in 2008, before ploughing, the soil texture and chemical properties determined revealed that the gravelly loamy sand soil had a soil organic carbon (SOC) of 12.1 g kg^{-1} and an effective cation exchange capacity (ECEC) of 9.6 cmol kg^{-1} (Table 1).

Composition of poultry manure used for the experiment

Chemical compositions of the poultry manure (Table 2) used for the experiment showed a C: N ratio of 12.3 and total P of 56.0 g kg^{-1}.

Table 1: Initial Soil Texture and Chemical Properties of the Experimental Site

Parameter	Value
Sand (g kg^{-1})	826
Silt (g kg^{-1})	120
Clay (g kg^{-1})	54
pH	5.9
OC (g kg^{-1})	12.1
N (g kg^{-1})	1.0
Avail. P (mg kg^{-1})	18.25
Exchangeable cations (cmol kg^{-1})	
Ca	6.66
Mg	2.10
K	0.17
Na	0.63
H + Al	0.07
ECEC	9.63
Micronutrients (mg kg^{-1})	
Cu	1.50
Zn	0.88
Mn	14.05
Fe	7.50

Table 2: Chemical Properties of Poultry Manure used for the Experiment

Parameter	Value
pH	6.80
Organic C (g kg^{-1})	264.0
N (g kg^{-1})	21.4
C:N ratio	12.3
Total P (g kg^{-1})	40.2
Total K (g kg^{-1})	1.2
Ca (g kg^{-1})	27.2
Mg (g kg^{-1})	2.6
Na (g kg^{-1})	0.4
Fe (g kg^{-1})	5.6
Cu (mg kg^{-1})	37.3
Kn (mg kg^{-1})	206.6
Mn (mg kg^{-1})	261.0

Effect of tillage on soil chemical properties

Soil pH values of 6.2 and 6.79 obtained after the 2008 and 2009 cropping periods, respectively under MT were significantly higher ($P \leq 0.05$) than pH values under both CT and ZT. Soil pH was however, significantly lower under ZT than CT in 2009 (Table 3). Though, the soil TN was not significantly different among the tillage treatments in 2008, SOC and TN were higher significantly under both MT and ZT than CT at the end of 2009 cropping. The soil Avail. P was similarly affected by CT and ZT which were both significantly higher in Avail. P than MT (Table 3). The Avail. P was, however, very high under all the tillage systems than the pre-planting Avail. P (Table 1) of the soil. The ECEC was significantly higher under ZT than MT and CT at the end of each of the two years of cropping.

Interactive effects of tillage, NPK fertilizer and poultry manure on soil chemical properties

Combined application of NPK fertilizer and PM did not significantly affect soil pH under the three tillage systems but plots that received NPK treatments only had lower pH than NPK + PM treatments at both years of the study (Table 4). Also, there were no significant differences in soil OC content due to combination of NPK with PM in 2008 apart from the OC content of 25.1 g kg^{-1} for 150 kg N ha^{-1} (N_1) + PM_{20} under ZT and 90 kg N ha^{-1} (N_3) + PM_{20} under CT which were significantly higher than their controls (Table 4). In 2009, most plots treated with combinations of NPK and PM had higher OC than the control plots. Plot treated with N_1 + PM_{10} under MT had OC of 47.2 g kg^{-1} which was significantly higher than OC from N_1 + PM_{10} under CT but lower significantly than OC of 70.4 g kg^{-1} under ZT. In most cases, combination of NPK fertilizer with PM led to higher soil OC under MT than CT in year 2009. With the exception of TN of 2.15 g kg^{-1} that was significantly higher in N_2 + PM_{20} than 1.15 g kg^{-1} for the control plots under ZT,

Table 3: Effect of tillage on soil chemical properties after maize harvest

Year	2008					2009				
Tillage	pH (H_2O)	OC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	ECEC (cmol kg^{-1})	pH (H_2O)	OC (g kg^{-1})	TN (g kg^{-1})	Avail. P (mg kg^{-1})	ECEC (cmol kg^{-1})
CT	6.0	16.50	1.38	26.64	6.31	6.69	2.79	0.32	65.59	8.05
MT	6.2	19.80	1.52	24.33	6.24	6.79	4.59	0.55	40.47	8.51
ZT	6.1	21.20	1.58	33.28	7.36	6.64	5.00	0.53	61.13	9.39
LSD ($P \leq 0.05$)	0.05	2.20	ns	7.13	0.49	0.04	0.44	0.08	13.25	0.79

OC = organic carbon; TN = total nitrogen; Avail. P = available phosphorus, ECEC = effective cation exchange capacity; ZT = zero tillage; MT = minimum tillage; CT = conventional tillage; ns = not significant.

Table 4: Interactive effects of tillage, NPK fertilizer and poultry manure on soil chemical properties at the end of the first and second years of the study

Year			2008					2009				
Treatments			pH	OC	TN	Avail. P	ECEC	pH	OC	TN	Avail. P	ECEC
Tillage	NPK	PM	(H_2O)	(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-1})	(H_2O)	(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-1})
ZT	N_0	0	6.10	16.5	1.15	4.18	5.67	6.65	40.9	4.4	13.88	7.77
		10	6.10	30.2	2.60	34.10	7.59	6.60	44.1	4.7	44.20	12.29
		20	6.15	24.8	1.80	45.10	8.27	6.65	45.2	5.0	98.68	9.24
	N_1	0	6.05	17.7	1.55	3.20	4.95	6.55	56.5	6.2	16.90	8.25
		10	6.15	17.5	1.10	44.48	8.67	6.65	70.4	7.5	48.93	9.95
		20	6.05	25.1	1.80	68.45	9.57	6.65	57.4	6.1	74.88	8.82
	N_2	0	5.80	19.8	1.60	6.25	5.17	6.65	38.5	4.0	33.13	9.12
		10	6.15	18.6	0.95	27.05	7.92	6.85	60.8	6.6	79.10	8.89
		20	6.20	22.7	2.15	57.75	8.81	6.60	49.5	5.3	137.43	10.41
	N_3	0		18.6	1.05	4.10	4.47	6.50	48.2	4.9	30.10	7.71
		10	6.20	23.3	1.75	28.43	8.29	6.65	31.4	3.2	78.55	9.13
		20	6.15	20.3	1.40	76.25	9.05	6.70	57.2	6.2	77.75	11.32
MT	N_0	0	6.15	16.7	2.15	5.98	5.01	6.75	29.9	5.9	12.85	8.84
		10	6.20	16.2	1.40	35.05	7.54	6.85	41.9	4.6	59.20	7.58
		20	6.15	17.6	1.75	43.00	8.10	6.75	57.9	11.5	101.65	11.85
	N_1	0	6.05	12.5	1.10	30.58	5.02	6.85	38.4	3.8	14.03	8.13
		10	6.25	17.1	1.60	28.20	6.14	6.70	47.2	4.8	29.68	7.54
		20	6.20	14.8	1.20	30.45	6.64	6.70	40.9	4.4	41.88	9.71
	N_2	0	5.95	15.6	1.30	5.18	4.50	6.75	45.1	3.5	24.73	5.67
		10	6.20	14.2	1.65	24.25	5.02	6.75	39.3	3.8	26.70	11.78
		20	6.20	17.6	0.95	33.33	8.53	6.75	82.4	10.0	57.42	7.61
	N_3	0	6.05	14.6	1.30	2.83	5.66	6.95	35.6	3.9	11.63	7.08
		10	6.15	16.2	1.35	18.78	6.44	6.85	40.9	4.4	48.80	7.34
		20	6.30	15.6	0.85	44.35	6.59	6.85	52.1	5.5	47.03	7.12
CT	N_0	0	5.95	17.4	1.40	4.88	5.29	6.80	16.6	2.1	20.53	6.57
		10	6.05	21.3	1.80	28.68	6.45	6.70	27.7	5.7	115.08	7.52
		20	6.30	22.3	1.70	57.93	9.83	6.70	25.1	2.1	65.03	8.95
	N_1	0	5.85	11.9	0.55	6.30	4.37	6.80	23.5	2.4	15.70	7.19
		10	5.95	21.9	1.60	28.98	6.93	6.70	20.0	2.1	47.63	10.39
		20	6.05	18.7	1.70	30.30	5.43	6.65	45.2	4.7	125.00	6.92
	N_2	0	5.85	20.7	1.95	10.08	4.24	6.60	27.1	3.0	23.60	6.75
		10	5.90	14.2	1.10	13.55	5.24	6.80	16.2	1.9	41.20	7.21
		20	6.00	20.5	1.30	52.80	6.28	6.50	31.4	3.1	123.58	8.02
	N_3	0	5.95	16.9	0.85	7.13	5.20	6.60	22.2	2.2	27.93	8.22
		10	6.05	21.7	1.70	35.28	6.31	6.75	42.1	4.8	47.42	8.94
		20	6.10	30.9	2.60	43.85	10.28	6.65	38.6	4.2	134.43	8.86
LSD ($P \leq 0.05$)			0.17	7.6	0.75	24.71	1.68	0.15	15.1	2.7	45.88	2.75

OC; TN; Avail. P; ECEC; ZT; MT; CT (see Table 3); PM = poultry manure N_0 = 0 kg N ha^{-1}, N_1 = 150 kg N ha^{-1}, N_2 = 120 kg N ha^{-1}, N_3 = 90 kg N ha^{-1}; 0 = 0 Mg ha^{-1} PM; 10 = 10 Mg ha^{-1} PM; 20 = 20 Mg ha^{-1} PM.

no significant difference was observed with combination of fertilizer and PM under the three tillage systems in 2008. Also, apart from TN of 2.15 g kg^{-1} for $N_2 + PM_{20}$ (2008) and 7.5 g kg^{-1} for N_1 + PM_{10} (2009) under ZT, and 10.0 g kg^{-1} for N_2 + PM_{20} (2009) under MT which were significantly higher than the control plots, no significant difference in TN was observed with combination of fertilizer and PM under all the tillage systems (Table 4). Generally, PM_{10} combined with various rates of fertilizer under the three tillage systems did not result in significant increase in soil Avail. P with the exception of N_1 + PM_{10} under ZT and N_3 + PM_{10} under CT while all fertilizer rates combined with PM_{20} resulted in significantly higher Avail. P than the controls in 2008. In 2009, combinations of NPK and PM significantly raised soil Avail. P than the control under ZT but the increment than the control under MT was not significant.

Under CT, PM_{20} combined with various rates of NPK fertilizer gave significantly higher Avail. P than the control and combination of PM_{10} with fertilizer rates. Soil Avail. P was consistently lower in plots treated with NPK fertilizer only compared with plots treated with only PM_{10} or PM_{20} and also lower than combinations of fertilizer rates with PM under all the tillage systems at both years of the study (Tables 4). In 2008, the ECEC was higher significantly with combined application of PM_{10} or PM_{20} with various fertilizer rates than the control under ZT. Only the ECEC of 8.53 cmol kg^{-1} for N_2 + PM_{20} and 10.28 cmol kg^{-1} for N_3 + PM_{20} under MT and CT, respectively were significantly higher than the control. In 2009, except the ECEC of 11.32 cmol kg^{-1} given by N_3 + PM_{20}, the ECEC were not significantly different where NPK fertilizer with PM were used under ZT. The ECEC of 11.78 cmol kg^{-1} for N_2 + PM_{10} and 10.39 cmol kg^{-1} for N_1 + PM_{10} under MT and CT, respectively were the only treatments where combined use of NPK and PM resulted in significantly higher ECEC than the control. Under each of the tillage systems, ECEC obtained from plots treated with NPK fertilizer only were lower than ECEC obtained from individual application of PM and combined use of PM and NPK fertilizer (Table 4).

Effect of tillage on maize yield and yield parameters

The plant height, dry matter, cob and maize grain yields, were significantly higher under MT than CT in 2008 cropping but except for the plant height which was higher significantly under MT than ZT, the grain yield and all the yield parameters were not significantly different between ZT and MT (Table 5). However, in year 2009, the cob and grain yields were significantly higher under MT than both CT and ZT. Though, cob and grain yields were significantly higher under ZT than CT in 2008, there were no significant differences among the grain yield and yield parameters in 2009 between ZT and CT (Table 5).

Interactive effects of tillage, NPK fertilizer and poultry manure on maize yield and yield parameters

Except the plant height of 1.83 m observed in plot treated with N_1 + PM_{20} under ZT that was statistically similar to the control in 2009, all plots treated with combination of PM and NPK fertilizer treatments gave significantly higher plant height than the control (Table 6). Generally, combined application of PM with NPK fertilizer increased plant height than the use of NPK fertilizer alone. With the exception of N_2 + PM_{10} that gave dry matter yield (DMY) of 2.69 Mg ha^{-1} and 3.71 Mg ha^{-1} under ZT and MT, respectively, combined application of PM_{10} with NPK fertilizers did not cause significant differences in DMY compared with the control whereas combinations of NPK with PM_{20} resulted in significantly higher DMY than the control under all the tillage systems. However, in the second year of the study, PM_{10} and PM_{20} combined with various rates of NPK fertilizer led to significantly higher DMY than the controls. Under MT in 2008, application of PM_{10}

Table 5: Effect of tillage on maize yield and yield parameters

Year	2008				2009			
Tillage	Plant height (m)	DMY (Mg ha^{-1})	Cob yield (Mg ha^{-1})	Grain yield (Mg ha^{-1})	Plant height (m)	DMY (Mg ha^{-1})	Cob yield (Mg ha^{-1})	Grain yield (Mg ha^{-1})
CT	1.81	1.83	2.03	1.33	2.21	2.91	2.56	1.91
MT	1.98	2.36	2.34	1.61	2.30	3.15	2.95	2.28
ZT	1.86	2.14	2.23	1.50	2.18	2.78	2.35	1.76
LSD ($P \leq 0.05$)	0.09	0.34	0.18	0.15	0.11	0.31	0.24	0.19

ZT; MT; CT (see Table 3); DMY – Dry matter yield.

Table 6: Interactive effects of tillage, NPK fertilizer and poultry manure on maize yield and yield parameters

Year			2008				2009			
Treatments			Plant height (m)	DMY (Mg ha^{-1})	Cob yield (Mg ha^{-1})	Grain yield (Mg ha^{-1})	Plant height (m)	DMY (Mg ha^{-1})	Cob yield (Mg ha^{-1})	Grain yield (Mg ha^{-1})
Tillage	NPK	PM								
ZT	N_0	0	1.38	0.57	1.49	0.15	1.91	1.83	1.19	0.59
		10	1.58	0.71	2.53	1.97	2.01	1.83	1.78	1.30
		20	2.51	4.09	2.50	1.62	2.16	2.21	2.07	1.55
	N_1	0	1.65	1.36	1.66	1.09	1.93	1.39	1.50	1.10
		10	2.00	1.69	1.95	1.25	2.29	3.04	2.87	2.28
		20	2.15	2.90	2.52	1.79	1.83	3.05	2.93	2.29
	N_2	0	1.55	1.39	2.06	1.42	2.30	4.02	1.83	1.34
		10	2.10	2.69	2.46	1.74	2.50	4.41	3.31	2.50
		20	1.84	1.86	2.50	1.68	2.64	3.36	3.69	2.89
	N_3	0	1.63	0.93	1.65	1.12	1.92	1.43	1.40	1.01
		10	1.88	1.65	2.26	1.86	2.37	3.51	2.51	1.93
		20	2.11	5.87	3.16	2.31	2.37	3.32	3.17	2.46
MT	N_0	0	1.65	1.31	1.49	0.94	1.73	1.83	1.80	1.45
		10	1.79	1.83	2.42	1.60	1.93	1.88	2.80	2.17
		20	1.90	1.47	2.35	1.22	2.13	2.58	2.67	2.10
	N_1	0	2.11	1.83	2.27	1.51	2.32	2.97	3.00	2.28
		10	2.14	2.48	1.67	1.24	2.60	3.42	3.37	2.67
		20	1.61	3.29	2.32	1.66	2.73	4.58	3.32	2.58
	N_2	0	2.00	2.06	2.18	1.56	2.17	2.62	2.18	1.54
		10	2.29	3.71	2.99	2.16	2.56	3.14	3.27	2.45
		20	2.29	2.97	3.09	2.28	2.64	3.84	3.47	2.75
	N_3	0	1.76	2.20	2.10	1.47	1.73	2.51	2.47	1.87
		10	2.03	2.48	2.45	1.77	2.50	4.24	3.27	2.51
		20	2.15	2.66	2.79	1.91	2.63	4.21	3.78	3.01
CT	N_0	0	1.36	1.12	1.81	0.55	1.77	1.51	0.79	0.24
		10	1.67	1.78	2.00	1.45	1.78	2.91	2.26	1.63
		20	1.70	3.00	1.92	1.34	2.27	2.28	2.22	1.62
	N_1	0	1.61	1.11	2.00	1.32	1.94	2.07	1.51	1.14
		10	1.98	1.78	1.85	1.17	2.38	3.36	2.81	2.21
		20	1.97	2.79	1.87	1.27	2.40	3.92	3.38	2.62
	N_2	0	1.62	1.33	1.55	0.96	1.99	2.30	2.89	2.02
		10	2.09	1.48	2.08	1.59	2.40	3.50	3.09	2.39
		20	2.04	2.58	2.67	1.83	2.39	3.50	2.94	2.25
	N_3	0	1.43	1.97	1.62	1.03	2.14	2.04	2.71	2.09
		10	2.10	1.90	2.40	1.65	2.46	4.14	2.99	2.24
		20	2.17	2.13	2.56	1.84	2.57	3.34	3.19	2.42
LSD ($P \leq 0.05$)			0.31	1.19	0.64	0.54	0.38	1.08	0.82	0.67

ZT; MT; CT (see Table 3); PM; N_0; N_1; N_2; N_3; 0; 10; 20 (see Table 4); DMY = dry matter yield

or PM_{20} with NPK fertilizer majorly gave no significant differences in DMY compared with sole use of NPK while under ZT and CT, application of PM_{20} with NPK fertilizer gave significantly higher DMY yield than sole use of NPK fertilizer. Likewise, in 2009, compared with sole use of NPK fertilizer, significantly higher DMY was observed only where PM_{20} was combined with NPK fertilizer under MT whereas under ZT and CT, combined use of PM_{10} or PM_{20} and NPK fertilizer resulted in significantly higher DMY compared with plot treated with sole NPK fertilizers (Table 6).

At both cropping years, except the cob yields of 1.95 Mg ha^{-1} and 1.67 Mg ha^{-1} given by N_1 + PM_{10} under ZT and MT, respectively that was similar to the control in 2008, combined application of PM and NPK fertilizer under ZT and MT significantly increased maize cob yield than the controls. However, only the cob yields of 2.67 Mg ha^{-1} for N_2 + PM_{20} and 2.56 Mg ha^{-1} for N_3 +PM_{20} under CT were higher significantly than the control in 2008 but in 2009, all combined application of PM and NPK fertilizer gave significantly higher cob yield than the control. Under ZT in 2008, PM_{10} combined with NPK fertilizer did not significantly increase cob yield relative to plots that received sole NPK fertilizer but plots treated with N_1 + PM_{20} or N_3 + PM_{20} gave significantly higher cob yields than plots treated with only N_1 or N_3, respectively while N_2 + PM_{20} increased cob yield by about 18% compared with N_2 plots. In 2009, all combined use of PM and NPK fertilizer under ZT resulted in significantly higher cob yield than sole use of NPK fertilizer. At both years of the study, there were no significant differences in maize cob yield between N_1 + PM_{10}; N_1 + PM_{20} and N_1 and between N_3 + PM_{10} and N_3 under MT while the cob yield was significantly higher in plots treated with N_2 + PM_{10}; N_2 + PM_{20} than N_2 and in N_3 + PM_{20} than N_3 (Table 6). In the CT system, the cob yields were generally statistically similar between combined and sole use of the nutrient amendments but the cob yield of 2.67 Mg ha^{-1} for N_2 + PM_{20} and 2.56 Mg ha^{-1} for N_3 + PM_{20} were significantly higher than cob yield given by N_2 and N_3, respectively in 2008. Also, in 2009, the cob yields of 2.81 Mg ha^{-1} and 3.38 Mg ha^{-1} for N_1 + PM_{10} and N_1 + PM_{20}, respectively were significantly higher than yield of 1.51 Mg ha^{-1} for N_1. At both years of the study under the three tillage systems, combined application of PM with NPK fertilizer gave significantly ($P \leq 0.05$) higher maize grain yield than the controls with the exception of grain yield of 1.24 Mg ha^{-1} given by MT + N_1 + PM_{10} that was insignificantly higher than the control (Table 6). Combined use of various rates of NPK fertilizer with PM_{20} generally led to grain yields that were higher but not significant compared with admixture of NPK fertilizer and PM_{10}. Except the grain yields obtained from N_1 + PM_{10}, N_2 + PM_{10} and N_2 + PM_{20} that were higher by about 13%, 18% and 15%, respectively than plots treated with NPK only in 2008, all combined application of NPK fertilizer and PM at both years resulted in significantly higher maize grain yield than sole use of NPK fertilizer under ZT. Under MT, only N_2 combined with PM_{10} or PM_{20} gave significantly higher grain yield than N_2 plots at both years but grain yield of 3.01 Mg ha^{-1} for N_3 + PM_{20} plot was also significantly higher than grain yield of 1.87 Mg ha^{-1} for N_3 plot. Under CT in 2008, N_2 or N_3 combined with PM_{10} or PM_{20} gave significantly higher grain yield than sole use of N_2 or N_3 while N_1 combined with PM_{10} or PM_{20} gave significantly higher grain yield than N_1 in 2009. There were no significant differences in grain yields between combined nutrient amendment and sole application of PM under ZT in 2008 but the combination resulted in significantly higher grain yields than sole use of either PM_{10} or PM_{20} in 2009. Under MT, N_2 + PM_{10} and N_2 + PM_{20} gave significantly higher grain yield than sole use of PM_{10} or PM_{20} in 2008 while in 2009, N_2 + PM_{10} and N_2 + PM_{20} resulted in 11% and 24% grain yield increases, respectively compared with sole use of PM_{10} or PM_{20}. Grain yields given by other nutrient combinations under MT were not significant except grain yield of 3.01 Mg ha^{-1} for N_2 + PM_{20} that was significantly higher than 2.10 Mg ha^{-1} obtained from PM_{20} treated plot (Table 6). Under CT, there was no significant difference in grain yield between combined nutrient amendment and sole use of PM in 2008 while in 2009 combination of NPK fertilizer with PM_{10} or PM_{20} led to grain yield increments of between 26-32% compared with PM_{10} only and between 28-38% compared with PM_{20} only. Among the control plots, grain yield of 1.45 Mg ha^{-1} obtained under MT was significantly higher than those observed under CT and ZT in 2009 while that of ZT was higher but not differ significantly from CT. There was no significant difference in grain yield due to combined application of N_1 and PM_{10} or PM_{20} among the tillage systems while N_2 combined with PM_{10} under MT gave a statistically similar grain yield with ZT but significantly higher grain yield than CT in 2008. The use of N_2 + PM_{20} resulted in significantly higher grain yield under MT than ZT. There was about 20% increment in grain yield under MT compared with CT in 2008 and 22% increment in grain yield under ZT compared with CT in 2009. Also, application of N_2 + PM_{20} led to about 20% (2008) and 6% (2009) grain yield increments under ZT and about 20% increment under MT compared with CT (Table 6). However, there were no significant differences in maize grain yield between individual application of PM_{20} or PM_{10} and various NPK fertilizer rates.

DISCUSSION

At the onset of the study in 2008, the gravelly loamy sand soil used for the study had a low bulk density and hydraulic conductivity. The soil pH was slightly acidic and the available phosphorus was in the medium range while the soil organic carbon (SOC), the total nitrogen and ECEC were low (Landon, 1984). The low ECEC is indicative of sandy textured soils that invariably need more organic matter (Turf Revolution, 2010) to improve nutrient holding capacity. The poultry manure used for the study was adequate in all the nutrients except total nitrogen which was low (Hsieh and Hsieh, 1990) possibly due to its volatilization during the period for which the manure was left at the dump site. The C:N ratio of the manure was lower than 20 established by Spanish legislation for organic manure (Gil *et al*., 2008) and is an indication that the mineralization of the manure could exceed its immobilization (Busari *et al*., 2008).

As observed in the second year of this study, soil pH has been previously reported to be lower in no-till systems compared with CT (Rahman *et al*., 2008) while MT moderate soil pH than either CT or ZT. Significantly lower values of soil organic matter and total nitrogen under CT compared with ZT could be attributed to soil pulverization by conventional tillage leading to accelerated decomposition of soil organic matter (Rahman *et al*., 2008) and possible leaching of total nitrogen. Authors such as During *et al.* (2002) and Ali *et al.* (2006) have reported higher soil Avail. P under ZT or MT than CT. Therefore, the significantly lower Avail. P observed under MT than CT is not clearly understood as there was no significant difference in soil Avail. P between CT and ZT. The significantly higher ECEC obtained under ZT than tilled plots was similar to the finding of Lal (1997).

Generally, soil pH ranged from 5.80-6.95 under the three tillage systems whether manured or unmanured. These pH values fell within the normal range (Landon, 1984) require for maize production. Slight differences in pH between manured and unmanured plots under all the tillage systems is a pointer to the fact that acidity was not a major problem in the site used for this study. However, where PM was combined with NPK treatments, the lower pH values from plots with NPK only compared with PM + NPK plots was probably due to the acidifying effect of the nitrogen content of the inorganic fertilizer used. The acidifying effect was however, masked when PM and NPK were jointly applied (Busari *et al*., 2008). The better performance of manure treatments in raising SOC and total N under ZT and MT than CT, when PM was used singly or in combination with NPK fertilizer, is attributable to the conservation of native SOC or ability of poultry manure to sequester carbon (Sainju *et al*., 2008) in the soil under ZT and MT while CT enhanced decomposition of SOC thereby reduced soil carbon content (Rahman *et al*., 2008). The higher soil Avail. P under all the tillage systems compared with the initial soil Avail. P signifies that the PM used supplied high amount of phosphorus to the soil. The higher Avail. P in organically fertilized soils could be due to high microbial activity induced by the addition of organic residues which sped up phosphorus cycling (Parham *et al.*, 2002). The lack of significant difference in Avail. P between combination of various rates of NPK + PM_{10} and NPK + PM_{20} under ZT and MT and significantly higher Avail. P in plots treated with various rates of NPK + PM_{20} than NPK + PM_{10} under CT suggest that smaller rate of PM is needed to raise soil Avail. P under conservation tillage while higher rate (eg. 20 Mg ha^{-1}) is required where soil is conventionally tilled. The total phosphorus content of the PM used for the study was 4.02% and was higher than a value of 3.07% reported by Hsieh and Hsieh (1990) as the typical total P content for poultry manure. Therefore, the consistently higher Avail. P in plots treated with PM_{10} or PM_{20} (with or without NPK) compared with the plots that received NPK fertilizer only under the tillage systems was not unexpected. According to Eghball and Power (1999), manure application to ZT can result in increased residue on the surface and may reduce soil erosion. This may bring about reduction in leaching of basic cations under ZT with net result on increased ECEC. However, under MT and CT, significantly higher ECEC were observed only in some plots treated with PM_{20} plus various NPK rates than the control. This suggests that where soil is tilled, high rate of PM such as 20 Mg ha^{-1} is required to raise the soil's ability to hold and exchange cations.

Maize yield as influenced by tillage revealed that minimum tillage is more sustainable but zero tillage could result in a more or equal maize yield compared with conventional tillage based on management strategies adopted. The best crop yield under MT is evident from poor root development that is usually implicated for low yield under ZT (Jalota *et al*., 2010) and rapid structural deterioration caused by slaking and dispersion under CT (Guzha, 2004) which were possibly not the case under MT. Thus, apart from MT that is singled out in this study, the controversy over similarity (Merrill *et al*. 1996) or superiority (Lawrence *et al*., 1994) of grain yields of maize grown on zero or conventionally tilled soil still lingers.

Application of poultry manure generally caused MT to produce higher maize grain yield and yield parameters than other tillage systems but when higher rate of manure (20 Mg ha^{-1}) was applied, maize grain yield under ZT became comparable with that obtained under MT and higher than the yield under CT. Therefore, poor root development that is usually implicated for low yield under ZT (Jalota *et al*., 2010) due to surface compaction can be ameliorated with increased rate of poultry manure. Similarly, some researchers have reported superior yield from MT than ZT and CT (Ike, 1989; Jalota *et al*., 2010) or from ZT than tilled plots (Merrill *et al*., 1996). The combined use of PM with NPK fertilizer that resulted in significantly higher plant height, DMY, cob and grain yields than sole use of NPK fertilizer explained complimentary roles of organic and inorganic manures in increasing maize productivity. This is because there were no significant differences in maize grain yield between individual application of PM_{20} or PM_{10} and various NPK fertilizer rates. It implies that neither chemical fertilizer nor organic manures alone can achieve stability in crop production (Huang *et al*., 2010), whereas the integrated use of organic and inorganic manures can significantly raise soil productivity (Busari *et al*., 2008). Combination of PM with NPK fertilizer rates raised grain yield generally in the order of MT>ZT>CT, even in the control plots MT gave significantly higher grain yield than ZT and CT. Therefore, sustainable crop production can best be achieved where minimum tillage is practiced. Jalota *et al*. (2010) also noted that maize yield was significantly higher in minimum tillage than CT and ZT.

CONCLUSIONS

It can be concluded from this study that combined application of PM and NPK fertilizer could neutralize the possible acidifying effect of nitrogen in the inorganic fertilizer. A rate of about 10 Mg ha^{-1} of PM is needed to raise the soil chemical quality indicators under conservation tillage while higher rate such as 20 Mg ha^{-1} of PM is required where CT is to be practiced. Among the tillage systems, minimum tillage is more sustainable in terms of maize productivity. However, application of 20 Mg ha^{-1} of PM under ZT could bring about a comparably high maize yield with MT and higher yield than CT. Higher maize production can be achieved when organic and inorganic fertilizers are jointly applied than their separate use.

REFERENCES

Ali, A., Ayuba, S.A. and Ojeniyi, S.O. 2006. Effect of tillage and fertilizer on soil chemical properties, leaf nutrient content and yield of soyabean in the Guinea savanna zone of Nigeria. Nigerian Journal of Soil Science 16: 126–30.

Busari, M.A., Salako, F.K. and Adetunji, M.T. 2008. Soil chemical properties and maize yield after application of organic and inorganic amendments to an acidic soil in southwestern Nigeria. Spanish Journal of Agricultural Research 6: 691–699.

Carter, M.R. 1993. Soil sampling and methods of analysis. Canadian Society of Soil Science, Leon Publishers, London. pp823.

During, R. A., Thorsten, H. and Stefan G. 2002. Depth distribution and bioavailability of pollutants in long-term differently tilled soils. Soil and Tillage Research 66, 183–195.

Eghball, B. and Power, J.F. 1999. Composted and non-composted manure application to conventional and no-tillage systems: corn yield and nitrogen uptake. Agronomy Journal 91: 819–825.

Gil, M.V., Carballo, M.T. and Calvo, L.F. 2008. Fertilization of maize with compost from cattle manure supplemented with additional mineral nutrients. Waste Management 28: 1432–1440.

Guzha, A.C. 2004. Effects of tillage on soil microrelief, surface depression storage and soil water storage. Soil and Tillage Research 76: 105–114.

Hati, K.M., Swarup A., Dwivedi A.K., Misra A.K. and Bandyopadhyay, K.K. 2007. Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring. Agricultural Ecosystems and Environment 119: 127–134.

Hsieh, S.C. and Hsieh, C.F. 1990. The use of organic matter in crop production. FFTC Extension Bulletin 360. 20pp.

Huang, S., Peng, X., Huang, Q. and Zhang, W. 2010. Soil aggregation and organic carbon fractions affected by long-term fertilization in a red soil of subtropical China. Geoderma, 154: 364–369.

Ike, I.F. 1989. Growth and yield of cowpea (*Vigna unguiculata*) in a Leossial sandy loam soil under three cultivation methods. Nigeria Journal of Technical Research 1: 7–10.

Jalota, S.K, Singh, S., Chahal, G.B.S., Ray S.S., Panigraghy S., Bhupinder-Singh and Singh K.B. 2010. Soil texture, climate and management effects on plant growth, grain yield and water use by rain-fed maize-wheat cropping system: Field and simulation study. Agricultural Water Management 97: 83–90.

La1, R. 1997. Long-term tillage and maize monoculture effects on a tropical Alfisol in western Nigeria. II. Soil chemical properties. Soil and Tillage Research 42: 161–174.

Lal, R. 1989. Conservation tillage for sustainable agriculture: tropics vs. temperate environments. Advances in Agronomy 42: 85–197.

Landon, J.R. 1984. Booker Tropical Soil Manual. A hand book for soil survey and agricultural land evaluation in the tropics and subtropics. London: Longman group, England. 450pp.

Lawrence, P.A., Radford, B.J., Thomas, G.A., Sinclair, D. and Key, A.J. 1994. Effect of tillage practices on wheat performance in a semiarid environment. Soil and Tillage Research 28: 347–364.

Merrill, S.D., Black, A.L. and Bauer, A. 1996. Conservation tillage affects root growth of dry land spring wheat under drought. Soil Science Society of America Journal 60: 575–583.

Ojeniyi, S.O. 1991. Soil tillage method and soil properties: Effect on Okra at Akure southwest Nigeria. Journal of Agricultural Science and Technology 1: 70–71.

Parham, J.A., Deng, S.P., Raun, W.R. and Johnson, G.V. 2002. Long-term cattle manure application in soil I. Effect on soil phosphorus levels, microbial biomass C, and deshydrogenase and phosphatase activities. Biology and Fertility of Soils 35: 328–337.

Rahman, M.H., Okubo, A., Sugiyama, S. and Mayland, H.F. 2008. Physical, chemical and microbiological properties of an Andisol as related to land use and tillage practice. Soil and Tillage Research 101: 10–19.

Sainju, U.M. and Singh, B.P. 2001. Tillage, cover crop and kill-planting date effects on corn yield and soil nitrogen. Agronomy Journal 93: 878–886.

Sainju, U.M., Senwo, Z.N., Nyakatawa, E.Z., Tazisong, I.A. and Reddy, K.C. 2008. Soil carbon and nitrogen sequestration as affected by long-term tillage, cropping systems and nitrogen fertilizer sources. Agricultural Ecosystems and Environment 127: 234–240.

SAS, 1999. SAS/STAT User's Guide. Version 8. Statistical Analysis System Institute Inc., Cary, NC, USA.

Turf Revolution. 2010. A new life style for yo ur lawn. Available online at http://209.213.232.153/TR/articles/cati onexchangecapacity.pdf