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Effects of Tillage and Oil Palm Bunch Ash Plus Poultry Manure on Soil Chemical Properties, Growth and Ginger Yield

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***Abstract*—**Field experiments were carried out at Owo, southwest Nigeria to evaluate the effect of different tillage practices (zero tillage with mulch (ZTM), row tillage (RT) and conventional tillage (CT), and with or without oil palm bunch ash plus poultry manure (OBA+PM) on soil chemical properties, growth and yield of ginger. The experiment was laid out in a randomized complete plot design with three replications. Soil chemical properties, growth and fresh rhizome yield reduced with frequency/intensity of tillage imposed while application of OBA+PM increased them. Among the tillage practices, the highest fresh rhizome yield (15.0t ha^{-1}) was produced by ZTM which was significantly different from other tillage practices. Among the tillage – OBA+PM combinations, the most satisfactorily yield (20.1t ha^{-1}) was produced by ZTM+OBA+PM while the lowest yield (15.7t ha^{-1}) was in CT+OBA+PM.

***Keywords*—**Oil palm bunch ash, poultry manure, rhizome yield, tillage.

I. Introduction

GINGER (*Zingiber officcinale* Roscoe) belongs to the family *Zingiberaceae* and it is an important commercial crop grown for its aromatic rhizomes which are consumed as a spice, in medicine, and as a special vegetable in daily diets worldwide. According to the latest records from FAO, Nigeria's harvested area for ginger is 44,313 hectares, producing about 156,106 tons in 2009 [1]. Although the use of improved varieties and fertilizers has increased ginger production to a certain extent, the full potentials of crop production has not yet been achieved.

The major production problems responsible for its low yield are continues decline in soil fertility and lack of soil management requirements for ginger cultivation. Research recommendations with respect to tillage requirements are scarce for different ecological zones. Tillage affects soil properties, nutrient availability, loss and production of organic matter. Appropriate tillage is one of the major factors for increasing yield of crops since it creates suitable tilth for crop establishment. Tillage induces nutrient release, decomposition of organic materials and mineralization of organic nutrients. However, intensive or repetitive tillage causes rapid degradation of soil physical, chemical and biological qualities especially in case of Alfisol of southwest Nigeria [2], [3]. Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift to the conservation and zero tillage (no-tillage) methods for the purpose of controlling erosion process, conserving soil and water, mitigating drought, reducing tillage costs, increasing soil organic matter, boosting crop productivity and reducing net CO_2 emissions which contribute to global warming attenuations. Hence, there is need to examine the potential of growing ginger using zero and row tillage practices and their effect on soil fertility and ginger performance.

In a sustainable low-input agricultural system, where nutrient depletion is a serious constraint to crop production, the use of organic fertilizers such as oil palm bunch ash (a waste product of palm fruit processing which results from incineration of bunch refuse after fruit extraction) and poultry manure is inevitable. Soils have to be amended and managed in a special manner to be cultivated profitably. The effect of tillage and oil palm bunch ash and poultry manure on the actual rhizome yield of ginger does not exist. The current average tonnage per hectare in Nigeria for fresh rhizome yield is low, being estimated at about 12-15t ha^{-1} [1]. This implies that more research is needed to increase production to appreciable levels in order to meet global demand for ginger. Use of appropriate tillage method in combination with organic fertilizers that are cheap, sustainable, edaphologically suitable, economically viable, culturally acceptable, environmentally friendly and compatible is considered a major method of increasing ginger yield on a unit per area basis.

Organic manures are known to be effective in the maintenance of an adequate supply of organic matter into soil, with attendant improvement in soil physical and chemical conditions and enhanced crop performance [4], [5]. Enormous quantities of organic wastes such as oil palm bunch ash and poultry manure are available in Nigeria where they pose disposal problems and environmental hazards, and are at the same time effective sources of nutrients for root vegetable crops like ginger. Research information on tillage requirements of ginger in the forest-savanna transition zone of Nigeria and the implication of tillage – oil palm bunch ash plus poultry manure combination for the production of ginger is yet to receive research attention.

Nutrient management is always an important consideration for ginger because it requires large quantities of nutrients; especially K. Potassium is one of the most limiting factors for ginger production [6]. Therefore, continuous cultivation of a crop like ginger on the same land will lead to soil mining,

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degradation of soil quality and consequent low yield. For optimum target yield, it was indicated that ginger removed 58kg/ha N, 24kg/ha P and 111kg/ha K from the soil [7] compared with 30.7kg/ha N, 3.7kg/ha P and 26.0kg/ha K removes by sorghum [8]. This suggests that ginger is more likely to deplete soil nutrients especially K at a faster rate than sorghum. Hence, this call for fertility - enhancing technologies including the integrated application of organic manures / amendments that will ensures immediate nutrient release for the present crop as well as the long-term build up of soil nutrients. Based on the results of previous studies, the rates of organic manure/fertilizer ranging from 15-30t ha^{-1} have been recommended for ginger [9], [10]. Some studies have shown that incorporated oil palm bunch ash [11], [12] and poultry manure [13], [14] improved soil fertility and crop yields. Considering the high cost and scarcity of mineral fertilizers especially during growing period, it is imperative to intensify research into improving the natural means of replenishing lost nutrients in the soil in order to make crop production sustainable. To this end, this study was investigated to evaluate the effect of tillage and oil palm bunch ash plus poultry manure on soil chemical properties, growth and fresh rhizome yield of ginger in southwestern Nigeria.

II. Materials and Methods

A. Site Description

The experiments were carried out in 2009, 2010 and 2011 cropping seasons at the Teaching and Research Farm of Rufus Giwa Polytechnic, Owo on latitude 7^0 $12^{/}$N, longitude 5^0 $35^{/}$E in southwest Nigeria. Available climatic data indicate that the annual rainfall totals were 1547, 1456 and 1358mm, respectively for 2009, 2010 and 2011, respectively. The rainfall pattern is bimodal with peaks in the months of July and September. The rainy season commences in March, lasting till October, while the dry season is between November and February with mean monthly temperature ranging between 24°C and 32°C. The soil of the experimental site belongs to an Alfisol classified as Oxic Tropuldalf [15] or Luvisol [16] derived from quartzite, gneiss and schist [17]. The site was previously cropped to a variety of crops such as maize (*Zea mays* L.), cowpea (*Vigna unguiculata* Walp), cassava (*Manihot esculenta* Crantz), groundnut (*Arachis hypogaea* L.), melon (*Colosynthis citrullus* L.), etc. for at least 8 years before it was used for this experiment. The experiments were conducted for three cropping seasons of 2009, 2010 and 2011 on the same site.

B. Field Experiments and Treatments

The experiment each year consisted of 3 x 2 factorial combinations of tillage (seedbed type) and application of oil palm bunch ash + poultry manure (0, 20t ha^{-1}). The treatments compared at the site were (a) zero tillage with mulch minus oil palm bunch ash + poultry manure (ZTM): manual clearing with cutlass followed by treatment with paraquat (1, 1-dimethyl-4, 4-bipyridilium dichloride at the rate of 2.5kg ha^{-1} a.i. sprayed two weeks before planting on flat in the killed sod and without application of oil palm bunch ash + poultry manure, (b) zero tillage with mulch plus oil palm bunch ash + poultry manure (ZTM+OBA+PM): manual clearing with cutlass followed by treatment with paraquat (1, 1-dimethyl-4, 4-bipyridilium dichloride at the rate of 2.5kg ha^{-1} a.i sprayed two weeks before planting on flat in the killed sod and with application of oil palm bunch ash + poultry manure, (c) row tillage minus oil palm bunch ash + poultry manure (RT): in which the planting row (15cm wide) was hoe tilled to a depth of 10cm and inter row spaced (approximately 45cm wide) treated with gramoxone (a non-selective herbicide) at 3.5 litres per hectare [18], and without application of oil palm bunch ash + poultry manure, (d) row tillage plus oil palm bunch ash + poultry manure (RT+OBA+PM): in which the planting row (15cm wide) was hoe tilled to a depth of 10cm and inter row spaced (approximately 45cm wide) treated with gramoxone (a non-selective herbicide) at 3.5 liters per hectare [18], and with application of oil palm bunch ash + poultry manure, (e) conventional tillage minus oil palm bunch ash + poultry manure (CT): soil was ploughed and harrowed to a 20cm depth once with tractor – mounted disc plough and harrow and without application of oil palm bunch ash + poultry manure and (f) conventional tillage plus oil palm bunch ash + poultry manure (CT + OBA + PM): soil was ploughed and harrowed to a 20cm depth once with tractor – mounted disc plough and harrow with application of oil palm bunch ash + poultry manure. The six treatments were factorially arranged in a randomized complete block design and with three replications.

C. Crop Establishment and Determination of Growth and Yield Parameters

The experimental plot size in each trial was 12m x 10m. Blocks were 4m apart, and plots were 3m apart. Seed rhizomes ("Tafin Giwa" cv) were planted in April each year at a spacing of 20cm between rows and 20cm within rows, giving a plant population of 250,000 plants ha^{-1}. Oil palm bunch ash + poultry manure was applied in ring form at planting at the rate of 20t ha^{-1} (10t ha^{-1} oil palm bunch ash + 10t ha^{-1} poultry manure) thoroughly worked into the soil with a hoe. Weeding was manual with a hoe at 4 and 8 weeks after planting. Ten tagged plants were chosen randomly from each plot for determination of plant height, number of leaves per plant and number of tillers per plant at 150 days after planting when the ginger plants formed full canopy. Harvesting was done at 9 months after planting for the determination of ginger yield.

D. Soil Sampling and Analysis

Surface soil (0-15cm) samples were collected at experimental site before commencement of the study and those collected per plot basis at harvesting in 2010 (second crop) and 2011 (third crop) were bulked, air-dried and sieved for chemical analysis as described by Pansu and Gautheyron [19]. Soil pH was determined in soil-water (1:2) suspension using the digital electronic pH meter. Soil organic carbon was determined by the procedure of Walkley and Black by wet oxidation using chromic acid digestion [20]. Total N was determined by the micro-Kjeldahl digestion and distillation techniques [21]; available P was determined by Bray -1 extraction followed by molybdenum blue colorimetry [22]. Exchangeable K, Ca and Mg were extracted with a 1M NH_4 OAC, pH 7 solution. Thereafter, K was analysed with a flame photometer and Ca and Mg were determined with an atomic absorption spectrophotometer [23]. Particle size analysis was done using Bouyoucos hydrometer method.

E.Preparation and Chemical Analysis of Oil Palm Bunch Ash and Poultry Manure

Oil palm bunch ash was obtained from the oil palm processing unit of Ondo State Agricultural Development Project, Owo and the poultry manure was obtained from poultry houses at Rufus Giwa Polytechnic, Owo. The organic materials were processed to allow decomposition. The oil palm bunch ash was sieved to remove pebbles, stones and unburnt shafts. Poultry manure was stacked under a shed for 1 week to allow quick mineralization. In general, the organic wastes are readily available, sustainable and inexpensive for growing commercial quantities of ginger. Small sub-samples from the oil palm bunch ash and poultry manure used for the experiments were analysed to determine their nutrient composition. The samples were air-dried, and crushed to pass through a 2mm sieve before analysis. The samples were analysed for organic C, N, P, K, Ca and Mg. The percentage organic carbon was determined by the Walkley and Black procedure using the wet dichromate method, N was determined by micro-Kjeldahl digestion, followed by distillation and titration while the determination of other nutrients such as P, K, Ca and Mg was done using the wet digestion method based on 25-5-5mL of $HN0_3$–H_2S04-HCl04 acid [24]. Phosphorous was measured colorimetrically by the molybdate blue method in an auto-analyser, K by flame photometry, Ca and Mg by atomic absorption spectrophotometer [23].

F.Statistical Analysis

The data collected from each experiment were subjected to analysis of variance using the SPSS package and treatment means were compared using the Duncan's multiple range test (DMRT), and the least significant difference (LSD) at $p < 0.05$ probability level [25].

III. Results and Discussion

A. Initial Soil Fertility Status and Chemical Properties of Oil Palm Bunch Ash and Poultry Manure

The soil was sandy loam in texture, slightly acidic and had bulk density of 1.38Mg m^{-3} and total porosity of 47.9% (Table I). The values of soil organic C, total N and exchangeable K were low, while available P, exchangeable Ca and Mg were adequate. Poultry manure used had significantly higher ($p< 0.05$) C, N and P nutrient concentrations and the lower C/N ratio of 7.4 compared with the OBA. The OBA had significantly higher ($p< 0.05$) values of K, Ca, Mg, and C/N of 10.5 compared with PM. The organic of C, N, P, K, Ca, and Mg constituents of combinations of the organic materials are expected to improve the fertility of the experimental soil and ginger yield. As the soil is also acidic, the oil palm bunch ash could help by reducing soil acidity [26].

B.Effect of Tillage Methods and Oil Palm Bunch Ash Plus Poultry Manure on Soil Chemical Properties

Zero tillage with mulch (ZTM) produced the highest values of soil organic C, N, P, K, Ca, and Mg for surface soil (0-20 cm) (Table II). The effects of tillage on soil nutrient concentrations (other than soil pH) were statistically significant in 2010 and 2011 ginger crop ($p< 0.05$). ZTM had significantly higher ($p< 0.05$) concentrations of soil organic C, N, P, K, Ca and Mg compared with RT and CT, but the soil organic C produced by RT was not statistically significant when compared with ZTM. RT had significantly higher ($p< 0.05$) soil organic C, N, K, Ca and Mg concentrations compared with CT. Soil pH was not affected by tillage in either year. The soil fertility after harvest in both years tended to decrease in the order: ZTM>RT>CT. The best fertility status of zero tillage with mulch compared with other tillage methods could be attributed to the presence of vegetative surface mulch, availability of nutrients, possibly reduced leaching and increased activities of beneficial soil fauna in organic matter decomposition [27]. This affirmed the conservation of soil organic matter and nutrient concentrations by zero tillage with mulch as opposed to conventional tillage systems which destroys soil chemical properties [28]. In all cases, conventional tillage (ploughing plus harrowing) gave the lowest values of soil organic C and nutrient concentrations compared to other tillage practices. The decrease in the nutrient reserve of the conventional tillage could be attributed to a number of processes such as leaching, increased biological activity and oxidation, and destruction of the soil structure by mechanical tillage which encourages soil erosion that preferentially removes colloidal fraction with high "enrichment ratio" [29], resulting in a progressive depletion of its nutrient reserves. Mueller-Harvey et al. [30] reported rapid mineralization of soil organic C, N, S and P for Alfisols in Nigeria. Therefore, it is confirmed that tillage degrades the quality of Alfisol while cultivation generally increases the depletion of soil organic matter and other soil nutrients and the degree of degradation of these fertility properties depended on the degree of soil manipulation imposed by the tillage systems.

Tillage had no significant effect on soil pH in 2010 and 2011 cropping seasons. Although the values decreased at the end of the second and third seasons of ginger cultivation, the decrease was less for untilled ZTM plots compared to conventionally tilled plots. This situation could be adduced to the loss of organic C and the leaching of cations beyond the sampling depth (0-20cm).

Irrespective of any tillage method, application of oil palm bunch ash + poultry manure significantly increased ($p< 0.05$) soil pH, organic C, total N, available P, exchangeable K, Ca and Mg concentrations after 2 and 3 years of cultivation (Table II). Oil palm bunch ash + poultry manure increased soil pH, organic C, total N, P, K, Ca, and Mg and these were significant in 2010 and 2011. These could be attributed to high concentrations of K, Ca, and Mg in OBA in combination with high concentrations of C, N and P in PM. Hence, because of the high concentrations of K, Ca and Mg, OBA + PM were able to increase soil pH and K. Therefore, OBA had liming effect, and it is an effective source of K for ginger crop. In Nigeria, oil palm bunch ash and poultry manure were used as source of K for yam and cassava [31], [32]. Soil organic C and nutrient concentrations in oil palm bunch ash + poultry manure treated plots were higher than untreated plots. Among the tillage – OBA+PM treatments, the soil fertility after harvest in 2010 and 2011 increased in the order: ZTM+OBA+PM > RT+OBA+PM > CT+OBA+PM. This finding attests to the positive cumulative effect of zero tillage and oil palm bunch ash + poultry manure on soil productivity.

In the present study, it was found that ZTM gave the lowest decrease in soil organic C concentration over the 3 years of study, and OBA+PM treated plots increased soil organic C by 12 and 23% in 2010 and 2011, respectively compared to untreated plots. Without OBA+PM application, soil organic C, N, P, K, Ca and Mg concentrations reduced at the end of the 3 years of study, but when tillage method was combined with OBA+PM, soil fertility increased over 3 years. This indicated that OBA + PM improved the soil degradation and had positive cumulative effect by continuously adding organic C and nutrients. ZTM+OBA+PM had synergistic relations in terms of combination to further enhance soil organic C and other nutrients. Similar results were found previously [31], [32].

At the end of 3 years of study, the percentage decreases in soil organic C concentration under different tillage methods were 20, 30 and 37% by ZTM, RT and CT, respectively while the percentage increases under the various combinations involving tillage plus oil palm bunch ash + poultry manure were 23, 12 and 5%, respectively. The percentage decreases in tot al N concentration under different tillage methods were 20, 40 and 53%, respectively, contrasting the increases of 40, 20 and 7% under the various tillage – OBA+PM combinations for ZTM+OBA+PM, RT+OBA+PM and CT+OBA+PM, respectively. The available P concentration decreases under different tillage methods by 14, 23 and 26% for ZTM, RT and CT, respectively, contrasting the increases of 24, 8 and 6% under the various combinations involving tillage plus oil palm bunch ash + poultry manure for ZTM+OBA+PM, RT+OBA+PM and CT+OBA+PM, respectively.

The percentage decreases in exchangeable K under different tillage methods were 18, 36 and 45% by ZTM, RT and CT, respectively, while the percentage increases under various combinations involving tillage plus oil palm bunch ash + poultry manure were 127, 100 and 73%, for ZTM+OBA+PM, RT+OBA+PM and CT+OBA+PM, respectively. The exchangeable Ca concentration decreases by 32, 50 and 64% under different tillage systems for ZTM, RT and CT, respectively, while it increases under the various combinations of tillage plus oil palm bunch ash + poultry manure by 43, 25 and 14% for ZTM+OBA+PM, RT+OBA+PM and CT+OBA+PM, respectively. The exchangeable Mg concentration decreases under different tillage systems by 22, 43 and 54% for ZTM, RT and CT, respectively, contrasting the increases of 48, 20 and 4%, under the various combinations involving tillage plus oil palm bunch ash + poultry manure for ZTM+OBA+PM, RT+OBA+PM and CT+OBA+PM, respectively.

TABLE I
PHYSICO-CHEMICAL PROPERTIES OF SOIL (0-20 CM DEPTH) BEFORE EXPERIMENTATION IN 2009 AND CHEMICAL COMPOSITION OF OIL PALM BUNCH ASH AND POULTRY MANURE USED

Soil properties	Value
Sand (g kg^{-1})	662
Silt (g kg^{-1})	164
Clay (g kg^{-1})	174
Textural class	Sandy loam
pH (H_20)	5.3
Bulk density (Mg m^{-3})	1.38
Total porosity (%, v/v)	47.9
Organic carbon (g kg^{-1})	11.8
Total N (g kg^{-1})	1.5
Available P (mg kg^{-1})	10.0
Exchangeable K (cmol kg^{-1})	0.11
Exchangeable Ca (cmol kg^{-1})	2.8
Exchangeable Mg (cmol kg^{-1})	0.54

	Organic C	N	P	K	Ca	Mg	
			%				C/N
Oil palm bunch ash	10.4b	1.76b	1.12b	13.4a	5.6a	1.79a	10.5
Poultry manure	22.5a	3.03a	1.40a	1.8b	0.86b	0.58b	7.4

Note: Values followed by the same alphabets on the same column are not significantly different at $p < 0.05$ according to Duncan's multiple range test (DMRT).

TABLE II
EFFECT OF TILLAGE AND OIL PALM BUNCH ASH PLUS POULTRY MANURE ON SOIL CHEMICAL PROPERTIES (0-20 CM) IN 2010 AND 2011 CROPPING SEASONS

Treatment	pH (Water)		SOC (g kg^{-1})		Total N (g kg^{-1})		P (mg kg^{-1})		K (cmol kg^{-1})		Ca (cmol kg^{-1})		Mg (cmol kg^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
ZTM	5.4b	5.3b	9.9bc	9.4d	1.4b	1.2cd	8.8c	8.6c	0.11d	0.09d	2.4d	1.9d	0.46d	0.42d
ZTM + 10 t ha^{-1} OBA + 10 tha^{-1} PM	6.7a	6.8a	13.2a	14.5a	1.7a	2.1a	11.5a	12.4a	0.24a	0.25a	3.2a	4.0a	0.76a	0.80a
RT	5.4b	5.3b	9.0d	8.3e	1.1cd	0.9e	7.9d	7.7d	0.09e	0.07e	2.0e	1.4e	0.38e	0.31e
RT + 10 t ha^{-1} OBA + 10t ha^{-1} PM	6.5a	6.7a	12.0b	13.2b	1.3ab	1.8b	9.9b	10.8b	0.21b	0.22b	2.8b	3.5b	0.63b	0.65b
CT	5.3b	5.2b	8.1e	7.4f	0.9e	0.7f	7.5d	7.4d	0.07f	0.06f	1.6f	1.0f	0.32f	0.25f
CT + 10 ha^{-1} OBA + 10t ha^{-1} PM	6.3a	6.4a	11.2bc	12.4bc	1.2bc	1.6c	9.6b	10.2bc	0.18c	0.19c	2.4c	3.2c	0.54c	0.56c

Note: Values followed by the same alphabets in the same column are not significantly different at $p < 0.05$ according to Duncan's multiple range test (DMRT). ZTM, zero tillage with mulch; ZTM + OBA + PM, zero tillage with mulch + oil palm bunch ash + poultry manure; RT, row tillage; RT + OBA + PM, row tillage + oil palm bunch ash + poultry manure; CT, conventional tillage; CT + OBA + PM, conventional tillage + oil palm bunch ash + poultry manure.

C. Effects of Tillage Methods and Oil Palm Bunch Ash Plus Poultry Manure on Growth of Ginger

Tillage had significant effect on growth components of fresh ginger in the first, second and third years (2009, 2010 and 2011 cropping seasons) (Table III). Averaged over the three years, the highest plant height (65.7cm) was produced by ZTM which was statistically similar to row tillage (63.9cm) and the lowest plant height (44.3cm) was produced by conventional tillage and it was significantly lower ($p< 0.05$) than other tillage treatments. Similarly, numbers of leaves were highest (20.1) in ZTM which was significantly different from RT (16.5) and CT (13.6) which produced the lowest value. ZTM also produced the highest number of tillers (8.9) when compared to RT (6.5) and CT (4.9) (Table III).

In the three trials, application of oil palm bunch ash + poultry manure in combination with tillage methods effects significant differences on the plant height, number of leaves and number of tillers of ginger (Table III). Among tillage plus oil palm bunch ash + poultry manure, zero tillage with mulch plus oil palm bunch + poultry manure (ZTM+OBA+PM) gave the highest values of plant height, number of leaves and number of tillers of ginger in 2009, 2010 and 2011 cropping seasons (Table III) and these were significantly different from row tillage plus oil palm bunch ash + poultry manure (RT+OBA+PM) and conventional tillage plus oil palm bunch ash plus poultry manure (CT+OBA+PM). Conventional tillage plus oil palm bunch ash plus poultry manure (CT+OBA+PM) gave significantly lower values of plant height, number of leaves and number of tillers of ginger among the tillage - oil palm bunch ash + poultry manure combinations. Among all treatments, the mean plant height of ginger over 3 years at the experimental site for ZTM, RT, CT, ZTM+OBA+PM, RT+OBA+PM and CT+OBA+PM were 65.7, 75.2, 63.9, 73.0, 44.3 and 53.7cm, respectively. The mean values for number of leaves were 20.1, 23.6, 16.5, 20.0, 13.6 and 16.6, respectively, while the mean values for number of tillers were 8.6, 12.2, 6.8, 9.4, 4.9 and 7.9 respectively (Table III).

TABLE III
EFFECT OF TILLAGE AND OIL PALM BUNCH ASH ON GROWTH COMPONENTS OF GINGER IN 2009, 2010 AND 2011 CROPPING SEASONS

Treatment	Plant height (cm)				Number of leaves per plant				Number of tillers per plant			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
ZTM	66.3b	65.8b	64.9b	65.7b	20.8b	19.9b	19.5bc	20.1b	9.3b	8.4c	8.0c	8.6c
ZTM + 10 t ha^{-1} OBA + 10 t ha^{-1} PM	74.1a	75.5a	76.0a	75.2a	23.2a	23.6a	23.9a	23.6a	11.9a	12.1a	12.5a	12.2a
RT	64.7b	64.3b	62.8b	63.9b	17.4d	16.5c	15.7de	16.5c	6.9d	6.6e	6.1d	6.5e
RT + 10 t ha^{-1} OBA + 10 t ha^{-1} PM	72.4a	73.1a	73.4a	73.0a	19.5bc	20.1b	20.4b	20.0b	9.2b	9.4b	9.7b	9.4b
CT	45.9d	44.2d	42.9d	44.3d	14.6f	13.7d	12.6f	13.6d	5.3e	4.9f	4.5e	4.9f
CT + 10 t ha^{-1} OBA + 10 t ha^{-1} PM	53.1c	53.8c	54.1c	53.7c	16.2de	16.7c	16.8d	16.6c	7.7c	7.9cd	8.1c	7.9cd

Note: Values followed by the same alphabets in the same column are not significantly different at $p < 0.05$ according to Duncan's multiple range test (DMRT). ZTM, zero tillage with mulch; ZTM + OBA + PM, zero tillage with mulch + oil palm bunch ash + poultry manure; RT, row tillage; RT + OBA + PM, row tillage + oil palm bunch ash + poultry manure; CT, conventional tillage; CT + OBA + PM, conventional tillage + oil palm bunch ash + poultry manure

D.Effect of Tillage Methods and Oil Palm Bunch Ash plus Poultry Manure on Fresh Rhizome Yield of Ginger

Tillage had a significant effect on fresh rhizome yield of ginger in the first, second and third years at the experimental site (Fig. 1). In the first year, the fresh rhizome yield of ginger (15.4t ha$^{-1)}$ produced by zero tillage with mulch was significantly higher ($p< 0.05$) when compared to row tillage (13.1t ha^{-1}) and conventional tillage with lowest fresh rhizome yield of 11.7t ha^{-1} (Fig. 1). Similar trend was also observed in the second year, ZTM gave the highest fresh rhizome yield of ginger (14.9t ha^{-1}) that was significantly different from RT (12.5t ha^{-1}) The lowest fresh rhizome yield (11.1t ha^{-1}) was also produced by CT and it was significantly lower ($p< 0.05$) than other tillage treatments (Fig. 1). In the third year at the experiment site, the trend was also consistent; ZTM gave the highest fresh rhizome yield (14.6t ha^{-1}) of ginger which was significantly higher ($p< 0.05$) than RT (12.1t ha^{-1} fresh rhizome yield). CT also produced the lowest fresh rhizome yield (10.8t ha^{-1}) of ginger and it was significantly lower ($p< 0.05$) than other tillage methods (Fig. 1).

In the 2009, 2010 and 2011 cropping seasons, application of oil palm bunch ash plus poultry manure in combination with tillage methods gave significantly higher ($p< 0.05$) fresh rhizome yield of ginger than their sole tillage systems (Fig. 1). Among tillage plus oil palm bunch ash plus poultry manure treatments, zero tillage with mulch plus oil palm bunch ash plus poultry manure (ZTM+OBA+PM) gave the highest fresh rhizome yield of ginger (20.1t ha^{-1}) and this was significant higher ($p< 0.05$) than row tillage plus oil palm bunch ash plus poultry manure (RT+OBA+PM). Among the tillage – oil palm bunch ash plus poultry manure combinations, conventional tillage plus oil palm bunch ash plus poultry manure (CT+OBA+PM) gave the lowest fresh rhizome yield of ginger (15.7t ha^{-1}). The fresh rhizome yield of ginger in the tillage - oil palm bunch ash plus poultry manure regime treatments/combinations increased over time, whereas that under various tillage regime treatments declined over time. The increase in fresh rhizome yield of ginger over time in the tillage-oil palm bunch ash plus poultry manure combinations/treatments could be attributed to relatively higher K, Ca and Mg concentrations in OBA and higher soil organic C, N and P concentrations in PM and their high residual effects on soil properties and were able to sustain three successive cropping of ginger in this study. Whereas the decrease in fresh rhizome yield of ginger over time in the various tillage treatments was related to the fact that tillage degrades soil properties with time and the degradation depends on the frequency or intensity of tillage imposed on soil [29].

Among all treatments, the mean fresh rhizome yield over 3 years at the experimental site for ZTM, ZT+OBA+PM, RT, RT+OBA+PM, CT and CT+OBA+PM were 15.0, 20.1, 12.6, 17.2, 11.2 and 15.7t ha^{-1} , respectively (Fig. 2). ZT+OBA+PM increased fresh rhizome yield of ginger by 34% relative to ZT alone. Relative to RT, RT+OBA+PM increased fresh rhizome yield of ginger by 37%. CT+OBA+PM in increased fresh rhizome yield of ginger by 40% compared with CT alone. These results confirmed that application of oil palm bunch ash plus poultry manure in combination with tillage improved growth and fresh rhizome yield of ginger, relative to tillage alone. Compared with untreated plots (control), oil palm bunch ash plus poultry manure significantly increased ($p< 0.05$) growth and fresh rhizome yield of ginger in the three years. This is expected because oil palm bunch ash plus poultry manure made available nutrients, especially N and K that are essential for plant growth which eventually led to increased fresh rhizome yield. Potassium is known to be strongly importance for the production of tuber crops [33]. Agbede et al. [32], in a field experiment conducted in forest - savanna transition zone of southwest Nigeria found that oil palm bunch ash plus poultry manure is superior to NPK fertilizer in promoting yield of yam. Similar result was found in a field experiment conducted on Ultisols of southeast Nigeria for cassava crop [31].

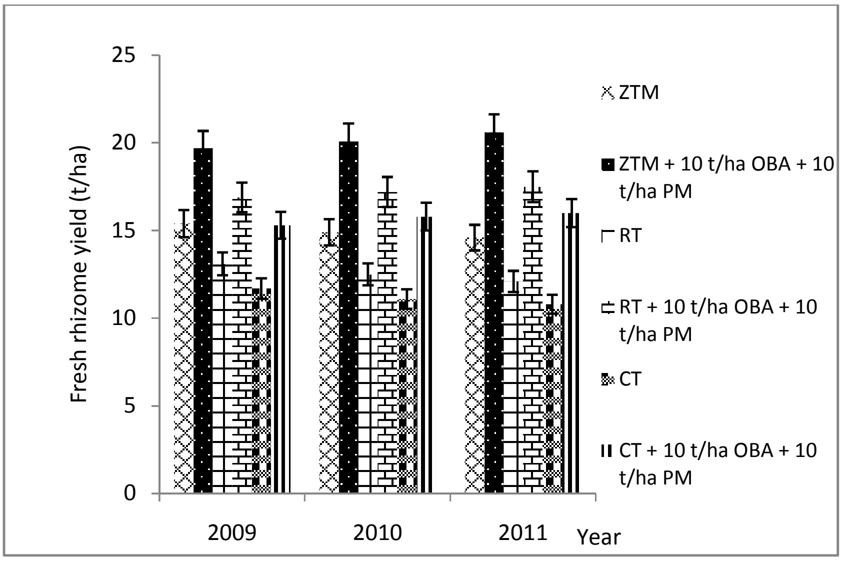

Fig. 1 Effect of tillage and oil palm bunch ash plus poultry manure on fresh rhizome yield of ginger

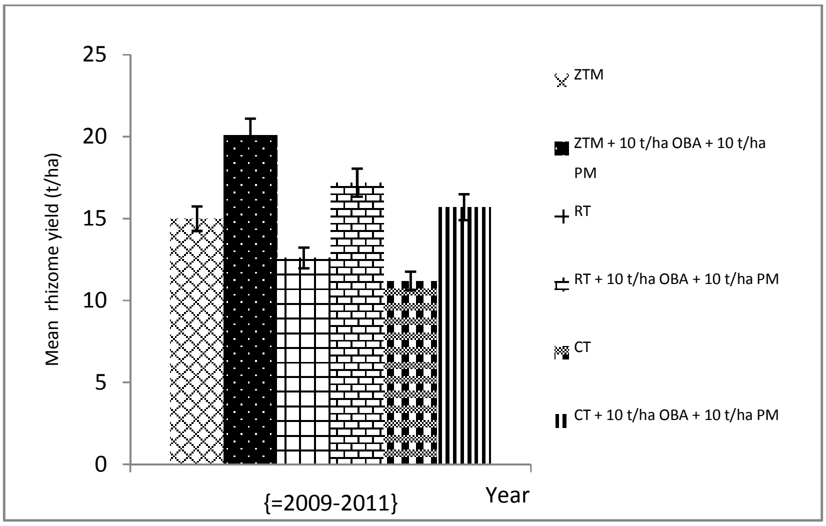

Fig. 2 Effect of tillage and oil palm bunch ash plus poultry manure on mean rhizome yield of ginger

E. Performance of Ginger

Tillage inform of ZTM increased significantly performance of ginger in the 3 years (2009, 2010 and 2011) relative to RT and CT. This was probably due to improved nutrition as a result of increased activities of beneficial soil fauna in organic matter decomposition. Hence, additional nutrients would have been made available to the crop from decomposition of weeds killed and left on soil surface by pre-plant herbicide treatment in untilled zero/mulch plots. Also the best performance of ginger under ZTM was due to better soil conditions favorable for growth and tuber development of ginger. For example, the initial soil bulk density value recorded for the site (1.38Mg m^{-3}) was not limiting to growth and development of ginger. A soil bulk density value of 1.40Mg m^{-3} was recommended as optimum for efficient crop production in the tropics [33], [34].

In the study, growth and rhizome yield of ginger reduced with increased frequency/intensity of tillage, and soil nutrient concentrations and organic C also tended to decrease similarly [27]. Hence, CT gave the lowest values of soil organic C, N, P, K, Ca and Mg concentrations, growth and rhizome yield of ginger. Agbede [29] had earlier found that for Alfisol of southwest Nigeria, zero tillage with mulch most conserved soil fertility and increased nutrient uptake and yield of cocoyam compared with conventional tillage method. Therefore, the Alfisol in the forest-savanna zone requires zero tillage with mulch. Hence, it was found in this study that zero tillage with mulch gave most productive soil in terms of performance of ginger and soil fertility.

In comparing zero tillage with mulch with row tillage, rhizome yield reduced by 19%, while conventional tillage reduced the fresh rhizome yield of ginger by 34%. Pooled over the 3 years the mean fresh rhizome yield of ginger for untreated and treated were 12.9 and 17.7t ha^{-1}, respectively. Hence, oil palm bunch ash plus poultry manure application in combination with tillage increased fresh rhizome yield of ginger by 37% compared with tillage alone. The ZTM+OBA+PM increased fresh rhizome yield of ginger by 22% compared with RT+OBA+PM and CT+OBA+PM. The zero ZTM + OBA + PM gave the highest fresh rhizome yield of ginger crops. This might be due to favourable chemical properties resulting from this treatment that helped in better establishment and growth of ginger plants. Therefore, ZTM+OBA+PM is recommended for ginger. It is affirmed that nutrient availability dictated the performance of ginger on an Alfisol of forest-savanna transition zone of southwest Nigeria.

IV. Conclusions

Ginger performance is favoured by zero tillage with mulch followed by row tillage as opposed to repetitive tillage involving ploughing followed by harrowing. Conventional tillage degrades soil chemical properties and reduced ginger productivity and is therefore not recommendation for ginger cultivation on an Alfisol of forest-savanna transition zone of southwest Nigeria. Application of oil palm bunch ash plus poultry manure at rate 10t ha^{-1} each to any tillage treatment improved soil fertility status, growth and yield of ginger. However, zero tillage with mulch in combination with oil palm bunch ash plus poultry manure gave the best production technology of ginger cultivation because the combination (ZTM+OBA+PM) improved soil fertility and yield of ginger than other tillage - OBA+PM combinations. Therefore, zero tillage with mulch in combination with 10t ha^{-1} OBA + 10t ha^{-1} PM is recommended for ginger cultivation on an Alfisol of southwest Nigeria for soil fertility and crop sustainability.

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