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THE EFFECT OF THREE YEARS OF TILLAGE AND POULTRY MANURE APPLICATION ON SOIL AND PLANT NUTRIENT COMPOSITION, GROWTH AND YIELD OF COCOYAM

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SUMMARY

Tillage and use of organic manure are important agronomic practices that sustain high crop and soil productivity. Hence, a three-year (2007 to 2009) study was conducted to evaluate the effect of site, tillage and poultry manure (PM) treatments on soil and plant nutrients composition, growth and yield of cocoyam (*Xanthosoma sagittifolium*). The study was a 2 × 5 × 5 factorial experiment with two sites (Owo – site 1 and Obasooto – site 2), five tillage methods; manual clearing (MC), manual ridging (MR), manual mounding (MM), ploughing plus harrowing (P+H) and ploughing plus harrowing twice (P+2H) and five levels of PM (0, 2.5, 5.0, 7.5, 10.0 t ha^{-1}). Treatments were replicated thrice. Soil OM, N, P, K, Ca, Mg and leaf nutrients reduced with increase in tillage intensity, thus MC conserved soil nutrients the most, and increased nutrient uptake. Soil and plant nutrient concentration was lowest under the P+2H treatment. The MC, MR and MM treatments led to faster growth and higher tuber yield. As PM increased from 0 to 10.0 t ha^{-1} soil pH, OM, soil and plant N, P, K, Ca and Mg increased. The 7.5 t ha^{-1} PM gave the highest leaf K, Ca and Mg values. Owo site had significantly higher yield and growth parameters of cocoyam compared with Obasooto site. Yield and growth parameters of cocoyam increased with increase in PM level up to 7.5 t ha^{-1}. Out of all tillage cum manure treatments, MC+7.5 t ha^{-1} PM gave the highest values of yield and growth parameters.

INTRODUCTION

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott), a member of the Araceae family, is a subsistence and emergency food source in many parts of the world, but a major staple food crop in Nigeria (a leading producer of cocoyam), South Pacific Islands and some parts of Asia (Uwah *et al.*, 2011). The corms and cormels are eaten boiled, fried, baked and roasted. In West Africa, the boiled cocoyam is sometimes pounded to produce a paste similar to pounded yam and eaten in the same manner. The corms and cormels may be peeled, dried and ground into flour and thus stored in a semi-processed form. The young leaves and petioles are made into soup, while the corms, cormels and leaves after curing can also be used as animal feed (Onwueme and Sinha, 1991). Cocoyams are the cheapest and most handy source of carbohydrate in meals that

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are recommended for aged people, diabetics, convalescents and most gastro-intestinal disorder patients and a good carbohydrate base for infant foods on account of their small-sized starch grains which are easily digested compared to yam (*Dioscorea spp*), cassava (*Manihot spp*) or sweet potato (*Ipomoea batatas*) (Som, 2007; Uwah *et al.*, 2011). However, the crop has not received research attention particularly concerning its tillage and manure requirements.

Tillage and use of organic manure are important agronomic practices that sustain high crop and soil productivity. Studies on tillage requirement for cocoyam are few and gave differing results (Adekiya *et al.*, 2011). Hence, there is need to study the tillage requirement and soil conditions influencing cocoyam in order to raise production level from the average yield of 5.1 Mt ha^{-1} to the potential yields of 8.0 Mt ha^{-1} and meet the demand for the corms and cormels. Also, previous studies were short-termed; aside from being inconclusive. Villanueva (1986) studied the effect of tillage intensity on production of upland taro (cocoyam) and found no significant differences between ploughing and harrowing once or twice. Ghosh *et al.* (1988) recommended ploughing once with the incorporation of farmyard manure, followed by harrowing, and if necessary, either mounding or ridging. In the Philippines, Pardales and Villamayor (1983) also found that ploughing and harrowing once was sufficient for taro (cocoyam) production. Enyi (1967 cited by Onwueme, 1978) reported that the yield of cocoyam (*Xanthosoma spp.*) is higher and corm shape is better when planted on ridges. Also, research information is quite scarce on the effect of organic wastes on soil chemical properties and performance of cocoyam. In Hawaii, taro (cocoyam) is usually grown in puddled-flooded soils with high inputs of fertilizers, resulting in very high yields of up to 60 t ha^{-1} (Plucknett *et al.*, 1973 cited by Agbede, 2008). Ogbonna and Nweze (2012) found that the application of the recommended N, P and K fertilizer rates of 200 and 250 kg ha^{-1} at Nsukka (Enugu State) and Umudike (Abia State), respectively on Ultisol grown to cocoyam in the southeast of Nigeria is not sustainable due to scarcity and high cost of chemical fertilizer. Moreover, the fertilizer did not lead to expected yield levels due to leaching of nutrients. Obasi *et al.* (2005), in their two-year study, found that in the second year PM applied up to 120 kg N ha^{-1} increased corm plus cormel yield from 8.4 to 18.7 t ha^{-1}, but above this rate decreased the yield of cocoyam. Also, swine and cow manures increased yield up to 180 kg N ha^{-1}. Nyakatawa *et al.* (2001) observed that it is possible to increase yield of crops on physically degraded soils by using organic resources such as manure for soil fertility improvement after adopting appropriate tillage practices. To this end, this paper reports a three-year study conducted at two sites to determine the effects of different tillage methods, PM and tillage cum PM treatments on soil and plant nutrients composition, growth and yield of cocoyam on an Alfisol in southwest Nigeria.

MATERIALS AND METHODS

Site description and experimental design

Field experiments were conducted at Owo (site 1 - latitude 7° 13′N, longitude 5° 32′E) and Obasooto (site 2 - latitude 7° 12′N, longitude 5° 32′E) in forest-savanna zone of southwest Nigeria. Obasooto is located 10 km from Owo. The soils at Owo and Obasooto belongs to the broad group Alfisol classified as Oxic Tropuldalf or Luvisol (FAO, 1998). The experimental sites had been under bush fallow for two years after arable cropping to a variety of crops such as yam (*Dioscorea rotundata* Poir), maize (*Zea mays* L.), groundnut (*Arachis hypogaea* L.), cassava (*Manihot esculenta* Crantz), melon (*Colosynthis citrullus* L.) etc. The predominant weeds at Owo (site 1) and Obasooto (site 2) were Siam weed (*Chromolaena odorata* L. King and Robinson), Water leaf (*Talinum triangulare* Jacq. Wild), Guinea grass (*Panicum maximum* Jacq.) and Haemorrhage plant (*Aspilia africana* Pers. Adams), interspersed with shrubs. The experiments were conducted to assess the long term effect (at year three) of cropping and soil management method on soil and plant nutrients composition, growth and yield of cocoyam.

The experiments consisted of a 2 × 5 × 5 factorial experiment with two sites (Owo – site 1 and Obasooto – site 2, five tillage methods: MC, MR, MM, P+H and P+2H and five PM levels (0, 2.5, 5.0, 7.5 and 10.0 t ha^{-1}). The rate of 7.5–10.0 t ha^{-1} was recommended for cocoyam production (Adekiya *et al.*, 2012; Hamma *et al.*, 2014). The 25 treatment combinations were arranged in a randomized complete block design and replicated thrice. Each block comprised 25 plots, each of which measured 12 m × 10 m. Tillage was followed by initial MC with cutlass. The same treatment was allotted to each plot at the two sites.

Crop establishment

Tillage was done in April each year (2007, 2008 and 2009). Cocoyam cormels weighing about 150 g are planted each year. A cormel was planted per hill at 1 m × 1 m to give 10 000 plants per ha. PM was applied three weeks after planting by ring method. Weeding was done manually at 45 and 110 days after planting (DAP). The same treatment was applied to each plot for three years.

Soil analysis

Prior to the commencement of the experiment in 2007, soil samples were taken from 0 to 15 cm depth at each site using steel core tubes. Ten core samples collected at each site were used for determination of bulk density after oven drying at 100°C for 24 h. Total porosity was calculated from bulk density using particle density of 2.65 Mg m^{-3}. Mechanical analysis was done using hydrometer method. Surface samples collected over each site were bulked, air dried with 2 mm sieved for chemical analysis. Also, samples collected over each plot at harvest of cocoyam in 2009 were analysed for chemical properties (AOAC, 2006). The organic matter (OM) was determined by Walkley and Black procedure using dichromate wet oxidation method, total N by micro-Kjeldahl digestion method, available P by Bray 1 extraction followed by molybdenum colourimetry. Exchangeable K, Ca and Mg were extracted with 1M ammonium acetate. Thereafter, K was determined using flame photometer, and Ca and Mg by EDTA titration method. Soil pH was determined in soil water medium at ratio of 1:2 using the digital electronic pH metre.

Leaf analysis

In 2009, two to three weeks old cocoyam leaves were collected at 168 DAP when the cocoyam plant reached its peak growth (Agbede, 2008; Hulugalle *et al.*, 1985; Ndon *et al.*, 2003). The leaves were collected from ten plants per plot for chemical analysis. The samples were oven-dried for 24 hr at 70°C and ground. Leaf N was determined by micro-Kjeldahl approach. Samples were dry ashed at 500°C for 6 hr in a furnace and extracted using nitric–perchloric–sulphuric acid mixture for the determination of P, K, Ca and Mg. Leaf P was determined using vanadomolybdate colourimetry method. K was determined using a flame photometer, and Ca and Mg were determined by EDTA titration method (AOAC, 2006).

Growth and yield parameters

Twenty plants were selected per plot for determination of plant height and leaf area per plant at 168 DAP when the cocoyam plant reached its peak growth in 2009. Plant height was measured from the ground level to the shoot apex. Leaf area was estimated using the mathematical model developed by Agueguia (1993) between linear measurements of leaves. It relates leaf area (Y) to the product of length (L) and breadth (B).

$$Y = k(\mathrm{LB}), \quad (1)$$

where the constant, $k = 0.923 + 0.004$.

The corm and cormel yields were determined by harvesting twenty cocoyam plants per plot and separated them into corms and cormels. They were washed and cleaned to remove traces of sand before weighing on a top loading balance to determine their fresh weights.

Preparation and analysis of manure

The PM used each year was stacked a week under a shed to allow for mineralization, samples were analysed for nutrient composition after being air-dried and crushed to pass through a 2 mm sieve. Analysis was done for organic carbon (OC), N, P, K, Ca and Mg (AOAC, 2006).

Statistical analysis

Data collected in 2009 were subjected to analysis of variance test and treatment means were compared using the Duncan's multiple range test (DMRT) and Least significant different (LSD) at $p = 0.05$.

RESULTS AND DISCUSSION

Initial soil fertility status

The properties of the soils at the experimental sites in 2007 are shown in Table 1. The soils at both sites 1 (Owo) and 2 (Obasooto) are slightly acidic, sandy loam in texture with high bulk density. The soils at sites 1 and 2 had low OM, total N, available P and exchangeable K. The exchangeable Ca was deficient at site 1, but adequate at

Table 1. Soil properties (0–15 cm depth) of sites before experimentation in 2007.

Property	Owo (Site 1)	Obasooto (Site 2)
Sand (%)	68.2	66.0
Silt (%)	16.0	14.0
Clay (%)	15.8	20.0
Textural class	Sandy loam	Sandy loam
pH (water)	5.58	5.72
Bulk density Mg/m^3)	1.55	1.54
Total porosity (%)	41.4	41.9
Organic matter (%)	2.97	2.90
Total N (%)	0.18	0.19
Available P (mg/kg)	4.5	5.0
Exchangeable K (cmol/kg)	0.15	0.13
Exchangeable Ca (cmol/kg)	1.78	2.39
Exchangeable Mg (cmol/kg)	0.81	1.03

Table 2. Nutrient composition of the poultry manure used.

Property	2007	2008	2009
Organic carbon (%)	14.8	14.6	14.0
Total N (%)	2.20	2.21	2.19
C:N	6.7	6.6	6.4
Phosphorus (%)	0.83	0.86	0.82
Potassium (%)	2.23	2.36	2.30
Calcium (%)	1.42	1.40	1.39
Magnesium (%)	0.58	0.60	0.57

site 2. The exchangeable Mg was adequate at both sites 1 and 2. Chemical analysis of PM utilized in 2007, 2008 and 2009 (Table 2) indicates that it contains nutrient elements (N, P, K, Ca and Mg) required for the growth of a tuber crop such as cocoyam. The OC was the highest. It is expected that the nutrients will be released into the soil for the uptake of the crop (Makinde *et al.*, 2011).

Effect of tillage and poultry manure on yield and growth parameters of cocoyam

The effect of tillage and PM on yield and growth parameters of cocoyam at Owo (site 1) and Obasooto (site 2) at the end of the third year (2009) are presented in Table 3. Owo (site 1) had significantly higher corm and cormel yields, plant height and leaf area compared with Obasooto (site 2). This can be adduced to better soil nutrients especially K at Owo site compared to Obasooto site. Among the tillage treatments, MC and minimally tilled MR and MM soils had higher values of corm and cormel yields, plant height and leaf area, respectively compared with mechanically tilled soils. The mean corm yield for MC, MR, MM, P+H and P+2H were 6.3, 5.4, 5.3, 4.8 and 4.2 t ha^{-1} respectively, values for cormel yield were 8.2, 6.8, 6.8, 5.7 and 5.5 t ha^{-1} respectively. The values for mean plant height were 0.55, 0.46, 0.46, 0.41 and 0.34 m respectively and the values for mean leaf area were 1.10, 0.96, 0.95, 0.85 and 0.76 m^2 per plant respectively. Therefore, relative to intensive repetitive mechanized

Table 3. Effect of tillage and poultry manure on yield and growth parameters of cocoyam in 2009 at Owo (Site1) and Obasooto (Site 2).

	Corm yield (t ha^{-1})	Cormel yield (t ha^{-1})	Plant height (m)	Leaf area (m^2)
Site (S)				
1.	5.4a	6.8a	0.47a	0.99a
2.	5.1b	6.4b	0.42b	0.86b
Tillage method (T)				
MC	6.3a	8.2a	0.55a	1.09a
MR	5.4b	6.8b	0.46b	0.96b
MM	5.3b	6.8b	0.46b	0.95c
P+H	4.8c	5.7c	0.41c	0.85d
P+2H	4.2d	5.5d	0.34d	0.76e
Poultry manure (PM) rates (t ha^{-1})				
0.0	4.4e	5.9e	0.36d	0.79d
2.5	5.0c	6.2d	0.41c	0.87c
5.0	5.5b	6.9b	0.48b	0.98b
7.5	6.2a	7.7a	0.55a	1.11a
10.0	4.9d	6.3c	0.42c	0.87c
S	0.0001	0.0001	0.0001	0.0001
T	0.0001	0.0001	0.0001	0.0001
PM	0.0001	0.0001	0.0001	0.0001
S × T	0.0001	0.0001	0.0001	0.0001
S × PM	0.03	0.025	0.0001	0.0001
T × PM	0.0001	0.0001	0.0001	0.0001
S × T × PM	ns	ns	0.0003	0.0118

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT); ns = not significant at 5% and 1% level of probability; MC = Manual clearing; MR = Manual ridging; MM = Manual mounding; P+H = Ploughing plus harrowing; P+2H = Ploughing plus harrowing twice; S = Site; T = Tillage method; PM = Poultry manure.

tillage (P+2H), MC increased corm and cormel yields by 50 and 49% respectively. The lower performance of cocoyam in mechanically tilled soils especially in soil with highest number of passes of implement (P+2H) was due to lower nutrient content. The lower nutrient content in the intensively tilled plots (P+2H) could be adduced to a number of processes such as leaching, increased biological activity and oxidation. Agbede and Ogundele (2015) reported rapid mineralization of soil OM, N, P, K, Ca and Mg for Alfisol in Nigeria due to intensive tillage. This indicates that tillage degrades soil properties with time and the degradation depends on the frequency or intensity of tillage imposed on soil (Agbede, 2008; Agbede and Ogundele, 2015). The growth and yield of tuber crops such as yam and cocoyam is limited by soil nutrients (Agbede, 2008; Agbede *et al.*, 2013; Hamma *et al.*, 2014). Agbede (2008) observed that availability of soil nutrients dictated performance of cocoyam and that soil quality was degraded by conventional tillage (CT) which gave the lowest nutrient content and moisture content compared with zero tillage with mulch (ZTM), zero tillage without mulch (ZTOM), MM and MR.

Irrespective of tillage method, corm and cormel yields, plant height and leaf area of cocoyam increased with application of PM up to 7.5 t ha^{-1}. The increases dropped

Table 4. Effect of tillage on chemical properties (0–15 cm) in 2009 at Owo (Site 1).

Tillage method	pH (water)	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
Manual clearing (MC)	5.5a	2.85a	0.14a	3.9a	0.13a	1.61a	0.72a
Manual ridging (MR)	5.4a	2.51b	0.12b	3.2b	0.10b	1.31b	0.69ab
Manual mounding (MM)	5.4a	2.49b	0.12b	3.1b	0.10b	1.30b	0.69ab
Ploughing + harrowing (P+H)	5.1ab	2.20c	0.10c	2.7c	0.08c	1.12c	0.66b
Ploughing + 2 harrowing (P+2H)	5.0ab	1.98d	0.09d	2.3d	0.06d	1.01d	0.65b

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT).

at 10.0 t ha^{-1} (Table 3). The overall mean corm yield were 4.4, 5.0, 5.5, 6.2 and 4.9 t ha^{-1} for 0, 2.5, 5.0, 7.5 and 10.0 t ha^{-1} PM respectively, while mean cormel yield were 5.9, 6.2, 6.9, 7.7 and 6.3 t ha^{-1} respectively. The mean values of plant height were 0.36, 0.41, 0.48, 0.55 and 0.42 m for 0, 2.5, 5.0, 7.5 and 10.0 t ha^{-1} PM, respectively. The values for leaf area per plant were 0.79, 0.87, 0.98, 1.11 and 0.87 m^2 per plant respectively. The increase in performance of cocoyam is consistent with increase in soil and plant nutrients associated with PM application. The finding that the 7.5 t ha^{-1} PM most increased leaf K, Ca and Mg, yield and growth parameters of cocoyam suggests that uptake of these nutrients most dictate performance of cocoyam since increase in soil K, Ca and Mg also terminated at 7.5 t ha^{-1} PM. Potassium is particularly important for carbohydrate synthesis in tuber crops (Agbede *et al.*, 2013).

When studied as individual factors, site (S), tillage (T) and PM significantly influenced yield and growth parameters of cocoyam (Table 3). The interactive effect of S × T, S × PM and T × PM were significant for yield and growth parameters of cocoyam. When all the three factors (S × T × PM) were considered together, interactions were significant for growth parameters of cocoyam, but not significant for yield of cocoyam. At both sites, the MC+7.5 t ha^{-1} PM gave the highest corm and cormel yields, plant height and leaf area of cocoyam, while the 7.5 t ha^{-1} PM gave the highest values of yield and growth parameters. The 7.5 t ha^{-1} PM also gave the highest soil and leaf K, Ca and Mg. It is affirmed that N supply and availability of the cations dictated the cocoyam performance, but at a certain soil organic N threshold or rather at rates exceeding 7.5 t ha^{-1} PM ammonium concentration causes toxic effects.

Tillage effect on soil chemical properties

The effect of tillage on soil chemical properties at Owo (site 1) and Obasooto (site 2) at the end of the third year (2009) are shown in Tables 4 and 5. In 2009 (third year), soil OM and nutrients contents reduced with increase in tillage intensity. The MC most conserved soil OM, N, P, K, Ca and Mg and the manual tillage (MR, MM) had higher values of soil OM and nutrients compared with mechanized tillage methods (P+H and P+2H). The most intensive tillage given by three passes of implement (P+2H) gave least values of nutrients. Hence, soil OM and nutrients reduced in the order (MC > MR = MM > P+H > P+2H). Also, the mechanized tillage methods gave least soil

Table 5. Effect of tillage on chemical properties (0–15 cm) in 2009 at Obasooto (Site 2).

Tillage method	pH (water)	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
Manual clearing (MC)	5.7a	2.80a	0.15a	4.6a	0.10a	2.12a	0.93a
Manual ridging (MR)	5.6a	2.49b	0.13b	4.1b	0.09b	1.67b	0.87b
Manual mounding (MM)	5.6a	2.47b	0.13b	4.1b	0.09b	1.68b	0.86b
Ploughing + harrowing (P+H)	5.2ab	2.00c	0.11c	3.1c	0.07c	1.51c	0.64c
Ploughing + 2 harrowing (P+2H)	5.0b	1.81d	0.08d	2.6d	0.05d	1.32d	0.41d

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT).

Table 6. Effect of poultry manure on soil chemical properties (0–15 cm) in 2009 at Owo (Site 1).

Poultry manure (t ha^{-1})	pH (water)	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
0	5.3bc	2.41e	0.11e	3.0e	0.09e	1.30d	0.68d
2.5	5.4bc	2.82d	0.13d	3.5d	0.10d	1.46c	0.77c
5.0	5.6ab	3.14c	0.15c	4.0c	0.12c	1.72b	0.99b
7.5	5.8a	3.51b	0.17b	4.7b	0.15a	1.96a	1.19a
10.0	5.9a	3.96a	0.20a	5.2a	0.14ab	1.94a	1.17a

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT).

pH which is consistent with the least values recorded for the cations K, Ca and Mg. Reduction in soil OM and nutrients due to tillage is attributable to loss and oxidation of OM (Ojeniyi and Adekayode, 1999, 2002) which is natural source of nutrients. Also, the initially porous nature of tilled soils especially in the first two years (Agbede and Ojeniyi, 2010) might have enhanced leaching of nutrients to subsoil. The MC, form of zero tillage, had highest soil OM and nutrients content. Zero tillage is known to conserve soil fertility in the long-run (Agbede and Ojeniyi, 2010). It gave highest concentration of nutrients under cocoyam in the third year of cropping compared with manual and mechanized tillage methods.

Effect of poultry manure on soil chemical properties

The effect of PM on soil chemical properties at Owo (site 1) and Obasooto (site 2) at the end of the third year (2009) are shown in Tables 6 and 7. Irrespective of tillage method, soil pH, OM, total N, available P, exchangeable K, Ca and Mg increased with level of PM from 0 to 10.0 t ha^{-1}. In case of K, Ca and Mg, however, the 7.5 t ha^{-1} PM gave highest values in all instances. General increase in soil nutrients content with addition of PM is consistent with the fact that PM is a natural and effective source of nutrients (Agbede and Ojeniyi, 2009, 2010; Ayeni *et al.*, 2010; Maerere *et al.*, 2001; Odedina *et al.*, 2011) and its presence also increases cation exchange capacity of soil. It also has liming effect (Odedina *et al.*, 2011).

Table 7. Effect of poultry manure on soil chemical properties (0–15 cm) in 2009 at Obasooto (Site 2).

Poultry manure ($t\ ha^{-1}$)	pH (water)	OM (%)	N (%)	P ($mg\ kg^{-1}$)	K ($cmol\ kg^{-1}$)	Ca ($cmol\ kg^{-1}$)	Mg ($cmol\ kg^{-1}$)
0	5.3b	2.31e	0.12e	3.7e	0.08e	1.68d	0.87d
2.5	5.5ab	2.80d	0.14d	4.0de	0.09d	1.91c	1.05c
5.0	5.6ab	3.19c	0.16c	4.5c	0.12c	2.24b	1.30b
7.5	6.1a	3.68b	0.21b	5.0b	0.15a	2.64a	1.63a
10.0	6.2a	4.12a	0.25a	5.9a	0.14ab	2.61a	1.61a

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT).

Table 8. Effect of tillage on leaf nutrients composition in 2009 at Owo (Site 1) and Obasooto (Site 2).

	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
Tillage method	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
MC	2.16a	2.60a	0.37a	0.41a	0.32a	0.39a	0.52a	0.59a	0.27a	0.19a
MR	1.90bc	2.15b	0.30b	0.35b	0.28b	0.29b	0.42b	0.44b	0.22b	0.16b
MM	1.96b	2.11b	0.31b	0.35b	0.28b	0.28b	0.41b	0.44b	0.21b	0.16b
P+H	1.77c	1.89c	0.26c	0.29c	0.22c	0.20c	0.36c	0.38c	0.18c	0.14c
P+2H	1.60d	1.70d	0.22d	0.25d	0.19d	0.17d	0.32d	0.30d	0.15d	0.11d

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT). MC = Manual clearing; MR = Manual ridging; MM = Manual mounding; P+H = Ploughing plus harrowing; P+2H = Ploughing plus harrowing twice.

Effect of tillage on leaf nutrients composition of cocoyam

The effect of tillage on leaf nutrients composition of cocoyam at Owo (site 1) and Obasooto (site 2) at the end of the third year (2009) are shown in Table 8. Leaf nutrients content reduced with tillage intensity; hence, leaf N, P, K, Ca and Mg reduced in the order MC > MR = MM > P+H > P+2H. Expectedly, the manual methods (MM, MR) had similar values. The most intense and repetitive tillage method (P+2H) had least values of plant nutrients. This finding is consistent with the finding that tillage reduced soil nutrients content over three years. The reduction led to decrease in nutrients uptake by cocoyam. In their study with sorghum, Agbede and Ojeniyi (2010) also observed that zero tillage gave highest leaf N, P, K, Ca and Mg concentrations in sorghum compared with MC, PL (Ploughing), P+H and P+2H. They also noted that nutrients concentration in sorghum decreased with frequency and intensity of soil manipulation. This was attributed to better soil fertility and water content adduced to zero tillage. The lower leaf nutrients observed by the authors for sorghum plants on mechanically tilled soils was adduced to soil degradation and lower moisture content which adversely affected nutrient uptake. Study by Adekiya *et al.* (2011) showed that in the first two years, MC gave highest values of soil chemical properties under cocoyam compared with manual and mechanized tillage.

Effect of poultry manure on leaf nutrients composition of cocoyam

The effect of PM on leaf nutrients composition of cocoyam at Owo (site 1) and Obasooto (site 2) at the end of the third year (2009) are shown in Table 9. Irrespective

Table 9. Effect of poultry manure on leaf nutrients composition in 2009 at Owo (Site 1) and Obasooto (Site 2).

	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
Poultry manure (t ha^{-1})	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
0	1.88e	2.09e	0.29e	0.33e	0.26d	0.27d	0.43d	0.43d	0.21e	0.16d
2.5	2.09d	2.35d	0.33d	0.38d	0.30c	0.31c	0.48c	0.48c	0.25c	0.19c
5.0	2.39c	2.66c	0.38c	0.43c	0.34b	0.35b	0.54b	0.55b	0.30b	0.23b
7.5	2.68b	2.99b	0.44b	0.51b	0.40a	0.43a	0.63a	0.61a	0.34a	0.27a
10.0	2.97a	3.28a	0.50a	0.57a	0.31c	0.32c	0.51bc	0.49c	0.27cd	0.19c

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT).

of tillage method, leaf N and P increased with the level of PM from 0 to 10.0 t ha^{-1}. In case of K, Ca and Mg, the increase persisted up to 7.5 t ha^{-1} PM and it dropped at 10.0 t ha^{-1} PM. It is affirmed that PM enhanced uptake of N, P, K, Ca and Mg by cocoyam. Similar observation was made with respect to sorghum (Agbede and Ojeniyi, 2010) that PM at 7.5 t ha^{-1} significantly increased plant N, P, K, Ca and Mg. The decreasing nutrients content in leaves at 10.0 t ha^{-1} PM is due to some nutrient imbalances between cations which have not been measured (e.g. $NH4^+$, Na^+) on the one hand and K, Ca and Mg on the other hand or it is related to ammonium toxicity and hence lower uptake rates. It could be seen that soil pH increased with PM up to 10.0 t ha^{-1}. In the study with cassava, Odedina *et al.* (2011) also found that PM increased leaf N, K and Mg in addition to increasing soil K, Ca and Mg.

CONCLUSIONS

For sustainable and enhanced productivity of cocoyam, soil fertility and nutrient availability, combination of MC and PM at 7.5 t ha^{-1} is recommended in the study area. MC most preserved soil fertility and sustained higher yield and growth of cocoyam while manure at 7.5 t ha^{-1} most improved yield and growth of cocoyam and nutrients concentration.

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