American-Eurasian J. Agric. & Environ. Sci., 13 (1): 121-125, 2013
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2013.13.01.1861

Effect of Poultry Manure on Soil Physical Properties, Nutrient Uptake and Yield of Cocoyam (*Xanthosoma saggitifolium*) in Southwest Nigeria

[1]*S.O.Ojeniyi,* [2]*O.A. Amusan and* [1]*A.O. Adekiya*

[1]Department of Crop, Soil and Pest Management,
Federal University of Technology Akure, Nigeria
[2]Department of Crop Production and Management Sciences,
Tai Solarin University of Education, Ijebu-Ode, Nigeria

Abstract: An experiment was conducted for three consecutive years to investigate the effect of poultry manure (PM) application on soil physical properties, performance parameters and nutrient uptake of cocoyam (*Xanthosoma saggitifolium*) in two locations in Southwest Nigeria. The treatments consisted of five tillage methods and five levels of poultry manure (0, 2.5, 5.0, 7.5 and 10 t ha^{-1}) arranged as a factorial experiment using randomized complete block design (RCBD) with three replicates. Soil temperature and bulk density were reduced as application rate of PM increased from 0 to 10 t ha^{-1} ,while porosity and moisture content increased. Leaf N and P increased with rate of PM up to 10 t ha^{-1} and leaf K, Ca, Mg, cormel and corm yield increased up to 7.5 t ha^{-1}. The r values between leaf N, P, K, Ca, Mg, cormel plus corm yield and PM were 1.00, 1.00, 0.62, 0.55, 0.61, 0.51, respectively. The PM significantly increased soil physical properties, nutrient uptake, growth and yield of cocoyam. It is recommended at application rate of 7.5 t ha^{-1} for optimum performance of cocoyam.

Key words: Cocoyam · Cormels · Corms · Poultry manure · Yield

INTRODUCTION

Cocoyam (*Xanthosoma* spp) is a tropical tuber crop and one of the six most important root and tuber crops world- wide [1, 2]. The corms and cormels of the plant are an important source of carbohydrate for human nutrition, animal feed and cash income for farmers. The crop is mainly cultivated by small-scale farmers in Asia, Africa and Latin America with Nigeria featuring as the highest producer in the world. In spite of its importance as a staple food in many countries, cocoyam has received very little research attention and is widely regarded as an under-exploited and insufficiently studied crop [3, 4].

The genus *Xanthosoma* belongs to the tribe Caladieae, of the family Araceae [5, 6]. The family Araceae contains two other genera – Alocasia and Colocasia, both also cultivated for their edible corms and cormels. The taxonomic position of the cultivated *Xanthosoma* species is unclear and in recent years, the tendency has been to give the name *Xanthosoma sagittifolium* to all cultivated *Xanthosoma* [7]. According to Bown [6] however, there are two main species – *X. sagittifolium* and *X. violaceum*. This division is based on the colour of the corm, cormels and leaves and on the shape of the cormels.

In fertile soils, cocoyam develops lush leaves and produce higher yields. The leave growth and cormel yield are increased by the addition of fertilizer and high fertilization reduces the time required for cormels to reach the maximum size [8, 9]. A major constraint to intensive production of cocoyam therefore, is low level of inherent soil fertility where it exists. To ameliorate the problem, complimentary use of organic manures and mineral fertilizers, which has proved to be sound fertility management strategy in many countries of the world has been advocated [10, 11]. Apart from enhancing crop yield, the practice has a greater beneficial residual effect than can be derived from the use of either inorganic fertilizer or organic manure when singly applied. In a very recent study carried out in South Eastern Nigeria, Uwah *et al.* [11] evaluated the effect of four rates of poultry manure and four rates of K fertilizer on the performance of

Corresponding Author: O.A. Amusan, Department of Crop Production and Management Sciences, Tai Solarin University of Education, Ijebu-Ode, Nigeria.

cocoyam for two years and reported a significant interaction effect of PM and K fertilizer both on corms and cormels weight and yield in the two years of study. According to them, PM at 15 t ha^{-1} in combination with either 80 kg or 120 kg K ha^{-1} maximized corms and cormels weight and yield in both years.

Cocoyam, being a root crop has a high requirement for K just like yam and cassava [12, 13]. Surveys in Nigeria and elsewhere revealed inconsistencies in the amount of K for optimum performance of cocoyam due mainly to differences in soil types and soil K status [14, 15]. Although the use of 400 kg ha^{-1} NPK 15:15:15 fertilizer is recommended [16], this is not sustainable due to high cost and scarcity of inorganic fertilizers. Experiment conducted at Ibadan, southwest Nigeria revealed significant increase in leaf area and cormel yield in response to combined use of inorganic and organic fertilizers. Treatments involving 400 kg ha^{-1} NPK 15:15:15 fertilizer, composted refuse plus poultry manure at 10 t ha^{-1}, and combination of the two treatments at 50:50 increased cormel yield by 36, 65 and 107% respectively [16].

As observed by Goenaga and Chardon [17], the yield potential of cocoyam is seldom realized mainly because of a lack of knowledge concerning diseases, proper management practices and physiological determinants that may limit plant growth and development. This work evaluates the effect of poultry manure on soil physical properties and performance of cocoyam (*Xanthosoma sagittifolium*) on an alfisol in Southwestern Nigeria.

MATERIALS AND METHODS

Field experiment was carried out at two sites in Owo Local Government Area (5°12'N, 5°32'E) of Ondo State in southwest Nigeria for a period of three years (2008, 2009 and 2010). The sites were Rufus Giwa Polytechnic, Owo (site A) and Obasoto (site B). The experiment at each site consisted of 5x5 factorial combinations of five tillage methods (manual clearing, ridging, mounding, ploughing plus harrowing, and ploughing plus twice harrowing) and five poultry manure levels (0, 2.5, 5.0, 7.5 and 10.0 t ha^{-1}. The 25 treatment combinations were arranged in a randomized complete block design (RCBD) and replicated three times. The poultry manure used for the experiment was dried and analyzed by standard procedures for chemical properties. It had the following characteristics: total P (24.80 g kg^{-1}); total N (20.00 g kg^{-1}); NH_4-N (1.4%); organic C (26.5%); C:N (18.9); Na (0.42%); K (0.72%); Ca (0.21%); Mg (0.16%); Zn (50.00 mg kg^{-1}); Cu (90.00 mg kg^{-1}); Mn (30.00 mg kg^{-1}). The main effect of poultry manure is reported in this paper.

Crop Establishment and Data collection: The plot size in each trial and site was 12m x 10m. At the onset of rainy season each year, cormels weighing about 150g was planted at 1m x 1m to give plant population of 10,000 per ha. Poultry manure was applied 3 weeks after planting (WAP) by ring method at 0, 2.5, 5.0, 7.5, and 10.0 t ha^{-1}. Weeding was done manually twice at 45 and 110 days after planting (DAP). The same treatment was applied to each plot for the three years of experiment.

Ten plants were selected per plot for determination of plant height and leaf area (using graphical method) at 168 days after planting. The cormel and corm yields were evaluated by harvesting 10 plants per plot and separated into cormels and corms. A top loading balance was used to determine weight.

Soil Physical Properties: One month after application of poultry manure, determination of certain soil physical properties in all plots commenced. This was done at monthly interval in five occasions each year. Five core samples were collected at 0-15cm depth from each plot using core samples and were used for evaluation of bulk density, total porosity and gravimetric moisture content after oven dried at 100°C for 24hr. Total porosity was calculated from values of bulk density and particle density. Soil temperature was determined at 15:00 hr with soil thermometer inverted to 5cm depth. Five readings were made per plot at each sampling time and the mean data was computed.

Leaf Analysis: In 2010, 2 to 3 cocoyam leaves were taken 168 days after planting from five plants per plot for chemical analysis. Samples were oven dried for 24hr at 70°C and ground. Leaf N was determined by micro - kjeldahl digestion method. Samples were dry- ashed at 500°C for 6 hr in a furnace and extracted using nitric-perchloric-sulphuric acid mixture for determination of P, K, Ca and Mg [18]. Leaf P was determined using vanadomolybdate colorimetry, K by flame photometer, and Ca and Mg using atomic absorption spectrophotometer. Data collected were subjected to analysis of variance test and treatment means were compared using the Duncan's multiple range test at P=0.05. Because of similarity, the mean data for the two sites were used in case of soil physical properties, growth and yield. However, data on leaf nutrient analysis were separately processed for each site.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 indicate that soil bulk density (Db) and temperature reduced with increased rate of application of poultry manure (PM) between 0 to 10.0 t/ha, while total porosity and moisture content increased in values. The application of PM at 2.5, 5.0, 7.5 and 10 t ha^{-1} decreased bulk density by 4.2, 13.9, 22.9 and 31.3% over the control in 2008. Similarly in the same year, the application of PM decreased soil temperature by 4.6, 7.8, 11.2 and 14.6% over control (Table 1). The pattern was similar in 2009 as well as in 2010. In 2010, the application of PM at 2.5, 5.0, 7.5 and 10 t ha^{-1} decreased bulk density by 4.8, 13.2, 22.9 and 91.5% over control while temperature also decreased by 3.9, 6.9, 10.2 and 13.8% over control (Table 3). The impact of PM on bulk density was however observed to be generally greater than the impact on soil temperature. Porosity on the other hand increased in 2008 by 4.6, 13.9, 20.9 and 27.1% over control when PM was applied at 2.5, 5.0, 7.5 and 10 t ha^{-1} respectively (Table 1). In the same year, moisture content also increased by 5.4, 15.4, 25.2 and 29.7%. In 2010, the effect of PM on both porosity and moisture content became more pronounced. Porosity increased by 6.3, 18.4, 28.4 and 34.6% over control at PM rates of 2.5, 5.0, 7.5 and 10 t ha^{-1},respectively while moisture content increased by 6.1, 20.1, 31.4 and 37.4% (Table 3). Increased total porosity associated with reduction in soil bulk density was found in this study to result in increased water infiltration and retention leading to reduction in soil temperature. In the three years of study very high correlation coefficients were recorded between the soil physical properties and PM (Table 4). High negative correlation coefficients were recorded between PM and bulk density and between PM and soil temperature (-0.99) while high positive correlation (0.99) were recorded between PM and soil total porosity, and between PM and soil moisture content.

Poultry manure also affected significantly the uptake of nutrients by cocoyam. Leaf concentrations of N and P increased progressively as the application rate of PM increased from 0 to 10.0 t ha^{-1} at both sites of study. In the case of leaf K, Ca and Mg, their concentrations in leaf increased progressively with PM rates uptill 7.5 t ha^{-1} and dropped when application rate of PM reached 10 t ha^{-1} (Table 5). Therefore, PM at 7.5 t ha^{-1} was found to

Table 1: Soil physical properties as affected by poultry manure in 2008

Manure t ha^{-1}	Bulk density g cm^{-3}	Total porosity %	Moisture content(%)	Temperature °C
0	1.44^{a}	45.7_{d}	17.5_{e}	32.1_{a}
2.5	1.38_{ab}	47.9_{cd}	18.5_{de}	30.6_{ab}
5.0	1.24_{c}	53.1_{b}	20.7_{c}	29.6_{b}
7.5	1.11_{d}	57.8_{ab}	23.4_{a}	28.5_{bc}
10.0	0.99_{e}	62.7_{a}	24.9_{a}	27.4_{c}

Values with similar letters in a column are not significantly different at P=0.05

Table 2: Soil physical properties as affected by poultry manure in 2009

Manure t ha^{-1}	Bulk density g cm^{-3}	Total porosity %	Moisture content (%)	Temperature °C
0	1.44_{a}	45.7_{b}	15.3_{d}	32.5_{a}
2.5	1.39_{ab}	47.7_{cd}	16.1_{cd}	31.2_{a}
5.0	1.25_{c}	53.0_{d}	18.2_{b}	30.2_{ab}
7.5	1.11_{d}	57.7_{ab}	20.4_{a}	29.2_{ab}
10.0	0.98_{e}	62.6_{a}	21.2_{a}	28.2_{b}

Values with similar letters in a column are not significantly different at P=0.05

Table 3: Soil physical properties as affected by poultry manure in 2010

Manure tha^{-1}	Bulk density g/cm^{3}	Total porosity %	Moisture content (%)	Temperature °C
0	1.66_{a}	37.1_{e}	10.7_{e}	30.3_{a}
2.5	1.58_{ab}	39.6_{de}	11.4_{de}	29.1_{a}
5.0	1.44_{c}	45.5_{c}	13.4_{c}	28.2_{ab}
7.5	1.28_{d}	51.8_{ab}	15.6_{b}	27.2_{ab}
10.0	0.14_{e}	56.8_{a}	17.1_{a}	26.1_{b}

Values with similar letters in a column are not significantly different at P=0.05

Table 4: Correlation(r) between rate of poultry manure (PM) and soil Properties, plant nutrient and yield

	2008	2009	2010
PM vs bulk density	-1.00	-0.99	-0.99
PM vs porosity	0.99	0.99	0.99
PM vs moisture	0.99	0.99	0.99
PM vs temperature	-1.00	-1.00	-1.00
PM vs Plant N	_	_	1.00
PM vs Plant P	_	_	1.00
PM vs Plant K	_	_	0.62
PM vs Plant Ca	_	_	0.55
PM vs Plant Mg	_	_	0.61
PM vs Yield	_	_	0.51

Table 5: Effect of poultry manure on leaf nutrient composition of cocoyam in 2010 (sites A and B)

	N%		P%		K%		Ca		Mg	
Manure t ha^{-1}	A	B	A	B	A	B	A	B	A	B
0	1.88_e	2.09_e	0.29_e	0.33_e	0.26_d	0.27_b	0.43_d	0.43_d	0.21_e	0.16_d
2.5	2.09_d	2.35_d	0.33_d	0.38_d	0.30_c	0.31_c	0.48_c	0.48_c	0.25_{cd}	0.19_c
5.0	2.39_c	2.66_c	0.38_c	0.43_c	0.34_b	0.35_b	0.54_b	0.54_b	0.30_b	0.23_b
7.5	2.68_b	2.99_b	0.44_b	0.51_b	0.40_a	0.43_a	0.63_a	0.61_a	0.34_a	$0 .27_a$
10.0	2.97_a	3.28_a	0.50_a	0.57_a	0.31_c	0.32_c	0.51_{bc}	0.49_c	0.27_c	0.19_c

Values with similar letters in a column are not significantly different at P=0.05

Table 6: Mean values of growth and yield parameters of cocoyam for three years

Manure t ha^{-1}	Plant height (cm)	Leaf area (cm^2)	Cormel yield (t ha^{-1})	Corm yield (t ha^{-1})
0	56.2_d	133.5_d	10.0_d	6.8_d
2.5	62.7_c	152.3_c	10.4_{cd}	7.7_c
5.0	70.3_b	173.6_b	11.8_b	8.5_b
7.5	80.0_a	196.7_a	13.0_a	9.4_a
10.0	63.0_c	155.7_c	10.7_{cd}	7.5_c

Values with similar values in column are not significantly different at P=0.05

be optimal for the uptake of K, Ca and Mg in cocoyam. This suggested that Ca, Mg and especially K are performance indicators for cocoyam. Abundant K supply has been reported to favour primary process of photosynthesis and ATP production as well as promote carbon dioxide assimilation and the synthesis and translocation of carbohydrate from the leaves to the tubers of potatoes, yam and cassava [11, 12, 19].

The application of poultry manure at the rate of 7.5 t ha^{-1} also gave optimal values for performance parameters of cocoyam as revealed by the mean values of such parameters in Table 6. All the parameters evaluated in this study i.e. plant height, leaf area, cormel and corm yields peaked at PM application rate of 7.5 t ha^{-1} and dropped when application reached 10 t ha^{-1} (Table 6). This implies that beyond application rate of 7.5 t ha^{-1}, cocoyam may not respond to the supply of poultry manure.

CONCLUSION

The study revealed that application of poultry manure significantly improved soil structure and soil moisture content as well as the uptake of N, P, K, Ca and Mg by cocoyam. Nutrient uptake, corm and cormel yields as well as other performance parameters of cocoyam were found in this study to peak when application rate of poultry manure reached 7.5 t ha^{-1}. Application of poultry manure at this rate is therefore recommended for cocoyam production as it gave maximum values of performance parameters and nutrient uptake.

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