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REGULAR ARTICLE

Manure placement method influenced growth, phenology and bunch yield of three *Musa* genotypes in a humid zone of Southern Nigeria

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ABSTRACT

Manure placement methods earlier evaluated in a greenhouse using the banana cultivar PITA 14 as a test-crop significantly influenced root system development, vegetative growth, nutrient uptake, whole-plant dry matter yield and distribution of the crop. These placement methods plus an additional treatment were re-evaluated in a field experiment over two cropping cycles using three Musa genotypes. The treatments were: a full dose of poultry manure placed on the soil surface – top dressing (T_1), a full dose of poultry manure applied as a base placement prior to planting – bottom dressing (T_2), a split combination of T_1 and T_2 – half the dose of manure placed as a bottom dressing and the other half as a top dressing (T_3), inorganic fertilizer (T_4) and no fertilizer (T_5) as a control. Results revealed that the main effect of genotype was significant ($P < 0.05$) for growth, phenology and bunch yield components. Cultivar PITA 23 was the tallest. However, PITA 14 produced more and healthier green leaves. The genotype, PITA 14 flowered earliest in the planting year crop but fruits of BITA 3 matured earliest. In the planting year crop, PITA 14 produced bigger fruits and heavier bunches. However, in the ratoon crop, BITA 3 supported the highest number of hands per bunch and longer and wider fruits; this genotype also produced the heaviest fruits and bunches. Growth parameters at flowering indicated that T_3 supported more green leaves and gave about 9 %, 9 %, 20 % and 33 % more leaves than T_1, T_2, T_4 and T_5 respectively, particularly in the ratoon crop. When T_3 was compared with T_5 there was a reduced number of days to flowering and fruit maturation by about 49 and 44 days, respectively. Split application of manure as half a bottom dressing and the other half as a top dressing (i.e. T_3) supported production of the heaviest fruits (208.1 g) and bunches (37.3 t ha^{-1}), especially in the ratoon crop. Therefore, placing half the dose of manure as a bottom dressing and the other half as a top dressing is recommended for sustainable plantain production in the high rainfall region of southern Nigeria.

Key Words: *Musa genotypes; poultry manure; placement; growth; bunch yield.*

INTRODUCTION

Growth, development and final yield of a crop depend on nutrient availability in the growing environment of the crop aside from climatic and management factors. Bananas and plantains (*Musa* spp L.), which are a staple food for rural and urban consumers in the humid tropics, require high amounts of nutrients especially nitrogen (N) and potassium (Robinson, 1996), which are often supplied only in part from the soil (Lahav, 1995). This probably explains why cultivation of this crop species, particularly in West and Central Africa, is in home gardens where they receive a continuous supply of organic matter and nutrients from household refuse (Baiyeri and Tenkouano, 2007). However, continued land degradation, rapid population growth (FAO, 1981), continuous cropping and leaching has drastically reduced the fertility status of most home gardens and farmlands in the humid tropics, thereby posing a challenge to sustainable crop production especially perennial crops such as banana and plantain. Most farmers have adopted the use of external nutrients in the form of fertilizer. Inorganic fertilizers are expensive for subsistence farmers and are often hard to obtain (Brandjes et al., 1989). Animal and green manures are a valuable source of crop nutrients and organic matter that can improve soil biophysical conditions making the soil more productive and sustainable for food production (Baiyeri and Tenkouano, 2007).

However, management of these nutrients is very important since fertilizer best management practices are based on the application of the correct fertilizer at an appropriate rate, time and place. Steward (2006) noted the importance of placing nutrients in such a way that it provides for rapid crop uptake and reduced potential loss. Previous studies on manure placement methods evaluated in a greenhouse using the cultivar PITA 14 as a test-crop showed placement significantly influenced root system development, vegetative growth, nutrient uptake, whole-plant dry matter yield and distribution in the crop (Baiyeri and Tenkouano, 2007, 2008). This work showed that placement of half the fertilizer dose of poultry manure as a bottom dressing and half on the surface, as top dressing, was the most effective. These placement methods, plus an additional treatment, were re-evaluated in a field experiment over two cropping cycles using three *Musa* genotypes.

MATERIAL AND METHODS

EXPERIMENTAL SITE

The field experiment was conducted over two consecutive crop cycles (2006-2008) at the International Institute of Tropical Agriculture (IITA), High Rainfall station, Onne, (4° 43'N, 7° 01'E, 10 m a.s.l), Rivers State, Nigeria. The station is located in a degraded rainforest swamp area, characterized by an ultisol derived from coastal sediments with an annual unimodal rainfall of 2,400 mm (Ortiz et al., 1997). The soil has a low pH (< 4.3) and a low cation exchange capacity. The relative humidity ranges from 78 % in February to 89 % in July and September. The average daily temperature is about 27 C and the average solar radiation was 14 MJ m^{-2} (Ortiz et al., 1997).

TREATMENTS AND EXPERIMENTAL DESIGN

Three manure placement methods comprising top (surface) dressing (T_1), bottom (base) dressing (T_2) and a split combination of top and bottom dressing, where 50 % of the manure placed at surface and 50 % placed below the surface (T_3). These were evaluated and compared with inorganic fertilizer (T_4) and a no manure control (T_5). The fertilizer treatments were tested on three *Musa* genotypes (BITA 3, PITA 14 and PITA 23). Genotype BITA 3 is an IITA cooking banana derived tetraploid hybrid while PITA 14 and PITA 23 are IITA plantain derived tetraploid hybrids.

The experiment was a 3 x 5 factorial using a randomized complete block design with three replicates. Each replicate was a single row plot of four (4) plants per manure placement treatment for each genotype. Poultry manure at 20 t ha^{-1} (which supplied an equivalent of 312 kg N ha^{-1} and 358 kg K ha^{-1}) was utilized. The chemical properties of the poultry manure are given in Table 1. The inorganic fertilizer consisted of urea (300 kg N ha^{-1}) and muriate of potash (456.5 kg K ha^{-1}) applied in six-split doses as recommended by Swennen and De Langhe (1985).

Table 1: Physicochemical characteristics of the experimental site and poultry manure used in the study.

Physical properties	Top soil (0-15 cm)	Sub soil (15-30 cm)	Poultry manure
pH (H_2O)	5.54	4.83	-
Organic carbon (%)	1.49	0.96	-
Sand (%)	77	71	-
Silt (%)	8.67	7.67	-
Clay (%)	14	21	-
Textural class	Sandy loam		-
Chemical properties			
Nitrogen (g/kg)	1.35	0.65	15.6
Phosphorus (mg/kg)	56	74	14
Potassium (g/kg)	1.8	1.25	17.9
Calcium (cmol/kg)	2.61	0.88	3.76
Magnesium(cmol/kg)	0.23	0.05	0.41
Sodium (cmol/kg)	0.34	0.34	-
Exch. Acidity (cmol/kg)	0.19	1.44	-
ECEC (cmol/kg)	3.7	2.8	-
Zinc (mg/kg)	4.7	4.1	11.4
Copper (mg/kg)	1.03	1.52	-
Manganese (mg/kg)	30.7	14.9	-
Iron (mg/kg)	161	211	313

CULTURAL PRACTICES

A composite soil sample of the experimental site was collected before the experiment and analyzed for physicochemical properties. The results are shown in Table 1. The site was manually cleared with a machete. Planting holes of 40 cm x 40 cm x 40 cm were dug and each of the holes, before planting, was treated with 15 g of Furadan 5G for control of the plantain weevil (*Cosmopolites sordidus*) and root-knot nematodes according to Obiefuna (1984). Plants were spaced at 3 m between rows and 2 m within rows, giving a plant population of 1,667 plants ha^{-1}. Every 4-6 weeks plants were desuckered. One follower sucker, as a ratoon plant, was maintained after flowering. Weeding was carried out by using the herbicide glyphosate and by slashing, when necessary. Pruning of dead leaves was done every 2-3 weeks and bamboo (*Bambusa* spp) stakes were used to prop plants up against wind damage especially those carrying bunches of fruit. Other agronomic management was as recommended by Swennen (1990). Plants were grown over two consecutive cropping cycles (2006-2008).

DATA COLLECTION AND ANALYSIS

Data were collected at two major growth stages for each plant, at flowering and at harvest. At flowering, plant height, pseudostem circumference (taken at 100 cm above the ground level), number of green leaves, youngest leaf spotted with black sigatoka fungal spores (the youngest leaf, counting from the top showing the first symptoms of black sigatoka disease) were recorded. The index of non-spotted leaf (INSL) was derived from the ratio between youngest leaf spotted at flowering (YLSF) and the total number of green leaves at flowering (NSLF) (Craenen, 1998). At harvest the bunch yield per plant, number of hands and fruits per bunch, fruit weight, fruit length and circumference were recorded. All the data collected were subjected to two-factor analysis of variance (ANOVA) in a randomized complete block design using GENSTAT Release 7.2 Discovery Edition 3 (GENSTAT, 2007). The ANOVA was carried out for each year of study and thereafter as a combined analysis over the two consecutive cropping cycles. The least significant difference (LSD) test at the 5 % probability level was used to compare treatment means.

RESULTS

MANURE PLACEMENT EFFECT ON GROWTH AND BLACK SIGATOKA DISEASE RESPONSE AT FLOWERING

Growth and black sigatoka disease response parameters were affected by manure placement method, particularly in the ratoon crop (Table 2). In the plant crop, plant height and pseudostem circumference were not significantly ($P > 0.05$) influenced by manure placement method. However, in the ratoon crop the tallest plants were generally those that had received manure. The split combination of bottom and top-dressing (T_3) significantly ($P < 0.05$) enhanced production of green leaves (11). The result of the combined analysis of the two crop cycles also showed that T_3 supported the most leaves (12). The severity of black sigatoka disease was mostly reduced in manured plants. Among manure placement methods, particularly in the ratoon crop, the number of youngest leaves which were spotted (9) and the corresponding index of non-spotted leaves (71.97 %) was higher in T_3.

Table 2: Main effects of manure placement method and genotype on the growth and black sigatoka response characteristics at flowering.

	Plant height (cm)			Pseudostem girth (cm)			Number of green leaves			Youngest leaf spotted			Index of non-spotted leaves		
Treatment/Genotype	PC†	RC	COM	PC	RC	COM	PC	RC	COM	PC	RC	COM	PC	RC	COM
Manure placement method															
Surface dressing (T_1)	314	394	354	57	71	94	11.0	10.0	11.0	10	9	9	76	71	73
Base dressing(T_2)	308	408	358	55	71	63	11.0	10.0	11.0	10	8	9	78	67	73
Split dressing (T_3)	326	403	364	60	72	66	11.0	11.0	12.0	9	9	9	74	72	73
Inorganic (T_4)	325	372	348	58	66	62	10.0	10.0	10.0	8	8	8	70	67	69
Untreated control (T_5)	328	397	362	58	68	63	9.0	9.0	9.0	8	7	7	72	67	70
$LSD_{0.05}$	ns	15	11.8	ns	ns	ns	1.14	0.69	0.64	1.0	1	0.6	3.1	4	2.5
Genotype															
BITA 3	297	389	343	55	73	64	11.0	10.0	10.0	9	8	9	79	69	72
PITA 14	323	358	340	60	64	62	11.0	11.0	11.0	9	9	9	70	73	72
PITA 23	340	438	388	57	72	64	10.0	9.0	10.0	9	7	8	76	65	70
$LSD_{0.05}$	12.7	12	8.7	2.9	3	ns	ns	0.54	0.50	ns	1	0.5	2.4	3	1.9

†PC= Plant crop; RC= Ratoon crop; COM= Combined analysis of plant and ratoon crop

GENOTYPE EFFECT ON GROWTH AND BLACK SIGATOKA DISEASE RESPONSE AT FLOWERING

The genotype influence on the growth and black sigatoka disease response of the plants are shown in Table 2. The hybrid, PITA 23 produced the tallest plants in both crop cycles while the pseudostem circumference was greatest in PITA 14 in the plant crop but least in the ratoon crop. There was no significant ($P > 0.05$) difference among the three *Musa* species in the number of green leaves and youngest leaves spotted by the black sigatoka fungal spores in the plant crop but PITA 14 produced the most and the healthiest green leaves in the ratoon crop.

MANURE PLACEMENT EFFECT ON PHENOLOGY, BUNCH YIELD AND YIELD COMPONENTS

Phenology was affected by manure placement method. Plants that had received manure flowered and matured significantly ($P < 0.05$) earlier than those that received inorganic fertilizer or no fertilizer (Table 3). In the plant crop, T3 plants flowered 6 and 25 days earlier than T_1 and T_2 plants respectively. Plant maturation was 9 and 24 days earlier in the split combination of bottom-and top-dressing compared with placing all the manure as a single top or bottom dressing respectively. Relative to the control plants (T_5), the days to flowering and maturation were significantly ($P < 0.05$) reduced by 53 and 37 days respectively in treatment T_3.

The bunch yield and yield components in the plant crop showed that plants that were fertilized generally gave higher bunch and fruit yields than control plants but these traits were similar in fertilized plants (Table 3). However, in the ratoon crop, T_3 plants produced the heaviest bunches (37.29 t ha^{-1}) and fruits (208.1 g) and the longest fruits (22.25 cm). The T_5 plants produced the lightest bunches (26.84 t ha^{-1}) and fruits (155.4 g) and the shortest fruits (20.13 cm). The number of fruits and fruit circumference were significantly ($P < 0.05$) higher in manured plants than in plants that had received inorganic fertilizer or no fertilizer.

GENOTYPE EFFECT ON PHENOLOGY, BUNCH YIELD AND YIELD COMPONENTS

In the plant crop, PITA 14 flowered and matured earliest, produced the heaviest bunches and fruits and the highest number of fruits (Table 3). Values for fruit length and circumference were statistically similar for PITA 14 and BITA 3 but were significantly ($P < 0.05$) longer and wider than in PITA 23. In the ratoon crop, the better performance of PITA 14 with respect to bunch yield and fruit metric traits was not sustained. In this case BITA 3 gave the heaviest bunches and fruits, produced the highest number of hands and fruits with the longest and widest fruits.

Table 3: Main effects of manure placement method and genotype on the phenology, bunch yield and yield components of plantain.

	Number of days to flowering			Number of days to fruit maturation			Bunch yield (t/ha)			Number of fruits/bunch			Fruit weight (g)		
Treatment/Genotype	PC†	RC	COM	PC	RC	COM	PC	RC	COM	PC	RC	COM	PC	RC	COM
Manure placement method															
Surface dressing (T_1)	245	481	363	362	588	475	23.9	33.5	28.7	113	127	112	152	180	166
Base dressing(T_2)	264	499	382	377	610	494	20.5	33.0	26.7	96	131	114	140	174	157
Split dressing (T_3)	239	469	354	353	577	465	23.3	37.3	30.4	111	126	119	147	208	177
Inorganic (T_4)	323	489	407	411	593	502	22.1	27.7	25.0	105	109	107	130	173	152
Untreated control (T_5)	307	494	403	403	593	499	16.3	26.8	21.4	90	129	109	119	155	137
$LSD_{0.05}$	36.6	ns	22.5	22.1	ns	16.0	4.45	5.23	3.38	ns	15	ns	21.7	23	15.2
Genotype															
BITA 3	276	480	378	366	564	464	19.8	34.5	29.4	94	137	116	137	212	175
PITA 14	226	479	353	342	600	471	24.7	26.1	25.4	115	101	108	154	176	165
PITA 23	324	500	414	436	613	525	19.2	29.9	24.5	100	135	117	122	146	134
$LSD_{0.05}$	28.3	ns	17.5	17.2	17	12.4	3.45	4.05	2.62	17.0	11	ns	16.8	18	11.7

†PC= Plant crop; RC= Ratoon crop; COM= Combined analysis of plant and ratoon crop

INFLUENCE OF INTERACTION OF MANURE PLACEMENT AND GENOTYPE ON GROWTH AND YIELD

The split combination of bottom- and top-dressing of the manure (T_3) significantly ($P < 0.05$) consistently reduced the number of days before plant maturation and enhanced the production of more green leaves in all three *Musa* genotypes. The hybrids, PITA 14 and BITA

3 were most influenced by this method of manure placement. In the ratoon crop, the number of green leaves at flowering and the number of days to plant maturity was 13 and 582 days, respectively, in PITA 14 and BITA 3 (Figure 1). Similarly, in the ratoon crop, the bunch and fruit yields were consistently heaviest in all three Musa genotypes particularly when they received the T_3 manure placement, with heaviest bunches (43.4 t ha^{-1}) and fruits (230.1 g) supported by BITA 3 (Figure 1).

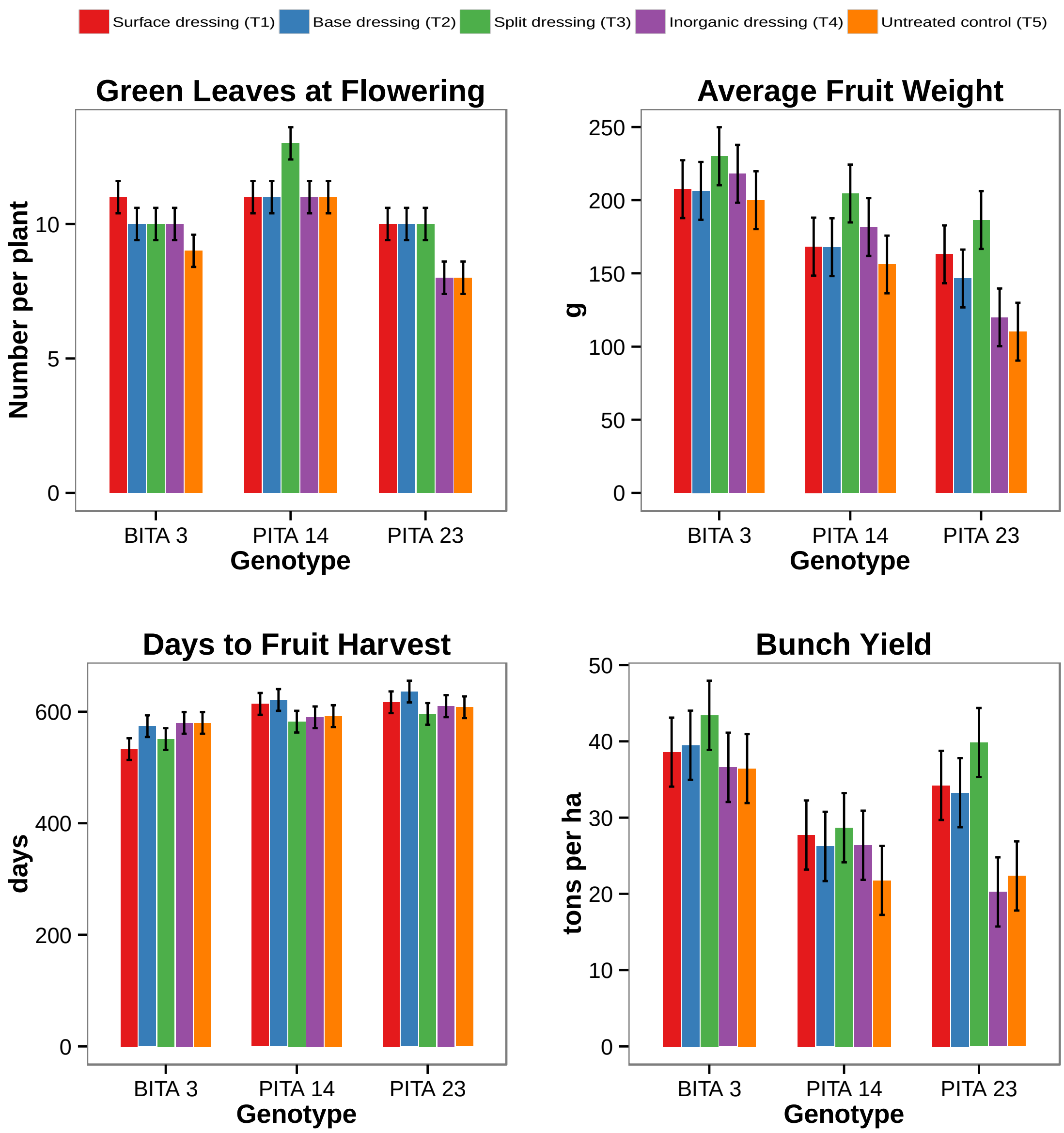

Figure 1. Genotype x fertilizer application interaction means for response variables “green leaves at flowering”, “days to fruit harvest”, “average fruit weight”, and “bunch yield”.

Discussion

The significant differences in all the growth characteristics observed between plants that received poultry manure (T_1 – T_3) and those that received inorganic fertilizer (T_4) or no fertilizer (T_5) indicated that manure application enhanced plantain growth. This is a confirmation of reports on the influence of manure on plantain production (Obiefuna, 1990, Baiyeri et al., 2007, 2008; Ndukwe et al., 2011). Poultry manure contains nutrients that can support crop production and enhance the physical and chemical properties of the soil by improving the moisture holding capacity, soil structure and retention and uptake of plant nutrients (Amanullah et al., 2010). The T_3 plants significantly produced more and healthier leaves than the other plants especially compared with manured plants. This suggests that placement method (a split combination of bottom and top dressing) of the poultry manure enhanced earlier and gradual release of nutrient elements, hence the availability of the nutrients around the rhizosphere of the roots for immediate absorption. The higher number and healthier status of leaves observed in this study particularly revealed this effect. This indicates that the production and health status of the plantain leaves respond to soil fertility. The higher the soil fertility the lower the black sigatoka severity on plantain as expressed by the plant through a higher number of standing (green) leaves and less leaf area with black sigatoka symptoms (Mobambo et al., 1994). Earlier work by Ndukwe et al. (2010) also showed that poultry manure reduces the severity of black sigatoka disease in *Musa* species.

The T_3 plants also flowered and matured earliest and produced the highest bunch yields and had good fruit traits. The highest number of green leaves together with the healthiest leaves, which the split combination of bottom and top dressing with manure enhanced, could have reduced the number of days to flowering and fruit maturation.

The healthier leaves as evidenced by the youngest leaf spotted at flowering in the hybrids could have led to their earlier flowering and better vegetative ratoon growth than in the landraces. Baiyeri et al. (2000) reported a positive correlation between youngest leaf spotted at flowering of the plant crop and early flowering as well as heavy bunch weights. Healthier leaves (enhanced by the T_3 placement) imply a larger leaf surface area for trapping light energy, which could have resulted in a higher efficiency in conversion of photoassimilate into higher bunch and fruit yields. In addition the poultry manure may have improved the soil physical conditions, moisture retention and increased soil organic matter content; a general potential associated with organic manures. Mbagwu (2002) reported that, in Nigeria, poultry manure significantly improved soil physical properties by decreasing bulk density, increasing total and macroporosity, infiltration capacity, available water capacity and moisture content (Agbede et al., 2008).

The influence of split combination of bottom and top dressing of poultry manure was evident across the three *Musa* genotypes, particularly in the ratoon crop where PITA 14 had the highest number of green leaves and a reduced maturation period of the plant and BITA 3 produced heaviest bunches and fruits. This further indicated that the T_3 method of manure placement could enhance sustainable productivity of Musa genotypes irrespective of their genome group. PITA 14 was the sturdiest and produced a higher foliage yield than BITA 3 or PITA 23. Relative to the plantain-derived tetraploid hybrids (PITA 14 and PITA 23), the banana-derived tetraploid hybrid, BITA 3, produce heavier bunches as a result of producing more hands and fruits per bunch with heavier fruits, which the hybrid has genetically. This signified that the genotype-by-environment interaction effect could not alter the expression of the genetic characteristics of the test crops since these *Musa* genotypes maintained their expressions irrespective of the different manure placement methods.

There may be high N loss through volatilization especially when manure is only applied as a top dressing. Mattila and Joki-Tokola (2003) noted nitrogen loss up to 50%, or more through volatilization; this can occur very quickly (Sharpe and Harper, 2004). On the other hand, placing all of the manure as a bottom dressing may result in lower nitrification and mineralization owing to lower temperatures and/or less available oxygen deep in the soil profile. The inorganic fertilizer releases nutrients faster than poultry manure and may have suffered high N and sulfur loss via volatilization. These shortfalls of placing the full dose of manure singly at either the top (T_1) or bottom (T_2) of the planting hole and using inorganic fertilizer explained why the split combination of T_1 and T_2 gave the best results with respect to growth and yield of the three Musa genotypes. The T_1 and T_2 placements could have complemented each other when half the dose of manure was placed at the bottom of the planting hole and the other half at the soil surface. Therefore, placing half the manure dose as a bottom dressing and the other half as a top dressing (i.e. T_3) was the most appropriate method for sustainable plantain production in the high rainfall region of southern Nigeria.

CONCLUSIONS

1. Growth parameters at flowering indicated that T_3 supported more green leaves and gave about 9%, 9%, 20% and 33% more leaves than T_1, T_2, T_4 and T_5 respectively, particularly in the ratoon crop.
2. Treatment T_3, when compared with T_5 reduced the number of days to flowering and fruit maturation by about 49 and 44 days, respectively.
3. The split application of poultry manure as a bottom dressing and the other half as a top dressing (T_3) produced the heaviest fruits (208.1 g) and bunches (37.29 t ha^{-1}), especially in the ratoon crop.
4. Placing half the dose of manure as a bottom dressing and the other half as a top dressing (T_3) is recommended for sustainable plantain production in the high rainfall region of southern Nigeria.

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