INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)

ISSN: 2223-7054 (Print) 2225-3610 (Online)

http://www.innspub.net

Vol. 7, No. 2, p. 100-110, 2015

RESEARCH PAPER OPEN ACCESS

Irrigation interval and fertilizer nutrient sources influenced growth and biomass yield of 'PITA 24' plantain (*Musa* spp. AAB)

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Article published on August 14, 2015

Key words: Plantain, Fertilizer use, Water stress, Biomass yield.

Abstract

In the current global climate change scenario, there are predictions of drought and water shortages. This study evaluated varying fertilizer treatments (organic – 20 t.ha^{-1} of composted poultry manure, inorganic – 400 kg N + 600 kg K_2O + 100 kg P_2O_5 per hectare, and the complementary doses thereof, and a no-fertilizer control) alongside three irrigation intervals (every 3 days, 6 days or 9 days) on growth and biomass yield of micro-propagated 'PITA 24' plantain. Results showed significant ($p \leq 0.05$) differences in growth and dry matter yield (DMY), and the distribution pattern following the irrigation and fertilizer treatments. Plant performances (height, girth, biomass yield, and leaf canopy indices) were superior and sometimes similar in plants that received organic fertilizer or the combined doses of organic/inorganic fertilizers. Similarly, plants that received water every 3 days had the best growth and DMY, followed by those of the 6 days interval. Growth lag and leaf losses were obvious in plants watered every 6 or 9 days interval. The worst hit by the transient moisture stress were the control plants and those plants grown with mineral fertilizers alone. DMY was significantly high in plants that received organic fertilizer alone, followed closely by plants that had the complementary fertilizer doses. These plants allotted greater proportion of the DMY to the aerial components, whereas the control plants accumulated more underground components. Results from the study suggest that transient moisture stress in plantains could be managed with judicious use of manure or complementary application with mineral fertilizers.

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Introduction

Edible bananas and the plantains belong to the genus *Musa* and family *Musaceae* (Stover and Simmond, 1987). These crops are essential component of the farming systems in sub-Saharan Africa, where more than 50% of the world plantain is produced (FAO, 1990). Plantains (*Musa* spp. AAB group) contribute greatly to socio-economic and nutritional significance in most parts of West and Central Africa, and serve an important starchy staple in the region (Akyeampong, 1999). They generate considerable income for smallholder farmers who produce the fruits in mixtures or sole plots on compound farms. Plantain fruits are rich source of dietary energy, vitamins (A, B_6 & C) and minerals such as calcium, potassium, phosphorus, iron and zinc (Ogazi, 1996; FAO, 1997).

Nigeria is one of the largest producers of plantains worldwide with annual production estimated at 2.4 million metric tons (Adesope *et al.*, 2004). The production of banana (*Musa* spp. AAA group) and plantain crops in Nigeria is clearly delineated by the regional rainfall pattern; the crops are mainly produced in the southern states where rainfall is distributed over 7-10 months, and rarely below 1500 mm annually. In southeast Nigeria, plantains are traditionally grown on heavily manured compound or home gardens where the productivity sustains for many years (Wilson *et al.*, 1987). Recently these crops are cultivated on large-scale distant farms where yield decline sets-in after a few production cycles due to poor management, diminishing levels of soil organic matter and susceptibility of the crop to corm weevil, nematodes and black sigatoka disease (Braide and Wilson, 1980). With the current global climate change scenario and the purported drought/water shortages, *Musa* production may wane in Nigeria, with the production areas drifting towards the deep rainforest region.

Perennial production of plantains and banana can be achieved with regular organic matter input (Swennen, 1990), especially under smallholder compound farms which receive continuous application of organic materials including compound refuse, farmyard manure and miscellaneous kitchen wastes (Ndubizu, 1979; Nweke *et al.*, 1988; Robinson, 1996). This management system may not sustain the emerging distant commercial farms due to the bulky nature of most manure; besides plantains are heavy feeders (Fox and Valenzuela, 1996) requiring liberal supply of plant nutrients.

The International Institute of Tropical Agriculture (IITA) advocates the use of resistant crop varieties as a cheap and eco-friendly measure to combat plant diseases, since most farmers readily adopt improved genotypes (Vuylsteke *et al.*, 1994). Consequently, a number of improved banana/plantain hybrids (like the 'PITA 24' plantain) have been bred which are high yielding and resistant to diseases/pests with good postharvest qualities. However, sustaining the yield of improved cultivars in the farmers' fields would require appropriate management practices, especially on soil fertility aspects.

Animal manure is a valuable source of crop nutrients and organic matter, which can improve soil biophysical conditions thereby making the soil sustainable for crop production (Mugwira, 1979; Baiyeri and Tenkouano, 2007). Organic fertilizers are bulky, yet they manifest many important characteristics. They improve soil moisture and nutrient retention and the exchange capacity, stimulate root development, control weeds and soil erosion, minimize soil temperature fluctuation, improve soil porosity, structure and tilth, and enhance biological activities in the soil (Kang and Balasubramanian, 1990; Bot and Benites, 2005).

Plantains respond positively to large doses of mulch and organic fertilizers, but the acquisition and transportation of organic manure (10 - 20 t/ha) for large-scale production could be quite tasking. It was, therefore, recommended that 25 - 30% of the nutrient needs of *Musa* crops be supplied with organic fertilizers and the balance by chemical fertilizers (Awodoyin, 2003). In order to compensate for nutrient losses in *Musa* fields, Smithson and Giller (2002) suggested the judicious combination of organic and mineral fertilizers. These authors averred that the use of organic fertilizers (and leguminous alley crops) are good agronomic practices, but may not release the required nutrients in good time to synchronize crop demand, yet the adoption is labour intensive. Mineral fertilizers fast-deliver more essential nutrients per unit weight than manure, but the sole use of synthetic fertilizers can escalate soil fertility problems in the long run (Chatzitheodorou *et al.*, 2004; Amujoyegbe *et al.*, 2007).

Soil water and plant nutrient management are key yield building factors in any crop production enterprise (Farhad, 2012). To achieve sufficient levels of nutrients in most agricultural soils, organic and inorganic fertilizers must be applied; and the optimal mix between the two depends largely on the accessibility, and the soil native characteristics particularly available soil water (Larson, 1996). Limited research has been conducted on the effect of manure on soil moisture retention and agricultural productivity in plantain-based systems. Potential benefits of manure application in boosting soil fertility status and moisture retention (especially during dry spell) holds promise in combating moisture deficit in *Musa* fields. In the present study, four fertilizer treatments (organic: 20 $t.ha^{-1}$ of composted poultry manure, inorganic: 400 kg N + 600 kg K_2O + 100 kg P_2O_5 per hectare, and the complementary doses thereof, and a no-fertilizer control) were evaluated alongside three irrigation intervals (every 3 days, 6 days or 9 days) on growth and biomass yield, vis-à-vis the moisture stress tolerance of micro-propagated plantain, 'PITA 24' under a screen-house environment.

Materials and methods

Experimental site

Micro-propagated plants of 'PITA 24' plantain (a hybrid Plantain of the International Institute of Tropical Agriculture) were transplanted unto 35 kg topsoil in black polybags measuring 75 cm × 40 cm (internal dimensions). The plants were grown for 16 weeks under a screen-house at the high rainfall station of the International Institute of Tropical Agriculture (IITA), Onne (40 43'N, 70 01'E, 10 m above sea level), Rivers State, Nigeria. The noon temperature within the screen-house varied between 28 and 31 °C, with a high relative humidity ranging from 78 – 89%.

Design of the experiment

The study was a 4 × 3 factorial experiment involving alternative sources of plant nutrients; thus, organic as composted poultry manure applied at 20 $t.ha^{-1}$; inorganic as 400 kg N + 600 kg K_2O + 100 kg P_2O_5 per hectare; complementary (i.e., combined half) doses of the organic and inorganic nutrients thereof; and the control plants (which were grown without any fertilizer amendment) alongside 3 irrigation treatment intervals applied at every 3 days, 6 days or 9 days. The twelve treatment combinations (i.e., fertilizer regime × irrigation frequency) were replicated eight times in a completely randomized design (CRD) format along an inter-row × intra-row spacing of 1 m × 0.5 m.

Treatment application

The primary fertilizer nutrients N, P and K were supplied using urea (46% N), single superphosphate (18% P_2O_5) and muriate of potash (60% K_2O), respectively. The poultry manure doses were adjusted to 10% moisture content, and were applied at full dose during planting as top-dressing and base placement (i.e., half the calculated dose applied as base placement and the balance as top-dressing). The inorganic fertilizer nutrients were applied top-dressed in two-split doses at 1 and 4 weeks after planting (WAP), respectively. The poultry manure samples were obtained from a deep litter range previously left in piles under tarpaulin cover for approximately 6 weeks. A 500 cm^3 of irrigation water was applied to each plant on daily basis until full stabilization at 8 WAP when moisture stress (i.e., the irrigation treatment) was introduced. Watering was henceforth maintained at 3, 6 or 9 days interval across the four fertilizer treatments.

Data collection

Baseline data were collected immediately after planting on plant height (cm), pseudostem base girth (cm), number of live leaves, and total leaf area (m^2) per plant calculated as the leaf length × broadest width × 0.8 for the live leaves following Obiefuna and Ndubizu (1979). Plant height was measured from the soil level to the V- junction of the topmost opposite petioles. Leaf area index (i.e., a ratio of total leaf area per plant to the land area allotted to a single plant) was calculated on the live leaves for each plant. These data were repeatedly collected at 4 and 8 WAP prior to the introduction of irrigation treatment and the purported moisture stress.

Irrigation treatment commenced at 8 WAP and continued through 16 WAP when the study was terminated. Data collection on plant growth parameters was repeated at 4 and 8 weeks following the irrigation treatment (i.e., at 12 and 16 WAP). Besides the growth parameters, total number of newly formed leaves and dead leaves were recorded. A leaf was recorded as emerged when it is 50 percent unfurled, and recorded as dead when it is 75 percent senesced.

At 16 WAP (i.e., after 8 weeks of irrigation treatment) 6 plants each across the treatment combinations were subjected to destructive sampling to assess the dry matter accumulation and partitioning pattern. Dry weights (g) of live leaves, pseudostem, corm and roots were measured after oven drying (65 °C, 120 h) to permanent weight. Data were also taken on the number of roots per plant and the length of the five longest roots. Physicochemical properties of the composite soil and poultry manure samples as used in the study were also studied.

Data analysis

Plant growth parameters were analyzed as cumulative growth difference based on the baseline data collected at planting. All data generated prior to the introduction of irrigation treatment were analyzed following the one-way procedure for completely randomized design (CRD) experiments using GenStat Release 10.3 DE (2011). Subsequent data sets collected on growth and dry matter accumulation (during/after the irrigation treatment) were subjected to Analysis of Variance (ANOVA) for two-factorial experiments in CRD. The treatment means were separated with Fisher's Least Significant Difference (F-LSD) at 5% probability level wherever the F-test was found significant.

Results

Physicochemical properties of substrates used

The composite topsoil used for this study was characterized as sandy loam (75% sand, 5% silt and 20% clay), and moderately acidic (pH 5.7) with moderate fertility (Table 1). The poultry manure sample was high in organic matter, and a host of other essential plant nutrients including N, P, Ca, Zn, Fe, and Mn.

Table 1. Chemical properties of the composite soil and poultry manure samples used in the study.

Substrate	pH [in water]		Organic carbon	Organic matter	Total N	Total P	Available K	Ca	Mg
						%			
Soil sample	5.7		0.94	1.62	0.092	0.014	0.003	0.015	0.002
Poultry manure	6.8		35.40	61.02	1.32	1.15	0.90	5.61	0.34
		Zn	Fe	Cu	Mn	Na			
				mg/kg					
Soil sample		9.97	250	1.25	12.0	87.4			
Poultry manure		149.60	642.26	62.64	445.87	13.60			

Effect of fertilizer on growth and leaf canopy parameters of 'PITA 24' plantain

Cumulative differences in plant growth parameters as recorded at 4 and 8 weeks after planting (WAP) were significantly ($p \leq 0.05$) influenced by the fertilizer treatments as shown in Table 2. Plants that received organic fertilizer alone and those that had combined application of organic and inorganic fertilizers had similar growth increment as regards to plant height and pseudostem girth, but the plants grown with complementary doses of both nutrient sources accumulated more leaves and hence recorded the highest leaf area and leaf area index. The control plants had the poorest growth, after the plants grown solely with inorganic fertilizer.

Effects of irrigation and fertilizer treatments on growth and leaf canopy parameters of 'PITA 24' plantain

Data presented in Table 3 are the combined effects of irrigation interval and fertilizer treatment on cumulative change in growth parameters of 'PITA 24' plantain measured after a growth period of 12 and 16 WAP. Irrigation interval, fertilizer treatment and the interaction effects significantly ($p \leq 0.05$) influenced all the growth parameters studied. The 3 days watering interval produced the highest cumulative growth in plant height, pseudostem girth, number of live leaves, photosynthetic leaf area and leaf area index at 12 and 16 WAP. Similarly, 6 days irrigation interval produced significantly better growth than the 9 days interval.

Following the fertilizer treatments, the best growth was observed in plants grown with organic fertilizer and the combined fertilizer sources, which were statistically similar in cumulative growth particularly at 12 WAP; but sole application of organic fertilizer produced numerically higher effects in most cases. Also, plants that received fertilizer produced significantly ($p \leq 0.05$) higher cumulative growth than the control plants.

Table 2. Effect of fertilizer treatment on †cumulative growth in 'PITA 24' plantain (*Musa* AAB) measured after a growth period of 4 and 8 weeks after planting (WAP).

	4 weeks after planting					8 weeks after planting				
*Fertilizer Treatment	Height [cm]	Girth [cm]	NLvs [#]	TLA [M^2]	LAI	Height [cm]	Girth [cm]	NLvs [#]	TLA [M^2]	LAI
Inorganic	9.8	1.5	2.4	0.20	0.41	19.0	3.4	5.8	0.47	0.94
Organic	15.7	2.9	3.3	0.30	0.60	33.0	6.1	8.2	0.75	1.51
(In)organic combination	14.8	2.4	4.0	0.35	0.71	32.1	5.9	8.7	0.91	1.81
Control	5.0	0.4	1.5	0.07	0.14	10.4	0.9	4.5	0.08	0.16
$LSD_{(0.05)}$	2.3	0.5	0.5	0.05	0.10	4.2	0.7	0.8	0.10	0.20

†Cumulative growth was measured as cumulative difference in plant growth parameter with reference to the base data collected at planting.

*Inorganic = 400 kg N + 600 kg K_2O + 100 kg P_2O_5; Organic = poultry manure at 20 tha^{-1}; (In)organic combination = complementary doses of 200 kg N + 300 kg K_2O + 50 kg P_2O_5 + poultry manure at 10 tha^{-1}; Control = no fertilizer amendment.

NLvs = number live of leaves; TLA = total leaf area; LAI = leaf area index; $LSD_{(0.05)}$ = least significant difference at 5% probability level.

At 3 days watering interval, the organic and the complementary doses of organic/inorganic fertilizer treatments produced similar effects on the growth parameters, but as the moisture stress increased (at 6 and 9 days watering intervals), cumulative growth became higher in plants that received organic fertilizer alone. The negative values observed in the leaf canopy parameters (number of leaves, leaf area, and leaf area index) are due to loss of leaf tissues resulting from moisture stress. These deleterious effects were most severe in the control plants which received no fertilizer treatment.

The absolute values for the plant growth parameters as recorded at the end of the 16 weeks study are presented in Table 4. Irrigation interval and fertilizer treatment, and the interaction effects significantly ($p \leq 0.05$) influenced most of the growth parameters.

Plant height, number of live leaves, leaf area, leaf area index, number of newly formed leaves and number of roots per plant were statistically superior in plants that received water every 3 days, and poorest with 9 days watering interval. Root length was neither influenced by irrigation interval nor the fertilizer treatment interaction effect. The 3 days watering interval recorded the least number of dry leaves per plant, whereas the highest number of dry leaves was recorded in plants that received water every 9 days.

Table 3. Effects of irrigation interval and fertilizer treatment on [†]cumulative growth in 'PITA 24' plantain (*Musa* AAB) measured after a growth period of 12 and 16 weeks after planting (WAP).

		12 weeks after planting					16 weeks after planting				
[‡]Irrigation Interval	Fertilizer type	Height [cm]	Girth [cm]	NLvs [#]	TLA [M²]	LAI	Height [cm]	Girth [cm]	NLvs [#]	TLA [M²]	LAI
3 Days	Inorganic	46.9	6.6	3.4	1.09	2.17	51.9	7.1	0.6	0.79	1.57
	Organic	50.6	8.7	6.1	1.35	2.70	56.3	9.7	5.6	1.43	2.87
	(In)organic	49.4	8.3	6.1	1.51	3.02	55.6	8.9	4.8	1.34	2.68
	Control	15.0	1.6	0.1	0.04	0.07	19.4	1.9	-0.3	0.02	0.05
	Mean	40.5	6.3	3.9	0.99	1.99	45.8	6.9	2.7	0.90	1.79
6 Days	Inorganic	25.6	4.0	3.3	0.64	1.27	30.6	4.1	0.5	0.38	0.75
	Organic	40.7	6.9	5.4	0.94	1.89	46.4	7.3	3.3	0.90	1.79
	(In)organic	38.1	6.1	4.8	0.85	1.70	43.1	5.8	-0.5	0.30	0.60
	Control	15.0	1.2	-0.5	-0.04	-0.07	15.0	1.1	-0.5	-0.04	-0.08
	Mean	29.9	4.5	3.2	0.60	1.19	33.8	4.6	0.7	0.38	0.77
9 Days	Inorganic	18.1	3.3	1.1	0.35	0.69	19.4	2.3	-1.4	0.13	0.26
	Organic	40.0	5.9	5.4	0.93	1.85	43.1	5.8	-0.1	0.36	0.73
	(In)organic	37.5	4.8	3.8	0.85	1.73	38.8	4.2	-3.3	-0.04	-0.08
	Control	14.4	0.4	0.1	0.01	0.01	14.4	0.1	-1.0	-0.04	-0.08
	Mean	27.5	3.6	2.6	0.54	1.07	28.9	3.1	-1.4	0.10	0.21
$LSD_{(0.05)}$ for irrigation interval		2.7	0.5	0.6	0.06	0.11	2.8	0.5	0.9	0.11	0.22
$LSD_{(0.05)}$ for interaction effect		5.4	1.0	1.2	0.11	0.23	5.5	1.0	1.7	0.22	0.44
	Main effect of fertilizer treatment										
	Inorganic	30.2	4.6	2.6	0.69	1.38	34.0	4.5	-0.1	0.43	0.86
	Organic	43.8	7.1	5.6	1.07	2.15	48.6	7.6	2.9	0.90	1.79
	(In)organic	41.7	6.4	4.9	1.07	2.15	45.8	6.3	0.3	0.53	1.06
	Control	14.8	1.1	-0.1	0.01	0.01	16.3	1.1	-0.6	-0.02	-0.04
$LSD_{(0.05)}$ for fertilizer treatment		3.1	0.6	0.7	0.07	0.13	3.2	0.6	1.0	0.13	0.26

Cumulative growth was measured as cumulative difference in plant growth parameter with reference to the base data collected at planting.

[‡]Irrigation treatment commenced at 8 WAP; fertilizer treatment and all other descriptions are same as in Table 2.

With the fertilizer treatments, the organic and (in) organic fertilizer combination produced the best performed plants. Plant height and pseudostem girth were at par and superior in these plants, followed by plants that received inorganic fertilizer alone. Sole application of organic fertilizer however produced plants that had significantly ($p \leq 0.05$) more leaves, more leaf area, higher leaf area index and greater number of newly formed leaves. Number of roots was statistically the least in plants that received inorganic fertilizer alone (and similar in other fertilizer treatments), whereas the control plants had the longest roots. The observed trends were true and similar across the irrigation treatments. It is pertinent to note that the superiority of sole application of organic fertilizer (over the other fertilizer treatments) became more pronounced as moisture stress increased at 6 and 9 days watering intervals. Plants that received sole application of organic fertilizer sustained the highest number of leaves, the largest leaf area and leaf area index at 6 and 9 days irrigation intervals.

Effects of irrigation and fertilizer treatments on dry matter yield and distribution in 'PITA 24' plantain

The dry matter yield (DMY) and the distribution pattern as influenced by irrigation interval and fertilizer treatment are presented in Table 5. Irrigation interval and fertilizer treatment significantly ($p \leq 0.05$) influenced DMY and the distribution pattern. Across the irrigation intervals, total dry matter yield (TDMY) was highest at 3 days irrigation interval, followed by the 6 days interval and least with plants that received water at 9 days interval. The control plants partitioned the least proportion of the accumulated DMY to the leaf and pseudostem tissues, and allotted the greatest DMY to the corm and root components. Dry matter distribution to the roots was however not significantly ($p > 0.05$) influenced by irrigation treatment and the fertilizer interaction effect. The greatest DMY was obtained at 3 days irrigation interval with the application of inorganic and organic fertilizer combination, followed by the organic fertilizer application. The DMY obtained at 9 days watering interval with organic fertilizer (92.3 g) is numerically higher than that obtained at 3 days watering in the control plants (85.6 g).

Table 4. Effects of irrigation interval and fertilizer treatment on growth parameters of 'PITA 24' plantain (*Musa* AAB) measured at the end of the study (16 weeks after planting).

‡Irrigation interval	Fertilizer type	Height [cm]	Girth [cm]	NLvs [#]	TLA [M²]	LAI	NFLvs [#]	DLvs [#]	Rts [#]	ARtL [cm]
3 Days	Inorganic	94.4	14.6	5.0	1.00	2.00	7.0	3.6	35	51.8
	Organic	93.8	15.8	9.8	1.61	3.22	6.3	0.9	48	55.5
	(In)organic	98.8	16.2	8.4	1.50	3.01	6.3	1.9	41	64.9
	Control	58.1	8.4	3.3	0.20	0.40	5.4	2.8	44	67.7
	Mean	86.3	13.8	6.6	1.08	2.16	6.2	2.3	42	60.0
6 Days	Inorganic	71.3	11.0	4.1	0.54	1.08	5.4	3.4	25	50.4
	Organic	83.6	13.5	6.9	1.05	2.10	5.4	2.4	31	56.6
	(In)organic	84.4	12.7	3.0	0.46	0.92	4.1	6.5	34	49.6
	Control	52.5	7.2	3.1	0.17	0.33	3.9	2.5	30	76.7
	Mean	72.9	11.1	4.3	0.55	1.11	4.7	3.7	30	58.3
9 Days	Inorganic	60.0	9.1	2.8	0.32	0.65	3.9	4.1	19	47.6
	Organic	82.5	12.5	3.6	0.54	1.07	4.3	5.9	32	46.8
	(In)organic	80.0	11.3	0.6	0.13	0.25	3.6	8.3	27	47.9
	Control	55.6	6.5	2.6	0.14	0.28	2.5	2.6	23	73.9
	Mean	69.5	9.8	2.4	0.28	0.56	3.5	5.2	25	54.1
LSD $_{(0.05)}$ for irrigation interval		3.3	0.3	0.7	0.11	0.21	0.5	0.8	5	ns
LSD $_{(0.05)}$ for interaction effect		6.6	0.6	1.5	0.21	0.42	1.0	1.6	ns	ns
	Main effect of fertilizer treatment									
	Inorganic	75.2	11.6	3.9	0.62	1.24	5.4	3.7	26	49.9
	Organic	86.6	13.9	6.7	1.07	2.13	5.3	3.1	37	53.0
	(In)organic	87.7	13.4	4.0	0.70	1.39	4.7	5.5	34	54.1
	Control	55.4	7.4	3.0	0.17	0.34	3.9	2.6	32	72.8
LSD$_{(0.05)}$ for fertilizer treatment		3.8	0.3	0.9	0.12	0.25	0.6	0.9	6	8.4

‡Irrigation treatment commenced at 8 WAP; description of fertilizer treatment is same as in Table 2.

NLvs = number of live leaves; TLA = total leaf area; LAI = leaf area index; NFLvs = total number of newly formed leaves, DLvs = total number of dry leaves; Rts = number of roots; ARtL = average root length; LSD$_{(0.05)}$ = least significant difference at 5% probability level; ns = non-significant mean difference.

Across the fertilizer treatments, TDMY was statistically similar and superior with organic fertilizer and the (in) organic fertilizer combination, but numerically higher with sole application of organic fertilizer (where the greatest DMY was allotted to the leaves). Dry matter distribution to the corm and root tissues were higher in the control plants compared to other fertilizer treatments. The control plants also allotted the least DMY to the leaf and pseudostem tissues. Dry matter distribution pattern was somewhat similar among the plants that received fertilizer nutrients (the fertilizer type notwithstanding). However, leaf dry matter yield was significantly ($p \leq 0.05$) highest in plants grown solely with organic fertilizer.

Table 5. Combined effects of irrigation interval and fertilizer treatment on dry matter yield of 'PITA 24' plantain (*Musa* AAB) and the distribution pattern to the respective plant parts. Destructive sampling was done at 16 weeks after planting.

		Dry matter yield (g)					Dry matter distribution pattern (%)			
‡Irrigation Interval	Fertilizer type	Leaves	Pseudostem	Corm	Roots	Total	Leaf	Pseudostem	Corm	Root
3 Days	Inorganic	44.8	44.6	6.7	27.9	124.0	35.7	36.4	5.5	22.5
	Organic	77.6	61.1	15.6	39.4	193.6	40.1	31.5	7.9	20.5
	(In)organic	85.4	62.4	13.6	55.8	217.2	39.0	29.3	6.3	25.4
	Control	10.4	20.9	13.4	40.9	85.6	13.8	25.8	16.6	43.8
	Mean	54.6	47.3	12.3	41.0	155.1	32.1	30.8	9.1	28.0
6 Days	Inorganic	22.8	28.7	5.4	25.5	82.4	27.8	34.9	6.7	30.6
	Organic	32.9	42.0	7.5	29.4	111.7	30.2	38.0	6.6	25.3
	(In)organic	20.0	33.2	7.3	21.3	81.7	22.9	41.3	9.9	25.9
	Control	8.0	19.1	10.3	21.2	58.6	14.1	33.7	17.7	34.5
	Mean	20.9	30.7	7.6	24.3	83.6	23.7	37.0	10.2	29.1
9 Days	Inorganic	12.4	18.2	5.6	15.0	51.2	21.4	36.5	12.3	29.8
	Organic	27.4	32.9	8.4	23.6	92.3	29.4	35.9	9.2	25.5
	(In)organic	5.8	23.6	5.2	21.5	56.2	11.0	43.3	9.6	36.1
	Control	6.0	12.8	8.0	17.9	44.7	14.2	30.0	18.5	37.3
	Mean	12.9	21.9	6.8	19.5	61.1	19.0	36.4	12.4	32.2
$LSD_{(0.05)}$ for watering interval		6.6	4.3	1.6	8.6	14.3	4.1	3.9	1.8	ns
$LSD_{(0.05)}$ for interaction effect		13.1	8.6	3.3	ns	28.6	8.2	ns	ns	ns
	Main effect of fertilizer treatment									
	Inorganic	26.7	30.5	5.9	22.8	85.9	28.3	36.0	8.1	27.6
	Organic	45.9	45.3	10.5	30.8	132.5	33.2	35.1	7.9	23.8
	(In)organic	37.1	39.7	8.7	32.9	118.4	24.3	37.9	8.6	29.2
	Control	8.1	17.6	10.6	26.6	62.9	14.0	29.8	17.7	38.5
$LSD_{(0.05)}$ for fertilizer treatment		7.6	5.0	1.9	ns	16.5	4.8	4.5	2.1	7.2

‡Irrigation treatment commenced at 8 weeks after planting; description of fertilizer treatment is same as in Table 2.
$LSD_{(0.05)}$ = least significant difference at 5% probability level; ns = non-significant mean difference.

Discussion

The variability observed in plant growth and dry matter yield and the distribution pattern in this study is attributable to varying fertilizer materials applied as nutrient sources, vis-à-vis the irrigation treatments. Plant growth and dry matter yield were superior and somewhat similar in plants that received organic fertilizer as poultry manure at 20 $t.ha^{-1}$ or the complementary dose of poultry manure at 10 $t.ha^{-1}$ plus inorganic fertilizer doses of 200 kg N + 300 kg K_2O + 50 kg P_2O_5 per hectare.

Previous studies on plantain nutrition (Aba et al., 2011; Ndukwe et al., 2011) recommended the application of poultry manure at 20 $t.ha^{-1}.yr^{-1}$ to sustain plantain yields on the sandy loam coastal plains of Onne (40 43'N, 70 01'E), south-south Nigeria. A follow-up study at the same location (Aba and Baiyeri, 2015) also recommended a combination of inorganic fertilizers at 400 kg N + 600 kg K_2O +

100 kg P_2O_5 per hectare, per annum. The present study supports the complementary application of organic and inorganic fertilizers for optimum performance of plantain crops, but acclaimed the sole application of organic fertilizer (in optimal dosage) for moisture limiting environments, typical of sub-humid tropical climate.

A maximum dry matter yield of 217.2 g was obtained with complementary application of organic and inorganic fertilizer nutrients at 3 days watering interval, compared to 193.6 g and 124.0 g obtained with sole application of organic and inorganic fertilizers, respectively. As watering interval increased to 9 days, the dry matter yield obtained from the application of inorganic fertilizers, organic fertilizer and the complementary doses thereof, dropped to 51.2 g, 92.3 g and 56.2 g, respectively; corresponding to 74%, 52.3% and 58% reduction in dry matter yield. This suggests that application of organic fertilizer improved the crop's resilience to moisture stress.

Researchers (Mugwira, 1979; Bot and Benites, 2005; Baiyeri and Tenkouano, 2007) have cited organic fertilizers (especially animal manure) as valuable source of crop nutrients and organic matter, which can improve soil biophysical conditions for sustainable crop production. In the present study, the application of poultry manure may have modulated the soil tilth and encouraged better nutrient uptake resulting to healthy and more vigorous plants. Moreover, poultry manure contains ample doses of plant essential nutrients including macro- and micronutrients, which may not be available in most mineral fertilizer recommendations.

Apart from possible volatilization losses, sole application of mineral fertilizers to moisture deficient soils creates osmotic imbalance at the plant root-soil interface which may interfere with water and nutrient uptake by plants (Jones, 2002). Banana and plantain crops rarely attain their full genetic potential for yield due to limitations imposed by moisture stress (Bananuka *et al.*, 1999) and poor soils (Robinson, 1996). The reduced growth and poor dry matter yield recorded in the control plants (grown without any fertilizer amendment) is an indication that the soils of the study location were deficient in some basic nutrients, and would not sustain plantain cultivation without external nutrient input.

Desiccation and loss of leaf tissues following the induced moisture stress were most severe in the control plants which received no fertilizer amendments. The reduction in leaf canopy parameters and the redistribution of accumulated dry matter to the root and corm components were adaptive mechanisms by the control plants to avert moisture stress. In poor resource soils, massive root formation helps crops to better explore the soil for nutrients and water, whereas reduction in photo-active leaf area minimizes transpiration loss, inasmuch as it affects the rate of photosynthesis and reduces crop yield.

Complementary application of organic and inorganic fertilizers supported optimum performance of plantain crops in this study, but organic fertilizers may be preferred in moisture limiting environments. Further investigations are however required under field conditions, particularly in sub-humid environments to substantiate these assertions.

Acknowledgement
The authors are grateful to the management and staff of the Plantain and Banana Improvement Programme (PBIP) of the International Institute of Tropical Agriculture (IITA), Onne, Rivers State, Nigeria for funding and allowing the use of IITA facilities for the conduct of this research.

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