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Full Length Research Paper

Manure placement effects on root and shoot growth and nutrient uptake of 'PITA 14' Plantain hybrid (*Musa* sp. AAAB)

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Low soil organic matter and associated poor soil fertility cause yield decline in *Musa* species, necessitating external nutrient input to maintain yield. Best fertilization practices include applying the correct fertilizer at the correct rate, time and place. In this regard, manure placement effects on growth, root system development and nutrient uptake of a plantain hybrid were evaluated in a screen-house. Three manure placement methods, whereby the full dose of manure was applied as top-dressing (T1), bottom-dressing (T2), or a split combination thereof (T3), were assessed together with a no manure control (T4). There was significant (P<0.05) treatment effects on most of the parameters studied. T1 gave the best growth indices 3 months after transplanting (MAT) but not at 5 MAT. The highest root NPK and leaf N at 3 MAT was associated with T3. T3 also induced the best plant growth at 5 MAT, followed by T2. Expectedly, the control treatment produced plants with the poorest growth. Whole-plant biomass yield and distribution were influenced by manure placement as was specific leaf area. Significantly large correlations between leaf-3 parameters and whole-plant growth indices were observed. Thus, dry weight of leaf-3 predicted whole-plant biomass yield with high reliability (r^2 = 94.1%), supporting leaf-3 analysis as a non-destructive alternative for assessment of plant performance in response to manure. It was apparent from the study that plant performance indices at 3 and 5 MAT showed that split dressing at the top and the bottom of the pots (T3) was a more sustainable method for manure application to *Musa*.

Key words: Plantain hybrid, manure placement; root and shoot growth; nutrient uptake, biomass yield.

INTRODUCTION

Bananas and plantains (*Musa* species L.) are the most important tropical fruit crops (Ortiz et al., 1998). They rank the fourth most important global food commodity after rice, wheat and milk in terms of gross value of production (INIBAP, 1992). They are staple foods for rural and urban consumers in the humid tropics and an important source of rural income particularly in some locations where small holders produce them in some compound or home gardens (Chandler, 1995).

In response to increased susceptibility of traditional varieties to several biotic stresses, genetic improvement programs were launched in many countries (Persley and De Langhe, 1987). Thus, genetic resistance to black Sigatoka (caused by *Mycosphaerella fijiensis* Morelet) was discovered in some diploid accessions in south-east Asia and successfully bred into plantain varieties to derive tetraploid hybrids (Swennen and Vuylsteke, 1993). Among the plantain-derived hybrids from the International Institute of Tropical Agriculture (IITA), 'PITA 14' is considered as one of the most promising, combining resistance to black Sigatoka with high yield, earliness and faster ratooning (Ortiz and vuylsteke, 1998).

The deployment of improved cultivars is a most powerful and cost-efficient means of enhancing crop productivity and farmers' incomes (Kueneman, 2002). Resistant cultivars are generally considered as the most appropriate components of integrated disease management because improved genotypes can be readily adopted by

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Table 1. Chemical properties of soil substrate and poultry manure utilized.

Characteristics	Soil substrate	Poultry manure
Nitrogen (%)	0.09000	1.56
Phosphorus (%)	0.01748	1.40
Potassium (%)	0.01900	1.79
Magnesium (%)	0.00264	0.41
Calcium (ppm)	272.0	-
Iron (ppm)	185.02	313.22
Zinc (ppm)	1.29	11.36
pH(H_2O)	5.3	-
Organic carbon (%)	1.17	-

- Not determined

African farmers (Vuylsteke et al., 1994). However, sustaining the yield of a new cultivar in the farmers' fields requires appropriate crop management practices, especially soil fertility management. In the tropics, rapid population growth and continued land degradation pose major challenges for soil fertility management on small farms (FAO, 1981). Thus, external nutrient inputs are essential to improve and sustain yields on these soils (Hossner and Juo, 1999).

Bananas require high amounts of nutrients which are often supplied only in part by the soil (Lahav, 1995). Several inorganic fertilizer combinations have been recommended for plantain in Nigeria (Ndubizu, 1981; Obiefuna, 1984a and 1984b; Baiyeri, 2002; Swennen, 1990). However, inorganic fertilizers are rather expensive for the subsistence farmers and often hard to obtain (Brandjes et al., 1989). In contrast, animal manure is often readily available and may constitute a valuable source of nutrients and organic matter, which can improve soil physical conditions (Munoz et al., 2004). Increasing organic matter content improves the biophysical characteristics of the soil, and makes it more sustainably productive. Thus, manure or compost application may increase soil nutrients and organic matter, with long lasting residual effects on crop yield and soil properties (Eghball et al., 2004).

Fertilizer best management practices are based on the concept of applying the correct fertilizer formula at the appropriate rate, time, and place (Gruhn et al., 2000; Fixen and Reetz, 2006). The way fertilizers are managed can have a major impact on the efficiency of nutrient use by crops and potential impact on the surrounding environment (Gruhn et al., 2000; Snyder, 2006). Thus, it is essential to place the nutrient in such a way that it provides rapid uptake by the crop and reduces potential losses (Steward, 2006). Lotfollahi et al. (1997) reported significant nitrogen fertilizer placement effects on root growth and grain protein of wheat.

Manure application to the soil surface may not be as effective as incorporated manure for crop production, because of potential nitrogen loss (Eghball and Power, 1999). Zake et al. (2000) compared different methods of applying coffee husks on soil fertility, root system and yield of banana, and concluded that the most effective option was to incorporate half and half-on-the-surface. The beneficial effect of mulching on plantain, via improved root growth and reduced susceptibility to nematodes has been documented (Coyne et al., 2005; Tenkouano et al., 2006). Comparatively little experimental information is available on plantain's response to organic manure, despite the predominance of manure-based cultivation of bananas in West Africa whereby pure stands of the crop are perennially maintained in plots that receive organic matter and nutrients from household refuse (Swennen, 1990).

This study was carried out to evaluate the effect of manure placement on the growth of plantain with emphasis on shoot growth, root development, and nutrient uptake.

MATERIALS AND METHODS

A pot experiment was conducted in a screen-house at the high rainfall station of the International Institute of Tropical Agriculture (IITA) located at Onne (4^0 43'N, 7^0 01'E, 10 m a.s.l.), in southeastern Nigeria. The average afternoon screen-house temperature is between 28 and 31°C and relative humidity of about 95%.

Media preparation

Large cylindrical pots (height: 80 cm, diameter: 60 cm) were filled with a substrate consisting of 60 kg of topsoil (at 14% moisture content) and supplemented with the equivalent of 20 tons ha^{-1} (approximately 7.5 kg at 85% moisture content) of manure derived from composted poultry droppings of about three weeks. The chemical properties of the soil substrate and poultry manure are shown in Table 1. The top soil used was sandy loam, generally low in plant nutrient elements and was acidic. However, the poultry manure was expectedly rich in macro and micro nutrients (Table 1), supplying the equivalent of 312 kg N/ha, 280 kg P/ha and 358 kg K/ha.

Three manure placement methods were assayed (Figure 1). The first method consisted of top-dressing whereby all the manure was applied at the top of the soil (Treatment 1). The second method consisted of below soil surface-dressing whereby the manure was disposed at 20 cm below soil surface of the pot and covered with the soil substrate (Treatment 2). The third method consisted of half top-dressing and half at 20 cm below soil surface (Treatment 3). These were compared to a control with no manure added to the substrate (Treatment 4).

Plant material and preparation

Treatment effects were assessed on 'PITA 14', a tetraploid plantain hybrid with high yield, multiple disease resistance and attractive phenological features such as earliness and short stature (Ortiz and Vuylsteke, 1998). Extensive on-farm tests carried out in Nigeria confirmed the superior performance of this hybrid compared with the local landrace, with good adoption prospects associated with high economic returns on investment (Lemchi et al., 2005).

Seedlings were obtained by horticultural propagation of corm explants on saw-dust as has been previously described (Kwa,

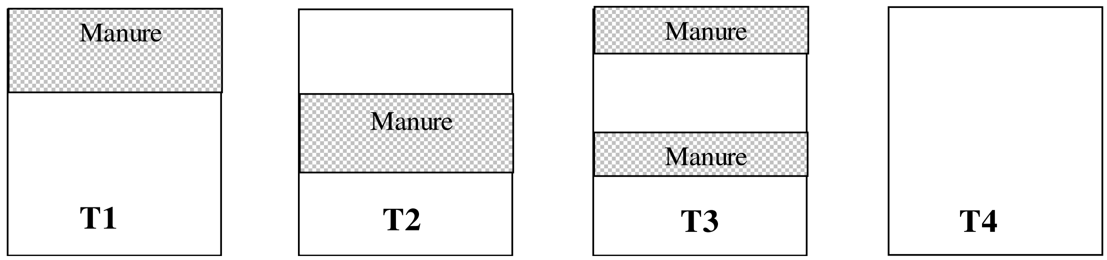

Figure 1. Schematic illustration of manure placement methods: manure placed at surface (T1), manure placed below surface (T2), 50% manure placed at surface and 50% placed below surface (T3) and no manure application (Control, T4).

2003; Faturoti et al. 2002; Baiyeri and Aba, 2005; Tenkouano et al., 2006). The seedlings were detached and transplanted directly into the pots that had been prepared as depicted above. The experimental layout was a completely randomized design, with 12 replicates for each treatment. Watering was provided twice per week and weeds were removed monthly throughout the duration of the experiment.

Data collection

Biomass production and distribution pattern were monitored at three and five months after transplanting (MAT), whereby three plants (per treatment) were sampled and subjected to determination of shoot and root growth parameters. Thus, length and diameter of roots were estimated from the best developed five roots per plant. Leaf area was calculated following the method of Obiefuna and Ndubizu (1979), while specific leaf area was calculated as the ratio of the leaf area to the dry weight of the leaf (Wright and Westoby, 2001). Plant height (cm) was measured from substrate surface to the V-junction of the last two fully expanded leaves while the plant girth (cm) was measured at the substrate surface level. Substrate attached to the corm and roots of sampling plants were carefully washed off under running water; thereafter roots were carefully removed from the corm and the number of live roots was counted. Corm height (cm) was measured as the vertical distance between the base and the top while the width was measured as the diameter. Root diameter was measured with vernier caliper. Sampled plants were sectioned into roots, corm, pseudostem and leaves, and were dry at about 70^{o}C until constant weights were obtained. Whole plant dry matter yield (WPDMY) was a sum of all the dry weights of a plant component. Nitrogen, phosphorus and potassium contents were assayed in the roots and the lamina of the third youngest leaf (leaf-3) as recommended by Lahav and Turner (1983), Turner and Hunt, (1984) and Lahav (1995). The micro-Kjeldahl method was used for the determination of total nitrogen while phosphorus was determined using the photometric method. The potassium content of the ashed and digested samples was determined by atomic absorption spectrophotometry. All the analytical procedures were as described in AOAC (1990).

Statistical analysis

Data were subjected to analysis of variance following completely randomized design (CRD) model using GENSTAT 5.0 Release 4.23DE, Discovery Edition 1 (GENSTAT, 2003). Multiple correlation analysis between leaf-3 growth and nutrient content parameters and other plant growth indices was performed. Similarly, the relationship between leaf-3 traits and whole-plant dry matter yield was examined. Test of significance of treatments means was by least significance difference at 5% probability level.

RESULTS

Root and shoot growth

Manure placement had significant ($P < 0.05$) effects on root and shoot growth parameters (Table 2). There were no differences between manure placement regimes for specific leaf area (SLA) for the whole plant or leaf-3 at 5 MAT, but all plants that received manure displayed significantly higher SLA than the control plants at 3 MAT. Similarly, surface application of manure (T1) enhanced shoot growth as well as root number and length of individual roots at 3 MAT. However, thicker cord roots were obtained with split application of the manure above and below the soil line (T3). To no surprise, the poorest growth was associated with control (T4) plants. However, the good performance of T1 plants was not sustained till 5 MAT, instead, T3 induced better growth followed by T2, which was associated with more pronounced growth differential between 3 and 5 MAT, compared to T1.

Biomass distribution

Biomass yield and distribution pattern are shown in Table 3. Total dry weight was highest in T1 plants and distantly followed by T3 plants at 3 MAT, but this was reversed at 5 MAT. It was notable that plants grown without manure apportioned more than 40 and 50% of the total photo-assimilate to roots and corms at 3 and 5 MAT, respectively. This high biomass partitioned into the root system did not translate to better shoot growth. Relative to partitioning pattern at 3 MAT, more dry matter was allocated to below ground parts at 5 MAT in all the treatments.

Leaf-3 attributes

Significant positive correlation coefficients between leaf-3 attributes and other plant growth parameters were found (Table 4) irrespective of plant age. At 3 MAT leaf-3 area had near perfect correlation ($r = 0.99^{**}$) with whole plant leaf area, fresh weight of corm and pseudostem.

Likewise, the leaf-3 area was positively correlated with whole-plant dry weight ($r = 0.95^{**}$). It was also, noted that

Table 2. Root and shoot growth responses of 'PITA 14' to manure placement at three and five months after transplanting as influenced by manure placement.

Months after planting	Manure placement[a]	Plant height (cm)	Plant girth (cm)	Number of leaves	Total leaf area (cm^2)	Area of leaf 3 (cm^2)	Specific leaf area (cm^2/g)	SLA-leaf 3 (cm^2/g)	Corm height (cm)	Corm width (cm)	Number of roots	Root length (cm)	Root diameter (cm)
3	T1	104.7	28.0	11.7	25143.0	3491.5	202.5	221.0	5.0	9.1	46.3	70.7	0.66
	T2	68.0	21.7	11.7	12514.6	1805.6	249.4	237.5	5.0	6.7	26.7	37.6	0.60
	T3	72.7	19.3	10.7	12601.6	1930.4	228.0	268.82	5.8	7.0	23.0	43.2	0.73
	T4	37.7	14.7	9.0	4377.5	890.3	171.9	222.3	4.5	4.9	27.0	65.3	0.45
	$LSD_{(0.05)}$	19.2	4.0	1.3	7711.2	1200.0	52.5	88.1	ns	1.1	16.9	26.2	0.16
5	T1	106.7	33.3	10.0	33836.8	4633.3	206.1	204.4	8.8	10.5	79.3	136.2	0.64
	T2	125.0	34.3	7.7	35991.5	5925.3	193.7	253.9	7.7	10.5	93.3	88.3	0.73
	T3	145.0	40.3	13.3	52625.1	6311.2	248.3	194.0	6.3	12.9	94.0	99.3	0.85
	T4	48.3	15.7	5.3	5217.6	1022.4	202.9	251.8	4.2	5.5	36.7	97.7	0.43
	LSD(0.05)	19.2	5.4	3.4	12026.8	1187.1	ns	ns	2.4	1.4	ns	ns	0.15

[a]T1: manure placed at surface; T2: manure placed below surface; T3: 50% manure placed at surface and 50% placed below surface; T4: Control, no manure application.

Table 3. Biomass production and distribution pattern of 'PITA 14' in response to the effect of manure placement at three and five months after planting.

Months after planting	Manure placement[a]	Dry weights (g)					Biomass distribution (%)			
		Root	Corm	Pseudostem	Leaves	Total	Root	Corm	Pseudostem	Leaves
3	T1	37.4	27.2	79.1	123.9	267.6	14.4	9.6	29.5	46.6
	T2	19.0	8.3	25.1	50.7	103.1	18.5	8.0	24.3	49.2
	T3	13.0	8.8	32.9	56.4	111.1	11.4	8.0	29.5	51.1
	T4	22.7	12.3	19.3	26.0	80.3	27.1	15.7	24.5	32.7
	$LSD_{(0.05)}$	ns	14.9	28.7	38.5	89.8	ns	4.3	ns	4.8
5	T1	179.6	89.2	147.1	164.6	580.4	31.7	14.6	24.9	28.8
	T2	120.1	75.8	154.8	182.5	533.2	23.0	14.3	28.8	33.9
	T3	219.4	103.6	217.0	217.4	757.6	28.9	13.5	28.3	29.2
	T4	60.5	30.3	33.5	26.5	150.8	31.9	22.1	25.5	20.6
	LSD(0.05)	95.2	ns	81.8	56.7	193.1	ns	ns	ns	ns

[a]T1: manure placed at surface; T2: manure placed below surface; T3: 50% manure placed at surface and 50% placed below surface; T4: Control, no manure application.

Table 4. Relationship between leaf-3 parameters and other plant growth traits

Whole plant traits	Leaf-3 variables					
	Area		Fresh weight		Dry weight	
	3 MAT	5 MAT	3 MAT	5 MAT	3 MAT	5 MAT
Shoot						
Plant height	0.97**	0.98**	0.94**	0.99**	0.93**	0.97**
Plant girth	0.90**	0.97**	0.91**	0.98**	0.87**	0.99**
Number of leaves	0.67*	0.73**	0.65*	0.79**	0.67*	0.86**
Total leaf area	0.99**	0.95**	0.99**	0.95**	0.96**	0.98**
Corm and root						
Corn height	0.05	0.57	0.03	0.56	-0.07	0.53
Corm width	0.94**	0.95**	0.94**	0.92**	0.92**	0.98**
Number of roots	0.75**	0.75**	0.82**	0.69*	0.81**	0.68*
Root length	0.40	-0.01	0.45	-0.01	0.48	0.53
Root diameter	0.33	0.87**	0.33	0.84**	0.26	0.83**
Biomass yield						
Leaf fresh weight	0.97**	0.95**	0.99**	0.97**	0.95**	0.99**
Pseudostem fresh weight	0.99**	0.92**	0.99**	0.94**	0.97**	0.95**
Corm fresh weight	0.99**	0.84**	0.98**	0.91**	0.95**	0.95**
Root fresh weight	0.84**	0.72**	0.91**	0.77**	0.87**	0.85**
Leaf dry weight	0.98**	0.94**	0.99**	0.89**	0.97**	0.91**
Pseudostem dry weight	0.97**	0.90**	0.96**	0.93**	0.97**	0.94**
Corm dry weight	0.78**	0.66*	0.84**	0.67*	0.82**	0.72**
Root dry weight	0.56	0.66*	0.64*	0.74**	0.69*	0.81**
Whole plant dry weight	0.95**	0.90**	0.97**	0.92**	0.97**	0.96**

*; **: Significant at 5% and 1% probability levels, respectively. MAT: Months after transplanting

the biomass yield (fresh or dry) of leaf-3 was significantly correlated with total plant biomass and fractions thereof partitioned to the roots, corm and leaves. Also leaf-3 biomass was positively associated with the number of roots. These highly significant relationships were main-tained at 5 MAT.

Predictive equations

Predictive equations between whole-plant dry matter yields (WPDMY) and some leaf-3 parameters and plant height were developed based on 3 MAT data (Table 5). Dry weight of leaf-3 gave the most reliable prediction of WPDMY. It had the highest coefficient of determination, the highest r-value between actual and predicted WPDMY, and the lowest deviation mean between the actual and predicted WPDMY values. Kendall's coefficient of concordance similarly showed dry weight of leaf-3 to be the most reliable predictor of WPDMY. Predicting WPDMY from area of leaf-3 and plant height are non-destructive methods but the equations developed thereof had relatively low coefficient of determination and high standard errors. However, the r-value between actual and predicted WPDMY using area of leaf-3 was high (0.95**).

Nutrient uptake

Nutrient uptake was influenced by manure placement (Table 6). The highest quantities of NPK were found in the leaves of T3 plants, which also showed the highest % N in the roots. In contrast, T1 plants had the highest percent P and K in the roots. The lowest concentration of NPK in roots and leaves were found in the control plants. Positive correlations were observed between roots and leaf-3 for their contents of nitrogen (r=0.87**) and phosphorus (0.65*). There was no elemental correlation for K in the roots and the leaves, but root K content was positively correlated with leaf-3 N (r=0.71**) and P (r=0.66**) contents, suggesting that K availability in soil and its uptake influence quantity of NPK translocated to the leaves.

Correlative responses

N, P, and K contents in the roots and leaf-3 were significantly correlated with plant growth and biomass production at 3 MAT (Table 7). N in root and leaf had positive correlation with corm height, root diameter and fresh weight of pseudostem; in addition, leaf N had positive and significant relationship with number of leaves per plant

Table 5. Predictive equations relating whole-plant dry matter yield (WPDMY) to plant height (PHT) and leaf-3 area (L3A), fresh weight (L3FW) and dry weight (L3DW).

Equation	Coefficient of determination (R^2)	Standard error (SE)	Probability level (P-value)	Correlation between actual and predicted	Deviation between actual and predicted values	Kendall's coefficient of concordance
WPDMY = 3 x PHT – 71.8	81.1	39.9	0.000	0.90**	0.08	0.968
WPDMY = 0.07 x L3A – 10.23	89.9	29.2	0.000	0.95**	8.70	0.969
WPDMY = 1.80 x L3FW + 8.84	93.7	23.0	0.000	0.97**	-0.13	0.963
WPDMY = 16.54 x L3DW – 5.68	94.1	22.3	0.000	0.97**	-0.03	0.982

Table 6. Concentration of nitrogen (N), phosphorus (P) and potassium (K) in roots and leaf-3 of 'PITA 14' as influenced by manure placement at 3 MAT.

Manure placement[a]	Root (%)			Leaf-3 (%)		
	N	P	K	N	P	K
T1	1.41	0.53	8.62	3.55	0.30	6.35
T2	1.93	0.44	7.53	4.08	0.26	6.67
T3	2.35	0.34	7.22	4.19	0.33	7.26
T4	0.85	0.15	3.03	2.21	0.21	2.19
$LSD_{(0.05)}$	1.14	ns	2.28	0.81	ns	1.48

[a]T1: manure placed at surface; T2: manure placed below surface; T3: 50% manure placed at surface and 50% placed below surface; T4: Control, no manure application.

Table 7. Correlation between plant growth attributes and the concentration of nitrogen (N), phosphorus (P) and potassium (K) in the root and leaf-3 of 'PITA 14'at 3 MAT.

Plant growth attributes	Root			Leaf-3		
	N	P	K	N	P	K
Shoot traits						
Plant height	0.18	0.77**	0.81**	0.46	0.62*	0.65*
Plant girth	0.06	0.70*	0.78**	0.38	0.39	0.58*
Number of leaves	0.40	0.63*	0.84**	0.74**	0.52	0.75**
Total leaf area	0.04	0.78**	0.76**	0.34	0.59*	0.55
Corm and root traits						
Corm height	0.86**	-0.10	0.31	0.71**	0.11	0.43
Corm width	0.21	0.68*	0.77**	0.47	0.56	0.63*
Number of roots	-0.47	0.42	0.36	-0.18	0.13	0.16
Root length	-0.73**	0.21	-0.04	-0.60*	0.15	-0.29
Root diameter	0.80**	0.09	0.55	0.82**	0.45	0.69*
Biomass yield traits						
Leaf fresh weight	0.02	0.70*	0.73**	0.29	0.54	0.51
Pseudostem fresh weight	0.77*	0.72*	0.69*	0.80**	0.62*	0.78*
Corm fresh weight	0.03	0.76**	0.74**	0.29	0.57	0.49
Root fresh weight	-0.28	0.57	0.51	0.01	0.33	0.34
Leaf dry weight	0.01	0.69*	0.67*	0.26	0.49	0.42
Pseudostem dry weight	-0.07	0.70*	0.58*	0.13	0.49	0.29
Corm dry weight	-0.35	0.39	0.34	-0.15	0.16	0.07
Root dry weight	-0.44	0.24	0.09	-0.28	-0.02	-0.04
Whole plant dry weight	-0.12	0.63*	0.56	0.11	0.41	0.30

but total leaf area was positively correlated with P and K in the root. Fresh biomass yield was significantly associated with the quantity of P and K whereas WPDMY only had significant positive relationship with root P.

DISCUSSION

The significant differences recorded in plant growth and biomass yield suggest that placement of manure probably affected nutrient release pattern and the eventual quantity of nutrients available to plant roots for absorption and utilization for growth. An earlier study by Eghball and Power (1999) on the effect of placement of composted and non-composted manure on corn yield and N uptake showed significant treatment effects on biomass yield, grain yield and N uptake.

Manure placed on the surface (T1) supported a better root and shoot development at 3 MAT probably because nutrient release and distribution pattern within the rhizosphere was better than the other placement methods. In contrast, bottom-dressing (T2) supported fewer and shorter roots which possibly explained the poor shoot growth of plants at 3 MAT. However, at 5 MAT T1 plants exhibited poorer performance probably due to leaching loss of nutrients and or earlier uptake by plants. Plant performance indices at 3 and 5 MAT showed that split dressing at the top and the bottom of the pots (T3) may be a more sustainable method for manure application to *Musa*. This treatment was associated with the second best plant growth at 3 MAT and the best at 5 MAT, possibly because it ensured a slower but steadier supply of nutrients to the plants.

Blomme et al. (2005) reported significant inter-dependence between root and shoot growth in *Musa* germplasm. In this study, plants that were not manured produced relatively many roots that were long, but they had the poorest shoot growth, probably due to poor nutrient availability in the soil. This study established that the quantity of NPK in plant roots and leaf-3 lamina had significantly positive correlation with growth and biomass production. Thus, the poor growth of the plants not manured was due to poor nutrient uptake.

Growth in *Musa* plant is significantly correlated with yield (Stover and Simmonds, 1987; Baiyeri and Mbah, 1994; Lahav, 1995; Baiyeri et al., 2000). Thus, it could be hypothesized that manure placement would have significant effect on the yield of field grown plants, as earlier reported for some other crops (Lotfollahi et al., 1997; Eghball and Power, 1999; Sistani et al., 2004). This postulate is supported by the facts that manure placement significantly influenced dry matter production and distribution as well as nutrient uptake and transfer.

Plants that were not manured had the lowest dry matter yield, partitioning about 40% of assimilate to root and corm. This could suggest that photosynthetic efficiency was influenced by fertility status of the growth medium. Besides, the results indicated that partitioning of photo-assimilate could be manipulated by fertilizer treatment since the manured treatments differed in dry matter partitioning pattern. Plants grown without manure had the lowest specific leaf area (SLA), suggesting thicker or denser leaf; however, under low light intensity, higher SLA is more advantageous for enhanced photosynthetic capacity (Evans and Poorter, 2001). SLA and leaf N are integral components of photosynthetic efficiency (Wright and Westoby, 2001). Thus, T3 plants that had the highest leaf-3 N and SLA were probably more efficient in conversion of carbon to energy matter for growth, thus explaining better growth indices at 5 MAT.

The positive relationship between leaf-3 biomass and root system development suggests that the biomass of leaf-3 is indicative of root system development in *Musa*. Thus, agronomic treatments that enhance biomass of leaf-3 would similarly support good root system development. Good root system will support proper ramification of the rhizosphere for moisture and nutrient uptake as well as ensuring good anchorage. Also, the high and significant relationship between leaf-3 dry weight and whole-plant dry matter yield suggests that the photosynthetic efficiency of an agronomic technology can easily be assessed using leaf-3 with some accuracy (r^2 = 94%) without complete removal of the whole plant. The area of leaf-3 had 98% predictive precision for the total leaf area per plant meaning that the later could easily be assessed without the rigour and time needed to determine the area of several leaves per plant. The significant relationship between area of leaf-3 and other plant traits assures a non-destructive assessment of plant performance in response to manure treatments. The high and positive coefficient of correlation suggests that deductions made based on leaf-3 are reliable for making predictive conclusions.

Fertilizer best management practices are based on the concept of applying the right fertilizer at the 'right rate, right time, and right place' (Fixen and Reetz, 2006). In this study, placing the manure in the right place to ensure optimum utilization by crop for growth, biomass production and distribution, and nutrient uptake and transfer were the focus. It was evident that placement of manure affected both shoot and root growth parameters, influenced total dry matter yield and distribution pattern, and significantly varied the quantity of NPK found in the roots and leaves. In all, it was apparent from the study that plant performance indices at 3 and 5 MAT showed that split dressing at the top and the bottom of the pots (T3) was a more sustainable method for manure application to *Musa*.

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