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Residual effect of plantain-targeted manure on substrate fertility and performance of follower maize (*Zea mays*) crop

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Key words
Plantains, manure placement, residual nutrients, maize growth

1 SUMMARY

Fertilizer placement method plays a vital role in modulating crop response to nutrients. Previous studies found a split combination of top-dressing and base placement of poultry manure superior (on growth and dry matter yield of plantain) to either of the placement methods used singly. The present study investigated the effect of manure placement method vis-à-vis the duration of growth of a previous plantain crop on the substrate fertility (nutrient leftover) and growth of a follower maize crop. In a pot experiment, three manure application methods, consisting of top-dressing (T1), base placement (T2), or a split combination of methods T1 and T2 (T3), were tested against a no manure control (T4) on growth and dry matter yield of 'PITA 14' (a plantain hybrid) for a growth period of 3 or 5 months. The residual fertility of the leftover substrates was evaluated, based on growth and biomass production of two maize varieties (acid and non-acid tolerant) for 9 weeks. The acidity, organic matter and NPK contents of the substrates were determined. Data were collected on percentage seedling emergence and vigour, plant height, stem diameter, number of live leaves, leaf area, leaf area index (LAI) and dry weights of shoot and root components. The duration of growth of the previous plantain crop and the manure placement methods significantly ($P < 0.05$) influenced nutrient leftover and all the growth parameters of the follower maize crop. The acid tolerant maize variety generally performed better than the non-tolerant variety. Longer duration of growth of the previous plantain crop reduced residual NPK. Top dressed soil (T1) substrate previously cropped for three months supported maize plants that had the highest LAI (0.56) and total dry weight (2.39g) at 3 WAP. However, at 6 and 9 WAP, substrates with split combination of top-dressing and base placement (T3) supported the highest LAI and total dry matter yield of maize. T3 substrates also maintained the highest residual nutrients and an ideal pH (6.6) for plant growth. Irrespective of manure placement method, maize growth performances were better in substrates previously cropped for three months than those cropped for five months. Maize performance in soil amended with manure but not previously cropped (positive control) was not better than other manured substrates, particularly those cropped for 3 months. The quantity of residual K had the highest correlation coefficient with LAI and total dry weight of maize. The results implied that nutrient mining and associated soil impoverishment in

plantain cultivation could be ameliorated through appropriate nutrient placement methods. A split combination of top-dressing with base placement of poultry manure in plantain fields ensures a slower but steadier availability of crop nutrients needed for better sustainability of crop yields.

2 INTRODUCTION

Yield decline in plantain cultivation is a common occurrence after few production cycles. This yield decline syndrome largely due to marginal soil fertility (Swennen, 1990) is a major obstacle to the expansion of plantain cultivations beyond backyards in most parts of tropical Africa.

Soil organic matter is an important indicator of soil fertility (Agboola & Obatolu, 1989). This suggests that management practices that enhance fertility of the top soil are imperative for better yield of *Musa* crops, since more than 65% of the root system is distributed in the top 30 cm depth of the soil (Araya *et al.*, 1989).

Plantains are heavy feeders and thus require large amounts of nutrients (Lahav, 1995) which could be supplied through a judicious management of organic manure (Baiyeri & Tenkouano, 2007). Animal manures are valuable sources of crop nutrients and organic matter which can improve soil biophysical conditions (Mbah & Mbagwu, 2006), thereby making the soil more productive and supporting a sustainable food production.

Fertilizer best management practices are based on the concept of applying the right fertilizer at the 'right rate, right time and right place' (Fixen & Reetz, 2006). An important part of optimizing crop response to a fertilizer nutrient is placing the nutrient in such a way that it is rapidly taken up by the crop thus reducing potential losses (Stewart, 2006). Earlier studies on 'PITA 14', a plantain hybrid, (Baiyeri & Tenkouano, 2007 & 2008) revealed that manure placement method significantly influenced plant growth and biomass production. These authors found a split combination of top- and bottom-dressing superior (in terms of plant growth, root system development, nutrient uptake and dry matter yield) to either of the placement methods used singly.

In the present study, we investigated the hypothesis that previous manure placement methods and the duration of growth of an earlier crop (reported in Baiyeri & Tenkouano, 2007 & 2008) could influence residual nutrients in the left-over substrate, and consequently influence growth of the follower crop, in this case, maize (*Zea mays*). Laboratory analysis of soil nutrients may not always reflect the quantities available for plant uptake. Thus, we grew maize, a plant that is highly sensitive and responsive to nutrient availability, to test if the methods of manure placement for growing plantain actually influenced nutrient leftover and, consequently the growth of a follower crop.

3 MATERIALS AND METHODS

3.1 Experimental site: 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 above sea level [asl]), in Rivers State, Nigeria. The average noon temperature of the screen-house was between 28 and 31 ^{0}C, and a high relative humidity of about 95% prevailed.

3.2 Design of experiment: Experimental treatments comprised of two accessions of maize grown on ten different soil substrates, which differed in manure placement method and period of growth of a previous plantain crop as described in Table 1. Substrates (T_1…T_4) were previously grown with 'PITA 14', a plantain hybrid, for a period of 3 or 5 months in a pot experiment (Baiyeri & Tenkouano, 2007 & 2008), under screen-house conditions.

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Table 1: Description of experimental soil substrates cropped with plantain followed by maize in Nigeria.

Substrate notation	Description
T_1-3MAP	Soil formerly grown with plantain for 3 months, where poultry manure was applied as top dressing (i.e., above ground placement).
T_1-5MAP	Soil previously grown with plantain for 5 months, where poultry manure was applied as top dressing
T_2-3MAP	Soil previously grown with plantain for 3 months, where poultry manure was placed below ground at a 20 cm depth.
T_2-5MAP	Soil previously grown with plantain for 5 months, where poultry manure was placed below ground at a 20 cm depth.
T_3-3MAP	Soil previously grown with plantain for 3 months, where half the manure dose was placed above and the complement placed below ground.
T_3-5MAP	Soil previously grown with plantain for 5 months, where half the manure dose was placed above and the complement placed below ground.
T_4-3MAP	Un-amended soil (no manure) previously grown with plantain for 3 months
T_4-5MAP	Un-amended soil previously grown with plantain for 5 months
T5 (negative control)	Fresh un-amended soil, not grown with any previous plantain crop
******T6 (positive control)	Fresh soil amended with poultry manure but not grown with any previous plantain crop

******T6 was amended with poultry manure, ratio 6:1 (Soil : PM, v/v). This reflects a 20 t ha^{-1} manure dose used for the previous plantain crop.

3.3 Treatment application: Two maize varieties 'ATP-SR' [an acid-tolerant (AT) accession] and 'BR9928-DMRSR', a non-acid tolerant (NAT) accession obtained from IITA, Ibadan, Nigeria, were grown in 10 soil substrates (described earlier) giving rise to 20 treatment combinations. Three seeds were sown per nursery bag of 2 kg soil, which were later thinned-down to one after complete emergence at 7 days after planting (DAP). Each treatment combination (substrate by maize variety) was replicated 15 times in a completely randomized design (CRD), with a spacing of 50 cm between rows and 25 cm within row. Plants were watered conscientiously twice every week to minimize drainage loss of plant nutrient. The substrates were analysed for pH, organic matter and NPK contents at the beginning of the experiment.

3.4 Data collection and analysis: At 3 – 7 DAP, data were collected on percentage seedling emergence. Seedling vigour (response and general performance of the seedlings) was visually assessed at 7, 14 and 21 DAP using a 4-point vigour scoring chart developed specifically for this study (Table 2). Destructive sampling was done at 3, 6 and 9 weeks after planting (WAP). Five seedlings were selected at random from each treatment combination for growth and biomass assessment. Data collected included plant height (cm), stem diameter (cm), number of live and dry leaves per plant and green leaf area (cm^2). Plant height was measured from the substrate surface to the V-junction of the last two terminal leaves, while the stem diameter was measured at the 10 cm height with vernier caliper. Leaf area (length x width x 0.75) was calculated for the live leaf tissues per plant following the recommendations of Elings (2000). Leaf area index (LAI) was calculated on the live leaves, as a ratio of the total leaf area of a plant to the land area allotted to a single plant. Dry weights (g) of live leaves, stem, tassels and roots were measured after oven – drying (65 ^{0}C, 72 hrs) to estimate the dry matter yield (g) and partitioning to root and shoot portions. All data were analyzed as factorials in CRD using GENSTAT Release 7.2 DE (GENSTAT, 2007).

Table 2: Vigour scoring chart for maize seedlings at juvenile growth stage (7 – 21 DAP).

Score	Interpretation
4	Stout girth, vigorous and deep green
3	Stout girth, vigorous but light-green colour
2	Spindly with narrow pale-yellow leaves
1	Retarded growth, generally poor appearance

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4 RESULTS

The analytical result of the soil substrates is shown on Table 3. The pH values for treatments $T_1 – T_3$ substrates were slightly acidic (an ideal condition for plant growth), while $T_4 – T_6$ were strongly acidic. Organic matter and NPK contents were higher in the manured substrates ($T_1 – T_3$ and T_6), although phosphorus level was relatively low in the T_6 substrate which was amended with poultry manure, but was not previously cropped with plantain. Duration of previous plantain crop influenced nutrient leftover, with the longer duration of growth of the previous crop reducing the residual nutrients. N and P levels were highest in T_3 substrate grown with plantain for 3 months.

Seedling emergence of the two maize varieties was significantly ($P < 0.05$) influenced by soil substrate (Figure 1). The T_4 substrates had the earliest emergence with more than 80% of the plants emerged at 4 DAP. At 6 DAP, 100% emergence was recorded only for the acid-tolerant maize sown in T_3 and T_4 substrates previously grown with plantain for 3 months. Generally, seedling emergence was higher in the acid-tolerant maize.

Table 3: Effect of soil substrates cropped with plantain for 3 or 5 months on organic matter, acidity and residual NPK.

Substrate*	PH (H_20)	OM (%)	N (%)	P (µg/g)	K (cmol⁺/kg)
T_1-3MAP	5.9	2.38	0.12	464.55	0.40
T_1-5MAP	6.0	2.55	0.13	329.41	0.17
T_2-3MAP	6.5	2.71	0.15	664.41	0.40
T_2-5MAP	6.7	2.69	0.12	552.13	0.40
T_3-3MAP	6.6	2.69	0.16	682.40	0.38
T_3-5MAP	6.6	2.52	0.13	601.19	0.36
T_4-3MAP	4.5	2.40	0.10	183.25	0.07
T_4-5MAP	5.3	2.40	0.11	174.86	0.04
T5	4.6	1.84	0.09	172.57	0.03
T6	5.3	2.07	0.10	214.90	0.37

*Substrate: see Table 1 for detailed description.

Table 4: Effect of soil substrate on growth and dry matter yield of two maize varieties at 3WAP.

Substrate	NLL	LA (cm²	LAI	Rdw(g)	Sh-dw(g	Tdw (g	%DM Roo	% DM Shoot
T_1-3MAP	7.3	699.80	0.56	0.31	2.08	2.39	12.96	81.04
T_1-5MAP	7.3	550.15	0.44	0.38	1.57	1.95	20.00	80.00
T_2-3MAP	7.6	619.33	0.49	0.38	1.72	2.10	17.59	82.41
T_2-5MAP	7.1	485.10	0.39	0.25	1.42	1.67	15.55	84.45
T_3-3MAP	7.5	629.37	0.50	0.32	1.83	2.16	15.11	84.89
T_3-5MAP	7.3	520.39	0.42	0.36	1.51	1.87	19.43	80.57
T_4-3MAP	6.3	361.64	0.29	0.41	0.94	1.35	30.01	69.99
T_4-5MAP	6.9	367.16	0.29	0.30	0.97	1.26	23.49	76.51
T5	5.6	228.57	0.18	0.28	0.61	0.89	31.49	68.51
T6	7.7	631.95	0.51	0.26	1.84	2.09	13.61	86.39
LSD (0.05)	0.5	93.72	0.08	0.10	0.32	0.38	3.45	3.45
Maize								
AT	7.2	570.04	0.46	0.35	1.61	1.97	19.34	80.66
NAT	6.9	448.65	0.36	0.30	1.28	1.58	20.50	79.50
LSD (0.05)	0.25	41.91	0.03	0.05	0.14	0.17	ns	ns

*Substrate: see Table 1 for detailed description; NLL = Number of live leaves; LA = Leaf area per plant; LAI = Leaf area index; Rdw = Root dry weight; Sh-dw = Shoot dry weight; Tdw = Total dry weight per plant; %DM Root = Percentage dry matter partitioned to the root portion; % DM Shoot = Percentage dry matter partitioned to the shoot portion; ns = non-significant at 5 % probability level.

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Figure 2 shows the seedling vigour of the two maize varieties as influenced by soil substrate at 7 – 21 DAP. The manured substrates produced healthier and more vigorous plants. Seedling vigour declined over time in T_4 and T_5 substrates (which had no manure). Generally, the acid-tolerant maize was more vigorous.

At 3 WAP, growth and dry matter variables were significantly ($P < 0.05$) influenced by the substrates (Table 4). Manured substrates (T_1 – T_3 and T_6) produced plants with more leaves, and also partitioned more than 80% of the total dry matter to the shoot. The T_1 substrate that was cropped with plantain for 3 months (T_1-3MAP) produced maize with the largest leaf area and highest dry matter accumulation. This was closely followed by the T_2 and T_3 substrates that were previously cropped with plantain for 3 months; these had similar productivity with the T_6 substrate.

Table 5: Growth and dry matter yield of two maize varieties as influenced by soil substrate at 6 WAP

Substrate	NLL	LA (cm²)	LAI	NDL	Ldw (g)	Sdw(g)	Rdw (g)	Tdw (g)	%DM Root	% DM Shoot
T_1-3MAP	8.3	2565.12	2.05	2.5	8.56	6.01	4.32	18.89	22.70	77.30
T_1-5MAP	5.7	1157.41	0.93	3.8	4.11	2.89	2.56	9.56	26.21	73.79
T_2-3MAP	9.3	2836.33	2.27	2.2	8.48	4.92	2.29	15.68	14.60	85.40
T_2-5MAP	6.8	1769.35	1.41	2.8	6.15	4.16	3.29	13.60	23.96	76.04
T_3-3MAP	9.6	3142.15	2.51	1.2	12.49	5.04	3.44	20.97	17.84	82.16
T_3-5MAP	7.3	1778.12	1.42	2.5	5.57	3.22	2.15	10.95	19.61	80.39
T_4-3MAP	4.8	592.54	0.47	3.4	2.22	1.83	1.88	5.93	31.69	68.31
T_4-5MAP	4.9	625.46	0.50	3.4	2.35	1.90	1.52	5.77	26.38	73.62
T5	4.0	350.68	0.28	3.0	1.15	0.90	1.21	3.26	37.65	62.35
T6	7.6	2003.99	1.60	2.6	6.60	4.54	2.75	13.89	19.78	80.22
LSD (0.05	0.5	208.53	0.17	0.78	2.81	0.53	0.59	3.01	4.64	4.64
Maize										
AT	6.6	1718.32	1.38	2.8	5.50	3.84	2.47	11.82	22.70	77.30
NAT	7.1	1645.91	1.32	2.6	6.03	3.24	2.61	11.88	25.38	74.62
LSD (0.05)	0.3	ns	ns	ns	ns	0.24	ns	ns	2.08	2.08

*Substrate: see Table 1 for detailed description; NLL = Number of live leaves; LA = Leaf area per plant; LAI = Leaf area index; NDL = number of dry leaves; Ldw = Leaf dry weight; Sdw = Stem dry weight; Rdw = Root dry weight; Tdw = Total dry weight per plant; %DM Root = Percentage dry matter partitioned to the root portion; % DM Shoot = Percentage dry matter partitioned to the shoot portion; ns = non-significant at 5 % probability level.

Maize growth and productivity were poorest in the T_5 substrate (un-amended soil with no previous plantain crop). Duration of growth of the previous plantain crop also influenced the productivity of the maize crop; growth and dry matter yield were generally better in substrates that supported plantain for 3 months as compared to those of 5 months duration. The acid tolerant maize also had better growth and yield variables as evident in number of leaves, leaf area and dry matter yield per plant.

Table 5 shows the effect of soil substrate on growth and dry matter yield of the two maize varieties at 6 WAP. Growth and dry matter yield were best in substrate T_3-3MAP (see Fig. 3). This was closely followed by the T_1 substrate that had plantain crop for 3 months. The T_5 substrate produced the poorest plants. This is evident from the low number of live leaves, leaf area, LAI and the total dry matter yield. The T_5 plants partitioned more than 37 % of the accumulated dry matter to the root region as compared to 27 % and below observed in other substrates. The non-significant effects observed between the two maize varieties suggested a similar growth pattern at 6 WAP.

At 9 WAP, the growth and dry matter variables of the maize crop were significantly ($P < 0.05$) influenced by the substrates (Table 6). Substrate T_2-3MAP sustained plants with the greatest number of live leaves, but plant height, stem diameter and total dry matter yield were best in the plants grown in T_3-3MAP (see Fig. 3). Number of live leaves and dry matter yield were generally poor

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in T_4 (with no manure), and poorest in T_5 which in addition to no-manure application, had no previous plantain crop. Generally, the acid-tolerant maize accumulated higher dry matter throughout the study period (Figure 3).

The correlative responses (Table 7) showed that the quantity of residual K had the highest correlation coefficients with LAI and total dry weight of maize. Similarly, LAI and total dry weight had a high significant positive correlation with N, P and substrate pH levels. LAI was also very highly correlated (r = 0.97) with total dry weight of maize.

Table 6: Effect of soil substrate on growth and dry matter yield of two maize varieties at 9 WAP

Substrate	Pht (cm)	StmD (cm)	NLL	NI	Ldw (g)	Tsl-dw (g)	Sdw g)	Rdw (g)	Tdw (g)	%DM Root	% DM Shoot
T_1-3MAP	149.8	1.2	10.5	5.	12.04	1.35	34.08	5.90	53.37	11.03	88.97
T_1-5MAP	79.1	0.8	9.0	5.	6.03	0.40	7.28	2.71	16.42	16.70	83.30
T_2-3MAP	142.8	1.2	11.8	4.	14.63	1.68	34.28	5.62	56.21	9.88	90.12
T_2-5MAP	138.2	1.0	9.3	5.	8.20	0.69	17.74	4.07	30.69	13.59	86.41
T_3-3MAP	160.4	1.3	9.5	6.	14.44	1.69	39.04	6.69	61.86	10.83	89.17
T_3-5MAP	133.2	0.9	9.2	6.	8.40	0.85	15.21	3.63	28.09	13.06	86.94
T_4-3MAP	75.0	0.6	7.6	5.	2.80	0.09	3.47	2.20	8.57	25.78	74.22
T_4-5MAP	76.2	0.6	7.6	5.	2.96	0.10	4.39	1.65	9.11	18.62	81.37
T5	56.6	0.5	6.4	4.	1.61	0.07	1.35	1.10	4.12	27.12	72.88
T6	149.4	1.1	9.5	6.	8.52	0.93	22.71	4.09	36.26	11.24	88.79
LSD (0.05)	16.75	0.1	0.8	0.	1.14	0.39	3.86	0.9	4.89	2.81	2.81
Maize											
AT	120.6	0.9	8.8	5.	7.96	0.79	19.20	3.74	31.69	14.79	85.21
NAT	111.5	0.9	9.3	5.	7.97	0.78	16.71	3.80	29.25	16.78	83.22
LSD (0.05)	7.49	ns	0.4	0.	ns	ns	1.73	ns	2.19	1.26	1.26

*Substrate: see Table 1 for detailed description

Pht = Plant height; StmD = stem diameter; NLL = Number of live leaves; NDL = number of dry leaves; Ldw = Leaf dry weight; Tsl-dw = tassel dry weight; Sdw = Stem dry weight; Rdw = Root dry weight; Tdw = Total dry weight per plant; %DM Root = Percentage dry matter partitioned to the root portion; % DM Shoot = Percentage dry matter partitioned to the shoot portion; ns = non-significant at 5 % probability level.

Table 7: Correlation between leaf area index (LAI) and total dry weight (TDW) of maize, soil NPK, acidity and organic matter content

	N	P	K	OM	pH	LAI	TDW
N	-	0.89**	0.60	0.85**	0.84**	0.78**	0.72**
P		-	0.79**	0.76**	0.90**	0.83**	0.74*
K			-	0.49	0.79**	0.90**	0.89**
OM				-	0.78**	0.56	0.54
pH					-	0.74*	0.71*
LAI						-	0.97**
TDW							-

**Significant at 1% probability level; * Significant at 5% probability level

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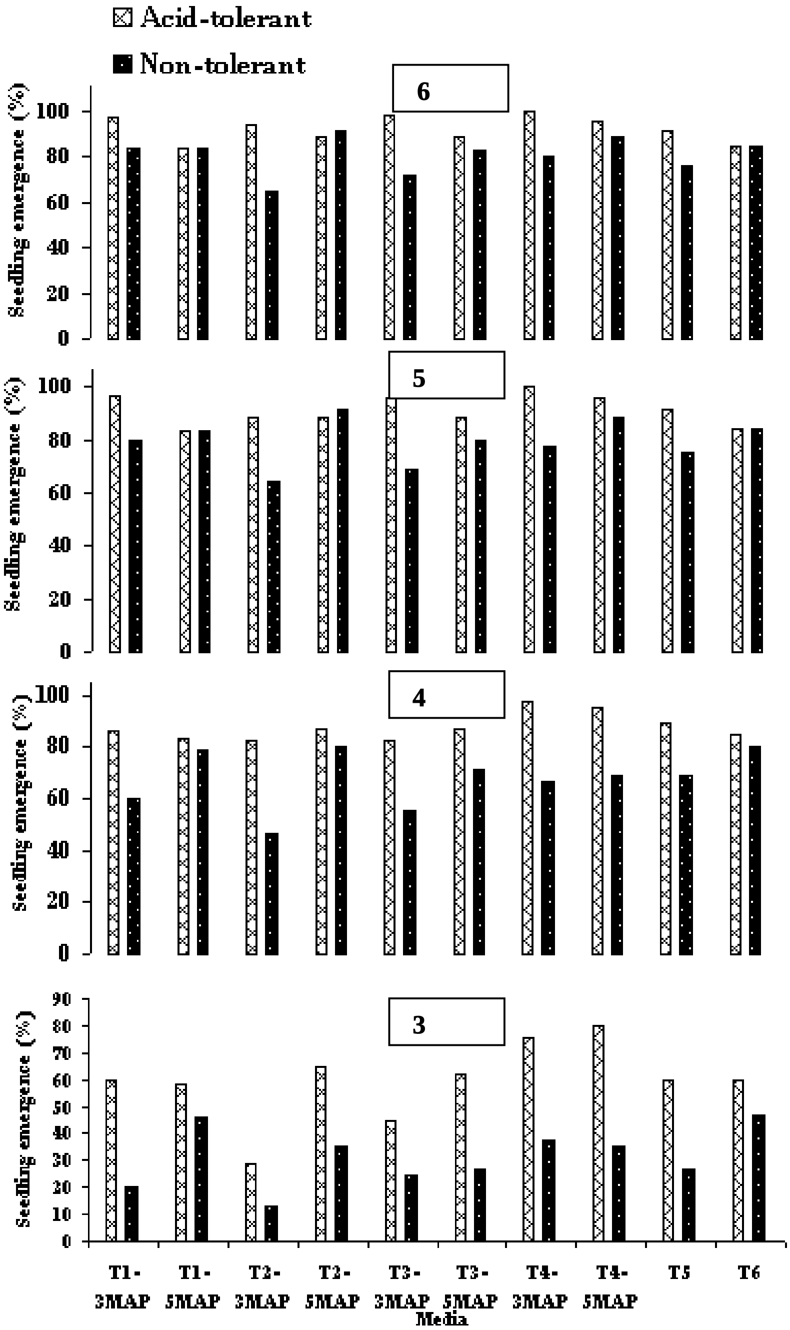

Figure 1: Seedling emergence of two maize varieties as influenced by soil substrate at 3- 6 days after planting. *Media: see Table 1 for detailed description

5 DISCUSSION

The significant differences observed in growth and dry matter yield in the follower maize crop suggested that manure placement method and duration of growth of the previous plantain crop influenced the nutrient status of the substrates. The earlier emergence recorded in T_4 substrates, which had no manure, could be related to variability in oxygen-CO_2 ratio of the growth media. Higher oxygen diffusion rates are required for emergence of shoots, whereas increasing CO_2 concentration depresses both germination and emergence (Mayer and Poljakoff-Mayber, 1989).

Available oxygen in the manured substrates may probably have served a dual function in mineralization of organic matter and the breakdown of food reserves in the seeds following hydration and enzymatic activation. The manured substrates, therefore, require higher oxygen for the organisms that aid decomposition whose activities may further generate CO_2. Similarly, higher concentrations of fertilizer and soluble salts in soil solution of the manured substrates could further suppress germination and seedling emergence due to osmotic and, in some cases, ion toxicity effects (Cardwell, 1982).

The increased growth and dry matter yield of maize grown in the manured substrates was made possible by the residual nutrients released from the applied poultry manure. Residual effects of manure or compost application can maintain crop yield levels for several years after manure or compost application ceases since only a fraction of the N and other nutrients in manure or compost became available to plants in the first year after application (Eghball *et al*., 2004).

The improved maize growth and dry matter yield consistently observed in T_3 substrates confirmed split dressing at the top and bottom, to be a better and sustainable method for manure application to *Musa* crops as earlier recommended by Baiyeri and Tenkouano (2007 & 2008). This treatment may have supported a slower but steadier supply of nutrients which conserved more nutrients for the follower maize crop (Baiyeri & Tenkouano, 2008). N and P levels were particularly high in T_3 substrate grown with plantain for 3 months, which supported the highest dry matter yield in the follower maize.

Substrates previously grown with plantain for 3 months supported a better maize yield than those of 5 months, probably because of higher nutrient removal following a longer duration of plantain growth. Interestingly, T_1 – T_3 substrates previously grown with plantain for 3 months supported a higher maize dry matter yield than fresh soil samples amended with poultry manure. This may be partly due to the time lag between manure application and subsequent mineralization for nutrient release or as a result of useful substances released in the rhizophere of the previous plantain crop.

Presence of micro-organisms in the rhizophere of many crop species induces an increased root exudation which in turn may improve plant nutrient availability (Prikryl & Vancura, 1980). Organic substances like vitamin B_{12} and plant growth hormones can be taken up passively by plants (Mozafar & Oertli, 1992). The probable available nutrients in root exudates of the previous plantain crop may have contributed to the difference in maize dry matter yield observed in T_4 (previously grown with plantain) and T_5 (no plantain) substrates which had no poultry manure.

Manured substrates (T_1 – T_3 and T_6) produced plants with greater number of leaves, larger leaf area and higher LAI suggesting a better photosynthetic efficiency. Leaf area index estimates the capacity of a crop to intercept photo-synthetically active radiation and synthesize carbohydrate (Elings, 2000). The existing relationship between LAI and photosynthesis may explain the high positive correlation coefficient ($r = 0.97^{**}$) observed in the present study between LAI and total dry weight.

Leaf area index of a crop as defined by Watson (1947) is the one-sided area of green leaf tissue per unit area of land occupied by that plant. The high correlative responses observed between residual K, LAI and total dry weight in this study, may be related to the regulatory function of K in opening and closing of the leaf stomates in the course of transpiration which influences photosynthetic rate (Sawhney & Zelitch, 1969). Besides, K is a key element in *Musa* nutrition (Lahav, 1995), and uptake could at times get to luxury consumption level. Thus, the extent of K mining from the substrate and consequently the residual K will be an important determinant of performance of the follower maize crop. This assertion is in line with the Liebig's law of minimum, "the most limiting factor of crop production determines the extent of crop performance".

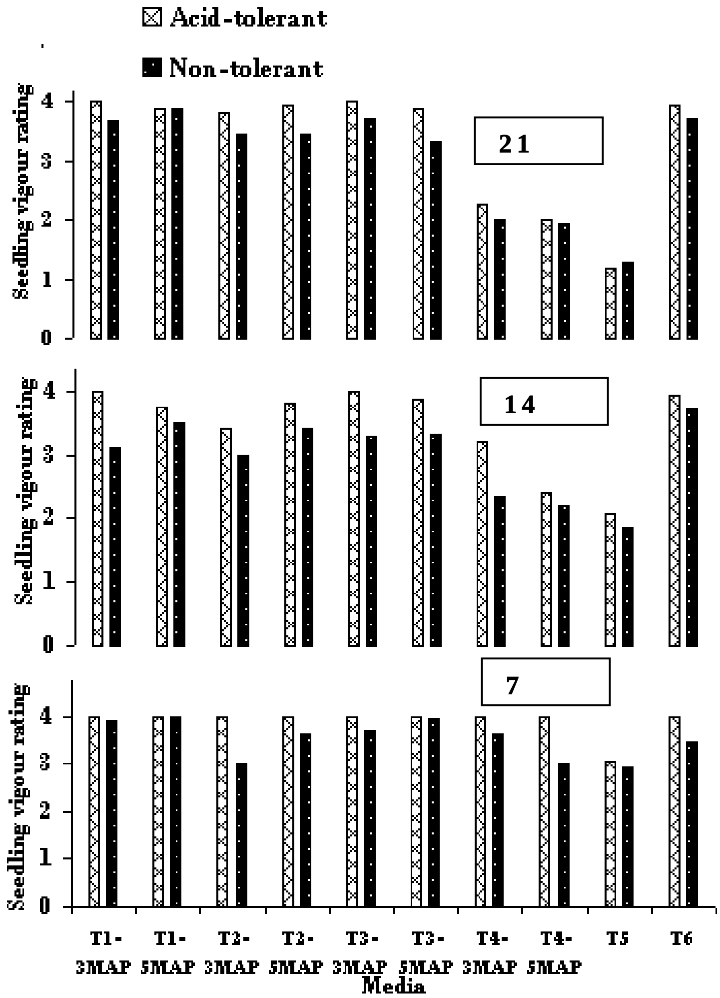

Figure 2: Seedling vigour of two maize varieties as influenced by substrate at 7, 14 and 21 DAP.
*Media: see Table 1 for detailed description

The better performances observed in the acid-tolerant maize is due to the inherent genetic potential and thus, better adaptability in acidic substrate environment. T_3 substrate previously grown with plantain for 3 months supported the highest dry matter yield of maize. This treatment maintained the highest accumulation of plant nutrients with an ideal pH (6.6) for plant growth.

This study revealed that manure placement method modulated residual nutrient levels probably by regulating plant nutrient uptake and /or minimizing leaching and volatilization losses. The results implied that nutrient mining and associated soil impoverishment in plantain cultivation could be ameliorated through appropriate nutrient placement methods

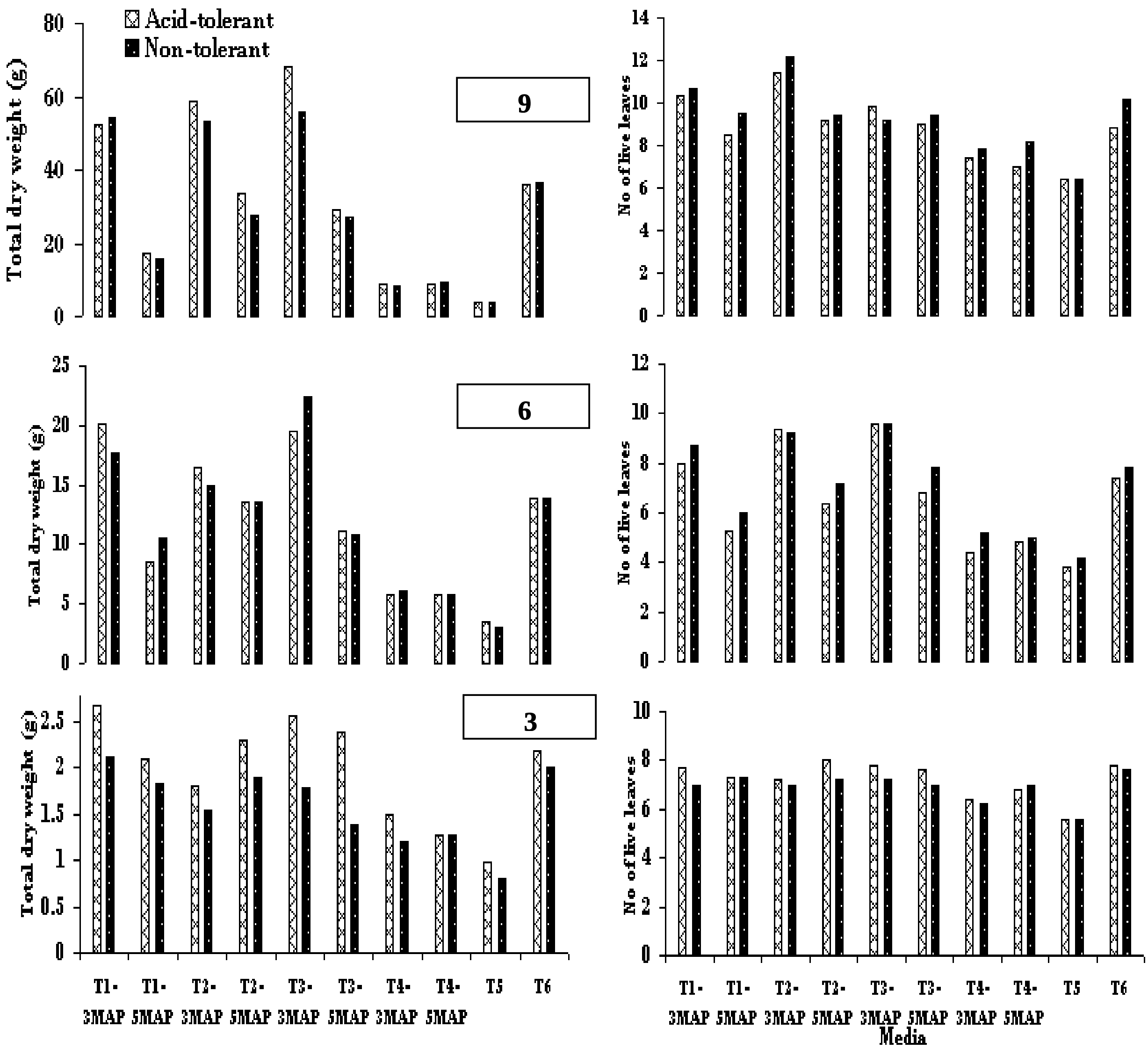

Figure 3: Effect of substrate on number of live leaves and total dry matter accumulation of two maize varieties at 3, 6 and 9 weeks after planting. *Media: see Table 1 for detailed description.

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