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Full Length Research Paper

Effect of organic and inorganic fertilizers on nutrient concentrations in plantain (Musa spp.) fruit pulp

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The number of fruits per bunch and nutritional quality of the fruits are important horticultural and breeding selection indices in *Musa* improvement programs. Three plantain hybrids ('30456-3', 'PITA 14' and '29525') and a landrace genotype, 'Agbagba', were evaluated for response to organic and inorganic fertilizers in a 4 x 3 factorial in a randomized complete block design (RCBD) in triplicate. Fruit parameters measured were fruit weight, edible proportion and pulp dry matter content; also, the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), iron (Fe) and zinc (Zn) in fruits were determined. These parameters were measured in two cropping cycles, the plant and ratoon crops, respectively. The hybrid, '29252' had the highest pulp N, K, Ca, Fe and Zn concentrations in the plant crop. In the ratoon crop, N and P were highest in '29525' and '30456-3', while the concentrations of the other nutrients did not differ among the genotypes. The landrace, 'Agbagba', produced the heaviest fruits, accumulated the highest pulp dry matter and fresh edible proportion in both crop cycles. Although in the plant crop, the fertilizer treatment did not affect most of the pulp nutrient concentrations, the P concentration decreased by 14.29 and 118.18%, respectively when inorganic fertilizer and poultry manure was applied. The N, K and Zn concentrations, respectively, increased by 6.45, 14.55 and 62.50% with inorganic fertilizer application, while all the nutrient concentrations were lowest when no fertilizer was applied. The fresh fruit weight, pulp dry matter content and fresh edible proportion were highest when poultry manure was applied.

Keywords: Plantain, genotype, fertilizer, pulp nutrient concentration, poultry manure.

INTRODUCTION

Plantain fruits remain one of the important sources of food energy and basic nutrients for proper nutrition of man. They can either be consumed unripe (roasted, boiled or processed into flour) or ripe (eaten fresh or fried), hence they are important staple foods for rural and urban consumers in the humid tropics and also serve as source of rural income, particularly areas where smallholders produce them in some compound or home gardens (Chandler, 1995). The proximate analysis and mineral concentrations in plantain fruits had earlier been elucidated by Yomeni et al. (2004), Adeniji et al. (2007) and Baiyeri et al. (2009). Presently, agricultural research is focusing on breeding food crops for improved macro- and micro-nutrient contents and quality (Hillocks, 2011; Aluru et al., 2008; Welch and Graham, 2004). These nutrients fortify food crops with adequate nutritional requirements for humans and livestock. Crops that have more micronutrients have been successfully bred by scientists through a process called biofortification (Ball, 2008). Irrespective of the variety, crop yield is a direct product of the resources available in the environment, the fraction of those resources captured by the crop, the effectiveness of the crop in converting captured resources into dry matter and the fraction of the dry matter partitioned to harvestable yield (Bidinger et al., 1996). Therefore, the ability of the crop to absorb

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nutrients from the soil plays a vital role in the nutritional composition of any food crop. Kannaiyan (1999) reported that the nutrient supply system of the soil, which is either through the native or applied sources (fertilizers), to a very large extent, governs the yield and uptake of nutrients by crops.

The rapid loss of soil fertility caused by intense rainfall, rapid mineralization (Uduma and Eka, 2006), unsustainable nature of cropping system due to dense population, erosion, volatilization and immobilization (Law-Ogbomo and Remison, 2008) is a common characteristic of most soils in the southeastern zone of Nigeria. This had necessitated the regular application of fertilizers, especially of organic sources. The availability and uptake of the nutrients from these fertilizers are very important if heavy bunches and fruits of plantain with high dry matter accumulation are to be produced.

The determination of the nutrient content of plant via leaf or tissue analysis is important in understanding the response of the plant to different nutrient quality levels. This is a very practical and useful technique for fruit trees and long duration crops (Rashid, 1996). Earlier work on plantain analysis was based on the leaves, roots and pseudostems. Among the new plantain derived tetraploid hybrids that were recently developed and released by International Institute of Tropical Agriculture (IITA), 'PITA 14', 29525' and '30456-3' had been reported to be high yielding, early maturing, ratooning faster and black sigatoka disease resistant, and tolerant varieties (Ndukwe et al., 2011; Ortiz and Vuylsteke, 1998). But there is dearth of information on their pulp nutrient concentrations, especially in response to fertilizer application, as *Musa* spp. generally require high amounts of nutrients and also following the findings of FAO (1981) that soil fertility management is one of the crop management practices that will sustain the yield of new cultivars in farmers' fields. The analysis of the pulps of these hybrids in comparison with the local variety will not only provide information on their nutrient concentrations but also the relative proportion of the different nutrient elements that are consumed.

Thus, the objective of this study was to evaluate the pulp nutrient concentrations of four plantain genotypes as influenced by organic and inorganic fertilizer application.

MATERIALS AND METHODS

The field trial was carried out for two crop cycles (June, 2006 to June, 2008) at the high rainfall station of the International Institute of Tropical Agriculture (IITA), Onne in Southeastern Nigeria (4°43´N, 7°01´E; 10 m above sea level). The station has an annual unimodal rainfall of 2400 mm and it is characterized by an ultisol derived from coastal sediments. It is located in a degraded rainforest swamp area. The site also has an average daily temperature of about 27°C and solar radiation of 14 MJm^{-2} (Ortiz et al., 1997). Table 1 shows the meteorological data of the experimental site during the study.

The experiment was a 4 x 3 factorial in a randomized complete block design (RCBD) and comprised four plantain genotypes ('PITA 14', 29525', '30456-3' and 'Agbagba') and three fertilizer treatment types (no fertilizer, poultry manure and inorganic fertilizer) replicated three times. Poultry manure was applied at 20 t/ha, while the inorganic fertilizer was applied as urea (300 kg/ha nitrogen) and muriate of potash (550 kg/ha K_2O) as recommended by Swennen and De Langhe (1985). The result of previous soil analysis showed that phosphorus (49.10 mg/kg) was already in high concentration. Therefore, phosphatic fertilizer was not used in this study. The inorganic fertilizer was applied in six-split doses per crop cycle, while the organic fertilizer was in half dose. The poultry manure was applied at planting and the remaining as top dressing, six months after planting (Ndukwe et al., 2009a). 'PITA 14' is a tetraploid plantain-derived hybrid of IITA characterized by high yield, black sigatoka disease resistance, short stature and faster cycling (Ortiz and Vuylsteke, 1998). The genotypes, '29252' and '30456-3' are newly selected plantain-derived hybrids of IITA. Both of them tolerate black sigatoka disease and relatively produce heavy bunches (Ndukwe et al., 2009b). 'Agbagba', is a Nigerian plantain landrace, most widely cultivated but highly susceptible to the leaf streak disease (black sigatoka disease) caused by *Mycosphaella fijiensis*.

The plants were grown for two consecutive cropping cycles (plant and the first ratoon crops). The experimental site was manually slashed with machete and the grasses were not burnt. Planting holes measuring 40 x 40 x 40 cm in dimension were dug. Composite soil samples from ten different points at depths of 0 to 15 cm and 15 to 30 cm were collected prior to planting for routine physicochemical analysis as described in AOAC (1990). The physicochemical property of the poultry manure was also analyzed (Table 2). Micro-propagated suckers were planted in the holes and spaced 3 m between rows and 2 m within rows. Each plant received 15 g of Furadan 5G to control plantain weevil (*Cosmopolites sordidus*) and root-knot nematodes (Obiefuna, 1984). One follower-sucker was maintained after flowering as the ratoon crop. At every four weeks, desuckering was repeated. 'Round Up', a systematic herbicide was used for weed control and bunch-bearing plants were propped against wind damage.

At maturity, bunches were harvested and the fresh weight was taken. The representative samples of the fresh fruits were weighed. The fresh peel and pulp from the middle fruit of the second hand were also weighed separately. The fresh edible proportion of the fruit which is the proportion of the fruit that is consumed was then derived from the fresh pulp and peeled as follows: (weight of fresh pulp/weight of fresh fruit) × 100.

The pulp fraction was oven-dried with Forced-Air Sanyo Gallenkamp moisture extraction oven at 70°C for 48 h (to obtain constant weight) for the dry weight measurement (pulp dry matter content). The pulp dry samples were also milled to pass through 0.2 mm sieve using Thomas Wiley Hammer Mill. The nitrogen, phosphorus, potassium, calcium, iron and zinc concentrations were determined following the standard procedures as recommended by AOAC (1990). The protein content was estimated by multiplying the nitrogen concentration by the conversion factor of 6.25 (Cioccia et al., 1995).

Each of the crop cycle was analyzed separately. All the data collected were subjected to the analysis of variance using GENSTAT Discovery 3 Release 7.5DE (GENSTAT, 2007). The treatment means were compared and separated using Fishers least significant difference (F-LSD) at 5% probability level.

RESULTS

Meteorological data of the study area

The annual rainfall amount during the first and second cropping cycles was above the critical annual amount

Table 1. The weather conditions at IITA High-rainfall station, Onne, from July 2006 to June 2008.

Year	Month	Total rainfall (mm)	Temperature (°C)	Relative humidity (%)
2006	July	480.60	25.65	80.80
	August	484.90	25.90	81.30
	September	688.50	25.30	83.55
	October	275.70	26.15	74.00
	November	0.00	28.40	67.90
	December	0.00	28.20	63.35
2007	January	0.00	27.80	59.30
	February	43.60	29.15	70.25
	March	184.50	28.80	73.00
	April	384.40	27.50	78.85
	May	392.40	27.30	78.55
	June	559.30	25.90	84.20
	July	313.70	26.10	84.10
	August	262.00	26.20	84.35
	September	484.70	26.10	83.65
	October	174.90	26.85	82.40
	November	384.60	42.25	82.55
	December	71.80	27.60	75.40
2008	January	35.30	26.50	69.70
	February	0.60	26.15	67.35
	March	43.90	25.40	78.25
	April	314.10	26.10	78.25
	May	114.70	25.35	80.90
	June	227.80	25.15	84.45

Table 2. Physicochemical properties of experimental soil and poultry manure.

Physicochemical property	Soil (0-15 cm)	Poultry manure
Physical properties		
pH (H_2O)	5.30	-
Organic carbon (%)	1.37	28.40
Organic matter (%)	2.40	49.80
Sand (%)	76.67	-
Silt (%)	8.00	-
Clay (%)	15.33	-
Chemical properties		
Nitrogen (g/kg)	1.30	15.60
Phosphorus (mg/kg)	49.10	14.00
Potassium (g/kg)	1.40	17.90
Calcium (cmol/kg)	2.06	3.76
Iron (mg/kg)	150.13	313.22
Zinc (mg/kg)	4.26	11.36
Magnesium (cmol/kg)	0.13	0.41
Sodium (mg/kg)	0.33	-
Copper (mg/kg)	0.72	-
Manganese (mg/kg)	27.01	-
Effective cation exchange capacity (ECEC) (cmol/kg)	3.19	-
Exchangeable acidity (cmol/kg)	0.20	-

Table 3. Effect of genotype on pulp nutrient concentrations and some fruit traits in the plant and ratoon crops.

Genotype	N	P	K	Ca	Protein	Fe	Zn	Fresh edible proportion	Pulp dry matter content (%)	Fruit weight (g/plant)
	g/kg					mg/kg				
Plant crop										
'29525'	0.84	0.10	1.72	0.10	5.24	20.94	0.96	53.01	26.90	89.30
'30456-3'	0.62	0.45	1.35	0.06	3.87	18.32	0.77	51.22	32.60	175.50
'Agbagba'	0.55	0.08	1.13	0.03	3.47	17.39	0.80	57.62	40.00	239.00
'PITA 14'	0.72	0.10	1.35	0.06	4.50	18.47	0.88	57.01	34.30	119.30
$LSD_{0.05}$	0.11	0.01	1.18	0.04	0.66	ns	ns	2.52	6.48	40.26
Ratoon crop										
'29525'	0.69	0.08	1.21	0.04	4.33	11.04	0.91	54.75	28.49	152.70
'30456-3'	0.60	0.10	1.21	0.04	3.77	9.38	0.79	51.47	30.49	186.20
'Agbagba'	0.54	0.07	1.08	0.04	3.39	9.54	0.75	62.32	38.86	312.60
'PITA 14'	0.62	0.09	1.15	0.04	3.86	11.56	0.84	60.14	35.81	173.60
$LSD_{0.05}$	0.04	0.01	ns	ns	0.28	ns	ns	1.78	1.18	27.80

ns, not significant.

(1,200 mm) required for plantain cultivation, although the distribution pattern in each crop cycle varied. No rainfall was experienced from November 2006 till January 2007 (first crop cycle). However, in the second crop cycle, the rainfall amounts from December 2007 till March 2008 were relatively small (ranged from 0.6 to 71.8 mm). The average temperature was 27°C. The relative humidity was relatively high (above 70%) except in those months when the rainfall amounts were reduced.

Effect of genotype

The variability among the plantain genotypes with respect to the pulp nutrient concentration levels showed that in the plant crop, '29525' accumulated the highest concentrations of N, K, Ca, Fe, Zn and protein, while P concentration was highest in '30456-3' (Table 3). In the ratoon crop, the pulp N and protein were highest in '29525' fruit pulp, while P concentration was highest in '30456-3'. However, the concentrations of K, Ca, Fe and Zn were statistically similar among the genotypes in the ratoon crop. The quantity of pulp N, P, K, Zn and protein accumulated by 'Agbagba' were lowest in the two crop cycles. The hybrids accumulated higher protein than the landrace, 'Agbagba'.

'Agbagba' produced the heaviest fruits (239.00 and 312.60 g/plant) and accumulated highest pulp dry matter (40.00 and 38.86%) and fresh edible proportion of the fruit (57.62 and 62.32%) in the plant and ratoon crops, respectively. Among the hybrids, in both crop cycles, the heaviest fruits were from '30456-3', while the pulp dry matter and fresh edible proportion were greater in 'PITA 14'. The genotype, '29525' however, had the lowest fruit weight and pulp dry matter content while fresh edible proportion was lowest in '30456-3'.

Effect of fertilizer type

In the plant crop, there was no significant effect of fertilizer type on pulp nutrient concentrations and other fruit characters, except that P concentration was highest with no fertilizer and least with organic fertilizer application (Table 4). In the ratoon crop, the N, K, Zn and protein contents significantly increased ($P < 0.05$), respectively, by 6.45, 14.55, 62.50 and 6.22% with the application of inorganic fertilizer, while the P concentration was highest when poultry manure was applied. However, when there was no fertilizer application (the control), the pulp N, P, K and Zn concentrations were lowest while the pulp concentrations of Ca and Fe were similar among the fertilizer treatment.

Table 4. Effect of fertilizer type on pulp nutrient concentrations and some fruit traits in the plant and ratoon crops.

Fertilizer type	N	P	K	Ca	Protein	Fe	Zn	Fresh edible proportion	Pulp dry matter content (%)	Fruit weight (g/plant)
	g/kg					mg/kg				
Plant crop										
Control	0.66	0.24	1.32	0.05	4.10	18.71	0.82	54.80	35.10	155.70
Inorganic	0.72	0.21	1.41	0.09	4.52	18.08	0.93	62.60	31.50	144.80
Organic	0.67	0.11	1.44	0.05	4.18	19.55	0.80	54.70	33.80	166.70
$LSD_{0.05}$	ns	0.01	ns	ns	ns	ns	ns	ns	ns	ns
Ratoon crop										
Control	0.62	0.08	1.10	0.04	3.86	9.60	0.64	57.70	33.93	198.90
Inorganic	0.66	0.08	1.26	0.04	4.10	11.86	1.04	55.77	32.67	196.70
Organic	0.57	0.09	1.13	0.03	3.56	9.68	0.78	58.04	33.63	223.20
$LSD_{0.05}$	0.04	0.01	0.09	ns	0.24	ns	0.17	1.54	1.02	ns

ns, not significant.

Table 5. Crop cycle effect on the pulp nutrient and protein concentrations and some fruit traits.

Crop cycle	N	P	K	Ca	Protein	Fe	Zn	Fresh edible proportion	Pulp dry matter content (%)	Fruit weight (g/plant)
	g/kg					mg/kg				
Plant crop	0.68	0.19	1.39	0.06	4.25	19.28	0.87	56.80	33.47	155.90
Ratoon crop	0.61	0.09	1.16	0.04	3.84	10.45	0.83	57.10	33.46	206.30
$LSD_{0.05}$	0.04	0.01	0.07	0.02	0.24	1.76	ns	ns	ns	15.88

ns, not significant.

The fresh edible proportion, pulp dry matter content and fruit weight were statistically similar among the fertilizer types in the plant crop. In the ratoon crop, plants that received poultry manure or no fertilizer accumulated higher pulp dry matter and fresh edible proportion than those in which inorganic fertilizers was applied.

Crop cycle effect

The pulp concentrations of all the nutrient elements and protein were higher in the plant than in the ratoon crop. The fruit weight and pulp dry matter content however were higher in the ratoon than in the plant crop but the fresh edible proportion were statistically similar in both crop cycles (Table 5).

DISCUSSION

The hybrids ('29525', '30456-3' and 'PITA 14') accumulated greater quantity of all the mineral nutrients than the landrace, 'Agbagba'. The results of Baiyeri et al. (2009) showed a similar trend. The hybrids may have better rooting system that enhanced better nutrient absorption capacity from the soil. These results conformed with the recent research focus on biofortification which aimed at addressing micronutrient deficiencies through the development or breeding of nutritionally enhanced (biofortified) staple food crops to improve food security, production and quality of life challenges (CIAT and IFPRI, 2006).

Adeniji et al. (2007) also reaffirmed in a separate study that new plantain hybrids were superior to the 'Agbagba' plantain in nutritional value, as evidently observed in this study.

The P concentration of the pulp in the plant crop decreased with external inputs of P. The information obtained from the result of the soil analysis (Table 2) showed that P concentration in the soil was relatively high (above the critical level for plantain production) (Ibedu et al., 1988). Low potential mobility of phosphorus ion and immobilization may have resulted within the rhizosphere of the control and organic manured plants, respectively; consequently, making P unavailable for mining and subsequent distribution to the sinks. The study of Cole et al. (1953) revealed that the precipitation of phosphorus is likely a more important mechanism of phosphorus removal from the soil solutions at higher concentration. In an acidic soil, like the soil of this study, aluminium and iron will generally precipitate phosphorus by the formation of complexes (chelates) in their reactions with P (Sanchez, 2007). The poultry manure may not have decomposed adequately to release its nutrients in the plant crop. Temporary immobilization (by micro-organisms for their cell growth and development) of phosphorus (and the three other elements- nitrogen, carbon and sulphur that make up cell protoplasm) in the manure and later release of P, after nutrient uptake and redistribution to the bunch may have occurred in the plant crop (FAO, 2005). This may be substantial as the values for fresh edible proportion of the fruits, pulp dry matter content and fruit fresh weight in plants that received poultry manure significantly did not even vary for either those that received inorganic fertilizer or no fertilizer, as may have varied if the manure had mineralized at the needed period. The fixation of P as a result of acidic environment together with the immobilization of some of the organic P by the activities of microorganisms in the poultry manure, may have accounted for the decreased P concentration with poultry manure in the plant crop. However, plantain pulp in the ratoon crop accumulated greater P when poultry manure was applied. The subsequent proper mineralization of the applied poultry manure could have increased the soil concentration and availability of P in the second crop cycle since poultry manure had been noted to contain high organic matter (49.80% was gotten from the poultry manure utilized in this study) which had been observed more commonly to hinder P sorption, thereby enhancing the availability. The humic acids and other organic acids in the organic matter often reduce P fixation through the formation of complexes with iron, aluminium, calcium and other cations that could have reacted with P to form complexes (Nagarajah et al., 1970). This could be the reason why the pulp P concentration increased with fertilizer application, especially organic fertilizer (poultry manure) in the second crop cycle (first ratoon crop).

The K concentration was highest followed by N and then Ca concentrations. The lowest was the Zn concentration. This agrees with earlier findings of Lahav and Turner (1983) and Lahav (1995). These authors established that K is removed in far greater quantities, by *Musa* species than other elements, followed by N and then by Ca. In addition, *Musa* spp. have a high demand of N and particularly K, which enhances high bunch and fruit dry matter (Robinson, 1996).

The highest concentration of pulp K was observed when inorganic fertilizer was applied to the plants in the ratoon crop. More nutrients may have been released by this inorganic fertilizer. Inorganic fertilizer is known to potentially release its nutrients faster than any organic manure because the nutrients are readily available and undergo rapid decomposition. Although the residual nutrients from the organic manure applied in the plant crop should have been available in the ratoon crop, the rapid release of nutrients from the inorganic fertilizer following its six-split applications, in comparison with the poultry manure, might have coincided with the period of nutrient redistribution to the bunches. Adequate availability of K enhances the translocation of most other nutrients (Robinson, 1996). This accounted for the greater concentration of most of the other nutrients such as N, Zn and Fe in the pulps when plant received inorganic fertilizer.

Ndukwe et al. (2009a) reported that fresh edible proportion of fruit and the pulp dry matter content is closely associated with the whole fruit weight. This explaines the higher pulp dry matter and fresh edible proportion of 'Agbagba' that had the highest whole fruit weight. Adeniji et al. (2006) showed that higher fruit edible proportion and dry matter content meant higher proportion of fresh fruit for consumption and processing as well as higher flour yield per unit weight of fresh fruit, respectively. Ndukwe et al. (2011) observed that 'Agbagba' genetically has bigger fruits than 'PITA 14', '29525' and '30456-3' (the newly selected hybrids) but big fruits may not necessarily translate to high pulp nutrient concentration as evidenced in the result gotten from this study, where all the newly selected hybrids gave higher pulp nutrient contents than the 'Agbagba'. The hybrids gave best quality in terms of mining nutrients to the most consumable part of the plant (pulp). In 'Agbagba', some proportions of the nutrients may have also been translocated to the peels. In a separate study (Ndukwe et al., 2009a), the peel dry matter of 'Agbagba' was found to be heavier than the hybrids ('PITA 14', '29525' and '30456-3'). The quality of staple foods, and not quantity, had recently formed the research drive of scientists so as to forestall malnutrition, especially within resource poor children and adults. These hybrids, especially 'PITA 14' and '29525' could therefore serve as good alternatives to 'Agbagba', a Nigerian local cultivar.

It was also observed that among the hybrids, '30456-3' genetically possess thickest peel with relatively big proportion of pulp. These traits may have resulted in the heaviest fruits attributed to it in the two cropping cycles yet 'PITA 14' accumulated the highest pulp dry matter. It could be that '30456-3' accumulates high moisture in the pulp which in conjunction with the thicker peel, might have increased the fresh fruit weight with lowest pulp dry matter accumulation, as obtained in this study.

One would have expected that the pulp nutrient and protein concentrations in the ratoon crops would be higher than those of the plant crop because of the nutrients that could have recycled from the decayed tissues of the plant crop. However, the reverse was the case. The pulp dry matter increased significantly in the ratoon crop, thus there could probably have been a dilution effect on the nutrients. The pulp dry matter might have increased in the ratoon crop without a commensurate change in the amount of pulp nutrient resulting in the reduction of the nutrient concentrations.

This is possible because the fresh fruits (which comprise proportions of dry matter and water) were heavier in the ratoon than the plant crop.

Conclusion

The outcome of the research work shows that the plantain hybrids possess enough nutrients to meet the daily requirements of man and his livestock. It was also found that the application of poultry manure significantly increased the pulp nutrient, protein contents, fruit weight, fresh edible proportion and pulp dry matter content of the genotypes, especially in the hybrids '29525' and 'PITA 14'. Therefore, the production and consumption of these hybrids could be increased with the guarantee that they will be greatly useful in meeting the nutritional requirements of man and livestock. These hybrids may serve as good alternatives to the local cultivar, 'Agbagba' vis-à-vis their high nutritional qualities, hence greatly reducing malnutrition. Besides, it was evident that the nutritional quality of the fruit pulp was positively respon-sive to the application of both organic and inorganic fertilizers.

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