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IMPACT OF ORGANIC AND INORGANIC FERTILIZERS ON THE POSTHARVEST FRUIT QUALITIES OF FOUR *MUSA* (AAB SUB-GROUP) GENOTYPES IN SUB-HUMID ZONE OF NIGERIA

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ABSTRACT

The postharvest fruit quality responses of four plantain genotypes (‘29525’, ‘30456-3’, ‘PITA 14’ and *Agbagba*) to fertilizer types (inorganic fertilizer, organic fertilizer and control (no fertilizer) were evaluated in 2006/2007 and 2007/2008 cropping seasons. The experimental design was a 4 x 3 factorial in randomized block design with three replications. There were significant differences ($P<0.05$) among the genotypes for fruit weight, edible proportion of fruits, pulp and peel dry matter contents, pulp colour rating and fruit ripening pattern. The mean over the two cycles showed that *Agbagba* had the heaviest fruit, edible proportion of fruits, pulp and peel dry matter contents. *Agbagba* and ‘PITA 14’ had the highest degree of lightness, redness and yellowness while fruit shelf life was longest in ‘29525’. The fertilizer type was not significant for most of the traits except edible proportion of fruits, pulp dry matter content and pulp degree of yellowness. Fertilizer types reduced the pulp degree of yellowness. The heaviest fruits and longest fruit shelf life were observed when organic fertilizer (poultry manure) was applied to *Agbagba* and ‘29525,’ respectively.

KEYWORDS: Plantain, hybrid, postharvest fruit quality, fertilizer and pulp colour,

INTRODUCTION

Plantain is a common staple food for many people in the developing countries as well as a popular fruit worldwide (Englberger *et al*., 2006). World production of plantain is about 100 million metric tons in 2005 (FAO, 2006). Postharvest research is concerned with maintaining crop quality until the crop reaches the consumer. It identifies quality parameters that are important to farmers, retailers and consumers as with the environmental factors that affect the quality (Ferris, 1998). The quality of plantain fruits is increasingly important for retailers who tend to look for more definitive assessment criteria (Caussiol, 2001). In Ghana, Nigeria and Honduras, consumers have developed distinct correlations between colour and the overall quality of specific product (Dadzie and Orchard, 1997).

The quality of any agricultural produce is pre-determined in the field (Wills *et* al., 1998), which suggests that poor quality fruits before harvesting can never be improved by postharvest treatments (Seymour *et al*., 1993). Costa *et al*. (2006) reported that nutrition, among other factors, is a critical determinant of quality fruits at harvest. Therefore, one of the ways of increasing the nutrient status is by boosting the soil nutrient content either with the use of organic materials such as poultry manure, animal waste and use of compost or with the use of inorganic fertilizers (Dauda *et al*., 2005). Some investigations have shown that adequate nutrient results in the production of high quality fruits and better nutritious plants (Mohammed, 2002; Ani and Baiyeri, 2008).

The development and dissemination of disease resistance, high yielding varieties of plantain and banana by various research institutions have evolved over the years (Adeniji *et al*., 2006). This has resulted in the selection of genotypes that combine multiple resistances with good horticultural attributes (Vuylsteke *et al*., 1997). This study was therefore carried out to determine the variation in some postharvest fruit qualities by four plantain genotypes as influenced by organic and inorganic fertilizers.

MATERIALS AND METHODS

The experiment was conducted at the International Institute for Tropical Agriculture (IITA), high rainfall station, Onne, Rivers State, Nigeria. The site is located on latitude 04° 43´N, longitude 07° 01´E and 10 m altitude. The area has a unimodally distributed annual rainfall of about 2,400 mm. The station is located in a degraded rainforest swamp area, characterized by an ultisol derived from coastal sediments. The soil has low pH and low cation exchange capacity (Ortiz *et al.*, 1997). The location is also associated with high relative humidity with average values ranging from 78% in February to 89% in July and September (Ortiz *et al.*, 1997). The soil characteristics of the experimental site and the organic fertilizer (poultry manure) used for the study are as presented in Table 1.

Two newly developed plantain hybrids (‘29525’ and ‘30456-3’) by International Institute for Tropical Agriculture (IITA), ‘PITA 14’ (IITA adopted and most stable plantain hybrid) and a Nigerian local plantain, *Agbagba* (as a control) were used for the investigation.

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Table 1: Physicochemical properties of the experimental site and poultry manure sample utilized for the study

Physicochemical properties	Soil	Poultry manure
Physical properties		
pH (H_2O)	5.30	6.23
Sand (%)	76.67	nd
Silt (%)	8.00	nd
Clay (%)	15.33	nd
Textural class	Sandy loam	
Chemical properties		
Organic carbon (%)	1.37	nd
Nitrogen (g/kg)	1.3	15.6
Phosphorus (mg/kg)	49.10	14.0
Potassium (g/kg)	1.4	17.9
Calcium (cmol/kg)	2.06	3.76
Magnesium(cmol/kg)	0.13	0.41
Sodium (cmol/kg)	0.33	nd
Exch. Acidity (cmol/kg)	0.20	nd
ECEC (cmol/kg)	3.19	nd
Zinc (mg/kg)	4.26	11.36
Copper (mg/kg)	0.72	nd
Manganese (mg/kg)	27.01	nd
Iron (mg/kg)	150.13	313.22

nd = Not determined

The postharvest study was conducted in the postharvest laboratory of IITA, Onne, Nigeria with an average ambient temperature of (28 ± 1)°C and a relative humidity ranging between (96-98)%. The experimental design was a 4 x 3 factorial in randomized complete block design (RCBD) with three replicates. This was made of four genotypes (‘29525’, ‘30456-3’, ‘PITA 14’, *Agbagba*) and three fertilizer types (organic fertilizer, inorganic fertilizer, no fertilizer (control)) in twelve treatment combinations. Each plot was a single row of five plants. Urea (300 kg/ha nitrogen) and muriate of potash (550 kg/ha K_2O) applied in six-split doses were used as inorganic fertilizers as recommended by Swennen and De Langhe (1985) while 20 t/ha of poultry manure was used as organic fertilizer. Half dose of the poultry manure was applied at planting and the remaining applied as top dressing at six months after planting. The plants were spaced at 3 m x 2 m, giving a planting density of 1667 plants/ha. Other crop management practices were carried out following the standard recommendations of Swennen (1990).

Fruits were sampled for two cropping cycles (plant and ratoon crops) when the bunches matured and at least one fruit on the first nodal cluster has started ripening (Swennen, 1990). From each harvested bunch, fruits were sampled from the second proximal hand per bunch according to Baiyeri and Ortiz (2000) and Caussiol (2001) and used for the ripening test. The fruit weight, length and circumference were measured immediately after harvest. The weights of the pulp and peel were determined after peeling the fresh fruits. The edible proportions of the fruits were calculated as the ratio of the pulp fresh weight and fruit fresh weight. Both pulp and peel fractions were oven dried at about 70°C for (24-36) hours to determine the dry matter contents, which was later calculated as the ratio of the dry weights and their fresh weights (Baiyeri and Tenkouano, 2008).

The fruits were kept under ambient laboratory conditions and ripening was monitored using four ripening stages deduced from a specific chart (Baiyeri, 2005) (Table 2).

Table 2: Fruit peel colour chart utilized for identification of ripening changes for banana fruits

Ripening stage	Description of peel colour	Ripening physiological phase
1	Green	Pre-climacteric
2	Pale green	Pre-climacteric
3	Pale green with yellow tips	Onset of climacteric
4	50% yellow, 50% green	Climacteric
5	More yellow than green	Climacteric
6	Pure yellow, complete ripeness	Climacteric
7	Yellow with black coalescing spots	Onset of senescence
8	50% yellow, 50% black	Senescence
9	More black than yellow	Senescence
10	Completely black	Senescence

Adapted from Baiyeri (2005)

These include stages 1 (completely green), 4 (50% yellow, 50% green), 6 (complete ripeness) and 10 (completely black). The colour of the pulp was quantitatively determined with the aid of a hand-held Colour-Tec PCM/PSM^{TM} colour meter to estimate the β-carotene (pro-vitamin A) content in the second proximal hand of the bunch following the recommendations of Adeniji *et al*. (2006) and Adeniji and Tenkouano (2008). This instrument generates a set of values for a* (degree of redness), L* (degree of lightness) and b* (degree of yellowness). The corresponding values of a*, L* and b*, which represent the reflectance of the sample viewed by the sensor (as displayed by the colour meter) were compared to Colour-Tec^{TM} CIE LAB Colour Chart to ascertain the pulp colour magnitude. Strong and linear relationship has been observed to exist between either a* or b* values for plantain pulp colour and β-carotene content (Englberger *et al*., 2006).

The data collected were subjected to analysis of variance with GENSTAT 5.0 release 4.23DE Discovery Edition (GENSTAT, 2003) following factorial experiment in RCBD. Mean separation to determine the effects of genotype and fertilizer type was by least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Effect of genotype

Results in Table 3 showed that the landrace, *Agbagba* produced heavier fruits (an average of 275.00g) than the hybrids (which ranged from 121.00 to 130.85g) in the two cropping cycles. Baiyeri and Tenkouano (2007) observed similar results with *Agbagba* and some hybrids. Among the hybrids, '30456-3' had the heaviest fruits in both cycles (the average being 180.85g) although the weight in the ratoon crop was statistically similar to 'PITA 14'. The hybrid, '29525' had the lowest fruit weights in both cycles. There was also a variation in the pulp and peel dry matter and the fruit edible proportion of the genotypes in both cycles. The highest pulp and peel dry matter and edible proportion of fruits (only in the ratoon crop) were produced by *Agbagba*. The higher fruit weight of *Agbagba* may have contributed to its higher fruit edible proportion and pulp dry matter content than the hybrids. This confirmed the finding of Baiyeri *et al*. (1999) that triploid genotypes had higher dry matter content than the tetraploid hybrids. *Agbagba* is a triploid plantain while the hybrids are tetraploids. Higher fruit edible proportion and dry matter content may mean higher proportion of fresh fruit for consumption and processing as well as higher flour yield per unit weight of fresh fruit respectively (Adeniji *et al*., 2006). Similarly, higher peel

Table 3: Main effect of genotype on some fruit metric traits and plantain pulp colour rating

						Pulp colour rating		
Cropping cycle	Genotype	Fruit weight (g)	Fruit edible proportion (%)	Pulp dry matter (%)	Peel dry matter (%)	mL*	ma*	mb*
Plant crop	29525	89.30	52.700	26.90	9.72	69.55	1.75	38.02
	30456-3	175.50	52.80	32.00	8.94	72.33	3.23	38.20
	PITA 14	119.30	57.60	34.10	11.34	74.74	5.74	42.35
	Agbagba	239.00	66.30	40.20	12.30	73.60	2.29	42.43
$LSD_{0.05}$		40.26	ns	6.39	0.98	1.84	1.21	1.34
Ratoon crop	29525	152.70	54.75	28.70	10.63	67.99	0.66	37.89
	30456-3	186.20	51.47	30.58	9.20	72.00	4.35	39.17
	PITA 14	173.60	60.14	35.35	12.84	73.47	6.73	43.16
	Agbagba	312.60	62.32	39.35	13.57	71.55	3.03	44.35
$LSD_{0.05}$		27.80	1.78	1.15	0.58	1.53	2.13	1.06

mL* = Mean value for degree of lightness (ranges from black with a value of zero at the bottom of the axis to white with a value of 100 at the top of the axis); ma* = Mean value for degree of redness, with a negative value for green and a positive value for red; mb* = Mean value for degree of yellowness, with a negative value for blue and a positive value for yellow.

dry matter implies higher feed for most common domestic ruminant animals such as goat and sheep as utilized in the rural areas in Nigeria. Fruit edible proportion was similar among the genotypes in the plant crop. Among the hybrids, 'PITA 14' had the highest (58.87%) edible proportion of fruit while '30456-3' had the lowest (52.03%), with respect to the mean of the two cropping cycles. Also among the hybrids, 'PITA 14' accumulated the highest pulp and peel dry matter whereas '29525' had the lowest in these two parameters. The degree of lightness was highest for *Agbagba* and 'PITA 14' in the plant crop, while in the ratoon crop *Agbagba* and '30456-3' rated highest. The degree of redness was highest for *Agbagba* in the ratoon crop and similar for all the genotypes in the plant crop. *Agbagba* and 'PITA 14' rated highest for degree of yellowness in the plant crop but 'PITA 14' rated highest in the ratoon crop for degree of yellowness. The colour variations that were observed between the different genotypes implied that genotypic differences existed in the pigment composition or pulp browning potential (Tourjee *et al*., 1998). The degree of lightness and yellowness (indices for measuring the level of pro-vitamin A carotene content in the pulp of plantain) generally rated highest in *Agbagba* and 'PITA 14'. A similar result had been obtained with *Agbagba* and 'PITA 14' by Adeniji and Tenkouano (2008). Pulp degree of yellowness has a strong and linear relationship to β-carotene content (Englberger *et* al., 2006; Gajewski *et al*., 2008). However, '29525' rated lowest in all the pulp colour combination indices.

Fig.1 shows the main effect of genotype on the ripening pattern of plantain. Green life and complete ripeness were longest for '29525' and 'PITA 14' whereas *Agbagba* and '29525' stayed longest at complete ripeness. This suggests that '29525' and *Agbagba* could be safe with a longer storability when there is minimal mechanical injury, which could emanate from the softening of fruit peel. Also longer duration at full (complete) ripeness meant that the fruit could maintain market value for an appreciable number of days. Shelf lives were longest for '29525' and *Agbagba* but shortest in '30456-3' in the two cycles. The longer shelf life of '29525' and *Agbagba* meant higher potential utility. The number of days to senescence is a marker for duration of commercial usefulness. Baiyeri and Tenkouano (2007) reported longer green life and shelf life of some hybrids ('PITA 26' and 'PITA 21') over the landrace, *Agbagba*.

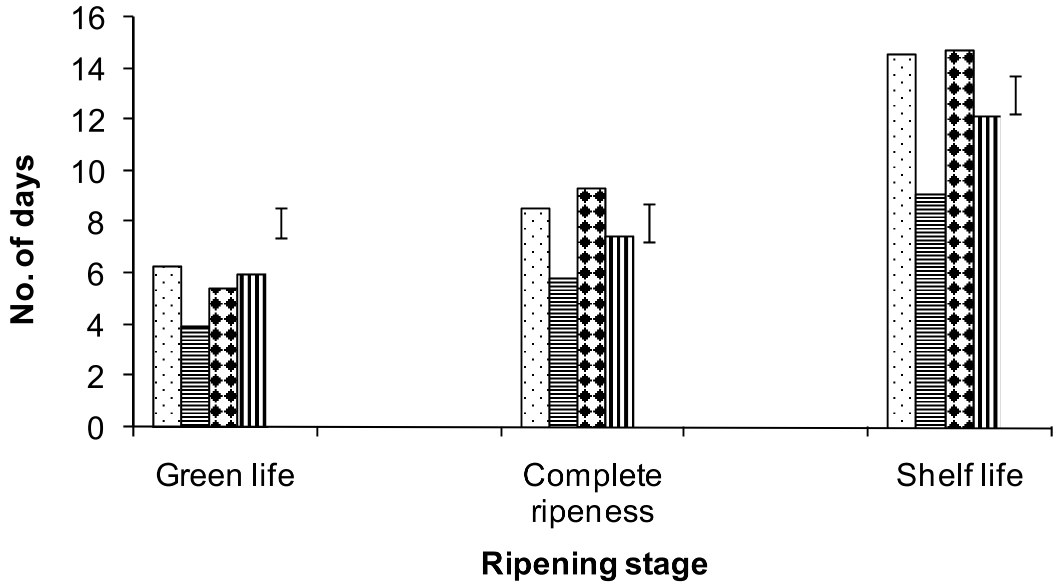

Fig. 1: Main effect of genotype on days to different ripening stages across two cropping cycles. Vertical bars represent $LSD_{0.05}$

29525 30456-3 Agbagba PITA 14

Effect of fertilizer types

Most of the postharvest fruit qualities did not vary among the fertilizer types except fruit edible proportion and pulp dry matter content in the ratoon crop as well as mean degree of yellowness in the plant crop (Table 4). In the ratoon crop, the fruit edible proportion and pulp and peel dry matter contents were higher for plants that received poultry manure or no fertilizer. The application of either organic or inorganic fertilizers reduced the degree of yellowness (an indicator for β-carotene in the pulps) of the fruits in the plant crop. Increased soil K increases nutrient uptake of K and P but decreases uptake of N, Ca, Mg and Cu. The fertilizers may have produced excess K which reduced the uptake of some nutrients including Ca, which is associated with yellow pulp of plantain (Robinson, 1996). The fruit ripening pattern did not vary among the fertilizer types in the two cropping cycles (Table 5).

Table 4: Main effect of fertilizer type on some fruit metric traits and plantain pulp colour rating

Cropping cycle	Fertilizer type	Fruit weight (g)	Fruit edible proportion (%)	Pulp dry matter (%)	Peel dry matter (%)	Pulp colour rating		
						mL*	ma*	mb*
Plant crop	Control	155.70	54.80	34.70	10.95	71.69	3.94	41.47
	Inorganic	144.80	62.20	31.30	10.07	72.70	2.82	39.66
	Organic	166.70	54.70	33.90	10.70	73.28	3.00	39.62
$LSD_{0.05}$		ns	ns	Ns	ns	ns	ns	1.16
Ratoon crop	Control	198.90	57.70	34.17	12.06	71.33	4.61	41.22
	Inorganic	196.70	55.77	32.75	10.80	70.79	3.47	41.52
	Organic	223.20	58.04	33.99	11.83	71.54	3.01	40.69
$LSD_{0.05}$		ns	1.54	0.99	0.51	ns	ns	ns

mL* = Mean value for degree of lightness (ranges from black with a value of zero at the bottom of the axis to white with a value of 100 at the top of the axis); ma* = Mean value for degree of redness, with a negative value for green and a positive value for red; mb* = Mean value for degree of yellowness, with a negative value for blue and a positive value for yellow.

Table 5: Main effect of fertilizer type on plantain ripening pattern in the plant and ratoon crops

	Plant crop			Ratoon crop		
Fertilizer type	Green life (days)	Complete ripeness (days)	Shelf life (days)	Green life (days)	Complete ripeness (days)	Shelf life (days)
Control	6.82	8.88	20.30	4.39	7.00	16.90
Inorganic	6.90	9.89	20.80	4.26	6.77	15.55
Organic	5.46	7.02	21.81	4.09	6.70	16.97
$LSD_{(0.05)}$	ns	ns	ns	ns	Ns	ns

Interaction effect

Genotype-by-fertilizer type interaction only influenced the fruit weight and fruit shelf life in the plant crop. *Agbagba* produced the heaviest fruits in either fertilized or no fertilized plots (Figs. 2 and 3). In the plots that received either organic or inorganic fertilizer, Agbagba and ‘304563’ produced similar and heaviest fruits than other genotypes. It was observed that although ‘30456-3’had the lowest fruit weight when it received no fertilizer yet there was an increase when it received either organic or inorganic fertilizer. This suggests that fruit weight is dependent on the genetic make up of a genotype and fertility status of the soil. The hybrid, ‘29525’ however, had the lowest fruit weight across the fertilizer types. The pulp colour rating was similar for the genotype and fertilizer type interaction. The application of either organic or inorganic fertilizer reduced the fruit shelf life of ‘29252’ and ‘PITA 14’. The reduction was greater with organic fertilizer application in ‘29525’ whereas the effect was similar for the two fertilizer types in ‘PITA 14’ and *Agbagba*. Fertilizer application however, increased the fruit shelf life of ‘’30456-3’ and *Agbagba* but there was no significant different between the organic and inorganic fertilizers. Cooper (1997) reported that the production of high quality fruit with a long shelf life is dependent upon the fertility of the soils.

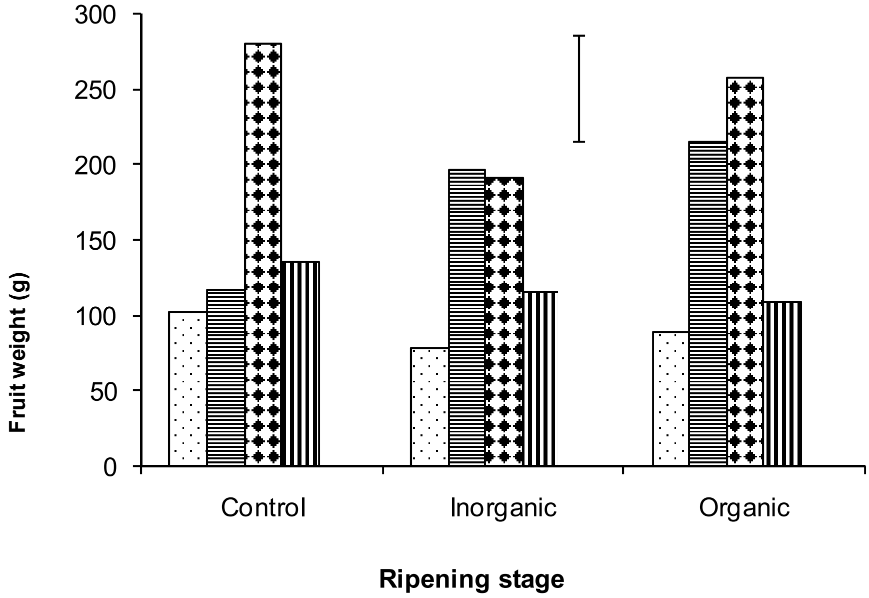

Fig. 2: Effect of genotype x fertilizer type interaction on fruit weight (g) in the plant crop. Vertical bar represents $LSD_{0.05}$

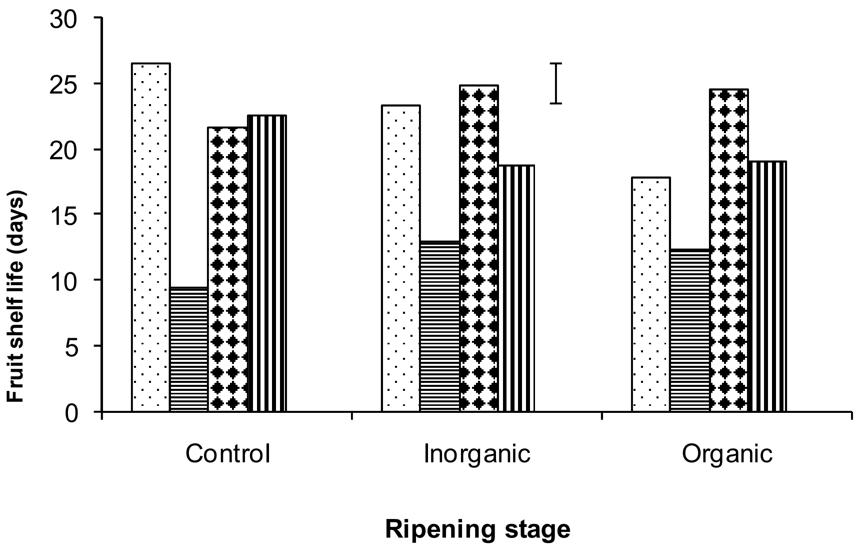

Fig. 3: Effect of genotype x fertilizer type interaction on fruit shelf life (days) in the plant crop. Vertical bar represents $LSD_{0.05}$

Effect of cropping cycle

The ratoon crops produced heavier fruits and higher peel dry matter content than the plant crop (Table 6). Baiyeri *et al*. (2005) obtained similar result, hence they reported that the plant and ratoon crops were different in their resource capturing as they existed in different environment. The ratoon crops may have had more assess to organic matter (decomposed plant parts of the plant crop) than the plant crop. This may have resulted to the higher fruit weight and peel dry matter content of the ratoon crop than the plant crop. However, the pulps from plant crop were lighter than those from the ratoon crops while the degree of yellowness was higher in the ratoon fruit pulps. Lighter pulp will give lighter flour which have higher consumer acceptance when the flour is processed into finished product such as instant fufu for diabetic patients. The higher degree of yellowness in the ratoon pulps may have been caused by the increase in nitrogen uptake as a result of the increase in soil-nitrogen concentration in the second cropping cycle (as a result of the retranslocation of organic matter from the plant crop). This increased nitrogen uptake may have resulted in greater synthesis of chlorophyll and the subsequent conversion of greater carotenoid pigment as ripening progresses.

The plant crop fruits stayed longer both at green life and days of full ripeness (Table 6). The plant crops was harvested during period of higher humidity (June to September) compared to the ratoon crops (December to March). Ortiz *et al*. (1997) had reported that the study location is associated with a relative humidity with average values ranging from 78% in February to 89% in July and September. Robinson (1996) reported that high humidity delays the internal synthesis of ethylene by preventing water loss. This explained why fruits harvested in the plant crop were observed to have longest green life and shelf life than those of the ratoon crop. The plant crop was similar to the ratoon fruits for edible proportion of fruits, pulp dry matter content, degree of redness and shelf life.

Table 6: Effect of cropping cycle on some of the postharvest fruit qualities

					Pulp colour rating			Ripening stage		
Cropping cycle	Fruit weight (g)	Fruit edible Proportion (%)	Pulp dry matter (%)	Peel dry matter (%)	mL*	ma*	mb*	Green life	Complete ripeness	Shelf life
Plant crop	155.90	56.80	33.47	10.57	72.50	3.31	40.15	6.53	8.71	13.08
Ratoon crop	206.30	57.10	33.46	11.56	71.24	3.70	41.13	4.26	6.84	12.22
$LSD_{0.05}$	15.88	ns	ns	0.37	0.82	ns	0.58	0.80	1.07	ns

mL* = Mean value for degree of lightness (ranges from black with a value of zero at the bottom of the axis to white with a value of
100 at the top of the axis); ma* = Mean value for degree of redness, with a negative value green and a positive value for red;
mb* = Mean value for degree of yellowness, with a negative value for blue and a positive value for yellow.

CONCLUSION

Poultry manure increased the shelf life of the genotype '29525' and produced the heaviest fruit with high fruit edible portion, and good pulp colour rating in *Agbagba*.

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