Postharvest Quality of Sweet Orange Fruits in response to Soil Amendments and Harvest time in South Western Nigeria

Odeyemi, O.M; Ajibola, O.W; Olubode O.O and Makinde, E.A.

Department of Horticulture, Federal University of Agriculture, Abeokuta, PMB 2240, Alabata, Ogun State. Nigeria

ABSTRACT

Nutrient management in sweet orange production has tremendous effects on fruit quality at the time of harvest. Two research trials were conducted between 2016 and 2017 production seasons to determine the effects of soil amendment and time of harvest on the physico-chemical properties of sweet orange fruits at maturity. Sweet orange trees were selected from an orchard managed under organic practices at the Federal University of Agriculture, Abeokuta, Nigeria. The soils were amended with poultry manure (PM) at: 0, 5, 10 and 15 t ha^{-1} in September, 2016 and March, 2017 at flowering stages. Physiologically- matured fruits were harvested during the first harvest season (March - April, 2017) and also during the second harvest season (August - September, 2017). Soil amendment of plants that received 10 t ha^{-1} PM produced fruits with significantly higher amount of total soluble solids (TSS) with reduced titratable acidity while fruits produced from plants fertilized with 15 t ha^{-1} had increased fruit weight, juice volume and vitamin C contents relative to fruits produced from plants that received 0 and 5 t ha^{-1} from first and second harvests. The lightness(L*) and yellowness (b*) values in peel colour of fruits harvested from plants that received 10 t ha^{-1} was improved compared with fruits that received 0 t ha^{-1} PM. Application of different rates of PM had no significant effects on juice colour of harvested fruits. Fruits from the first harvest had increased TSS values with reduced titratable acidity while fruits from second harvest had increased fruit weight, juice volume, vitamin C and L* in the juice colour. Sweet orange plants fertilized with 10 t ha^{-1} PM produced sweeter fruits while application of 15 t ha^{-1} PM produced heavier fruits with increased vitamin C and juice contents at first and second harvests.

Keywords: Orange fruits, harvest seasons, Poultry manure, plant nutrition, postharvest quality.

Corresponding author: bukie09@yahoo.com

INTRODUCTION

Sweet orange, *Citrus sinensis,* (Osbeck) is a member of the citrus group. The fruit is the most abundant citrus species produced for human consumption in the world (Reyes de Corcuera et al., 2014). Citrus fruits are a rich source of bioactive phenolic compounds and flavonones, possessing highly desired antioxidant properties (Mditshwa et al., 2018). They are considered as one of the major fruits consumed fresh or juiced due to its vitamin C content and anti-oxidant potential. Sweet orange is cultivated in the tropical and subtropical regions of the world with over 137 countries in the six continents (Ismail and Zhang, 2004). World leading producers of citrus include China, Brazil, India, Mexico, United States of America and Spain. Food and Agriculture Organization reported that Nigeria was ranked 9^{th} in the world, producing about 4.06 million tonnes of citrus with a world share of 2.8% harvested from 837,655 hectares (Factfish, 2018). Citrus is exotic to Nigeria but has become fully adapted and features in diverse traditional farming systems, with sweet orange constituting over 90% of citrus in Nigeria (Aiyelaagbe, 2001). A huge percentage from this total amount is destined for fresh fruit market. Agege 1 is a local land race variety of sweet orange that is very popular in South western, Nigeria because of its adaptability, good fruit quality, and high yield (Olaniyan and Fagbayide, 2007). According to Oluremi (2006), sweet orange production in Nigeria is significant, with heavy direct consumption primarily due to few and small capacity processing industries to convert to fruit concentrate and canned fruit. In sweet orange production, a balanced nutrient management through chemical fertilizers and or organic manures is the key for producing good quality fruit with desired storage ability (Ladaniya, 2008). Nutrient management could be carried out through soil and or foliar applications as the need arises. Fruit yield and quality of citrus are greatly influenced by N and K supplied in tropical soils because these nutrients are subjected to losses in the environment (Canterella et al., 2003). Inadequate mineral nutrition however, whether due to deficiency or excess may result to poor fruit quality. It is therefore necessary to achieve nutritional balance, in order to enable plants grow vigorously and produce fruits of desired quality. Organic manure increases soil nutrient status and enhances the soil biological, chemical and physical properties (Odeyemi, et al., 2015; Ibeawuchi et al., 2006). Poultry manure is an organic waste material consisting of faeces and urine from poultry (Makinde et al., 2016). It is considered to be relatively cheap and a good source of nitrogen for sustainable crop production, especially in the developing countries where inorganic fertilizers are no longer within the reach of poor-resource farmers due to its high cost (Rahman, 2004). In Nigeria, farmers have limited access to inorganic fertilizers because of their low production, availability, difficulty in procurement and poor distribution (Nigerian Institute of Social and Economic Research, 2003).

Previous reports on soil amendments in production of Agege 1 variety of sweet orange have majorly focused on growth and yield. However, there is paucity of information on the impacts of the poultry manure rates on the physico-chemical composition of fruits produced from Agege 1 with time of harvest in Nigeria. This study investigated the effects of different application rates of poultry manure as soil amendment on the postharvest quality of sweet orange fruit with harvest periods.

MATERIALS AND METHODS

Experimental Location

Nine year old sweet orange (cv Agege 1) trees budded on Cleopatra mandarin rootstock were superimposed with treatments at the organic fruit orchard situated at the Federal University of Agriculture Abeokuta, Nigeria (FUNAAB) (7˚ 5’ N, 3’ 20’E, 100 M above sea level) in September, 2016 and March, 2017. The area lies within the forest transition zone (Aiboni, 2001). The wet season usually extends from March to October while the dry season starts from November and ends in February.

Experimental Lay out

The sweet orange trees were spaced at 9.5 cm between rows and 3.5 cm within rows. A total of sixteen (16) stands of sweet orange trees were selected from the orchard for the experiment. The experiment was laid out in a randomized complete block design with four replicates.

Soil Sampling and Analysis

Soil samples from the orchard were obtained from samples randomly taken from various locations within the field. These were bulked together to obtain a composite sample from which a portion was analysed for physical and chemical properties to determine the initial nutrient status of the soil. Six core samples were taken from the top 30 cm of the soil to have a composite sample that was air-dried and grinded to pass through a 2-mm sieve. Particle size distribution was determined using the method of Gee and Or (2002); soil pH was evaluated in distilled water at 1:5 soil to water ratio using pH meter (Thomas 1996). Organic carbon was determined by Walkley–Black method (Nelson and Sommers, 1996) while total nitrogen was determined by Kjedahl method revised by Bremner (1996). Percentage organic matter was derived by multiplying % organic carbon by Broadbent factor of 1.72. Available phosphorus (P) by Bray-1 method was determined calorimetrically as described by Murphy and Riley (1962). Exchangeable acidity was determined by titration method (IITA 1997). Exchangeable bases were determined by extraction with neutral normal ammonium acetate at soil: solution (1:10). Sodium (Na^+) and potassium (K^+) in the extracts were determined by flame photometry while calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by Atomic adsorption spectrophotometer (AAS). Effective cation exchange capacity (ECEC) was determined by summation of total exchangeable bases and total acidity (Braize 1998).

Manure Application

Cured poultry manure (PM) was collected from birds raised under battery cage production system and applied at 0, 5, 10, and 15 t ha $^{-1}$. The PM was applied to the plants when the trees were flushing in ring form by digging a trench along the drip line and this was covered with top soil.

Orchard Maintenance

Weeding was carried out manually bimonthly from September, 2016 to October, 2017 with the use of a hoe.

Harvesting

Physiologically mature sweet orange fruits were harvested for the first harvest between March and April, 2017 and second harvest between August and September, 2017 to determine fruit quality from around the canopy. The harvested fruits from the different treatments were transported to the Laboratory of the Department of Horticulture from where they were sorted based on size, washed with clean water, air dried and weighed individually. All damaged fruits were removed from the lot.

Data Collection

Data were collected on the physical attributes and biochemical composition of the sweet orange for the first and second harvest. Fruit weight was determined by weighing individual fruits immediately after harvest with the use of a sensitive scale and readings were recorded appropriately in grams (g).

Laboratory Analysis

Juice volume (ml) was determined by peeling individual fruits then sliced into two portions. The juice content of both portions was squeezed out using a juice extractor (Binatone, JE-580). The juice was then filtered to remove the seeds and pulp. The juice volume was determined in a measuring cylinder calibrated in millilitres (ml). Total soluble solids (TSS) was determined by taking juice from fresh samples and placed on the reading surface of a hand held Brix Refractometer (model MFO32ATC). Reading was taken in degrees Brix. The pH of the juice samples were determined using a pH meter (Jenway, Model 3310, UK) previously standardized with buffers 4 and 7. Titratable acidity (TA) was determined by preparing 10 mls of fresh un-diluted juice, titrated with 0.1N sodium hydroxide in a beaker, using 2-3 drops of phenolphthalein as indicator to a pink colour end point. The titratable acidity was expressed as percentage citric acid. Vitamin C content of sweet orange fruits was determined using the titration method with the indicator dye 2, 6-dichloroindophenol to a faint pink end point. Peel and juice colours were evaluated using a colorimeter (Model CR-400/410, Konica Minolta, Netherlands) to measure colour parameters in L*, a*, b* which indicate the lightness, redness and yellowness of the fruits, respectively. Fruit firmness of individual fruits was determined using a hand-held penetrometer. Three independent force measurements were made at three equatorial points on each fruit, 90^o from each other (Barman et al., 2014).

Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) using GenStat Discovery Statistical package (GenStat, 2001) and means were separated using least significant difference at 5% level of probability.

RESULTS

Weather

Total rainfall recorded between October 2016 and October 2017 was 970.1 mm; monthly maximum temperature was between 28.2ºC and 35.9ºC while minimum temperature was between 21.1ºC and 27.6ºC. Relative humidity observed ranged between 55.3% and 77.4% (Table 1).

Soil Nutrient contents

The A horizon of the soil was an Oxic Paleudulf of the Iwo series with 86.8 % sand, 7.4 % silt and 5.8 % clay, with pH of 7.2. Nitrogen was very low, below the critical level of 0.25% recommended for citrus. Available P was high while exchangeable K was the minimum value recommended for citrus (Tucker et al, 1998) - Table 2.

Manure Nutrient Contents

The PM contained 1.47% N, 0.51% P and 1.1% K with an organic matter of 15.2% (Table 2). The 5 t ha $^{-1}$ PM applied was to supply 73.5, 255 and 55 kg ha^{-1} of N, P, and K, respectively; 10 t ha $^{-1}$ was to supply 147, 510 and 110 kg ha^{-1} N, P and K, respectively while 15 t ha $^{-1}$ will supply 220.5, 765 and 165 kg ha^{-1} N, P and K, respectively.

Effect of Soil Amendment on Fruit Quality

At first harvest, sweet orange fruits obtained from plants which soils were amended with 0, 5, 10, 15 t ha^{-1} PM had comparable TSS values, ranging from 8.4% to 8.99%. However, during the second harvest, fruits obtained from plants fertilized with 10 and 15 t ha^{-1} PM had comparable TSS values of 8.13% and 8.10% which were significantly higher than 7% and 7.46% values obtained from fruits harvested from plants that received either 0 or 5 t ha^{-1} PM (Table 3). At first harvest, Titratable acidity contents of the fruits were similar in all the treatments, ranging between 0.17% and 0.25%. However, during the second harvest, fruits fertilized with either 10 or 15 t ha^{-1} PM had reduced Titratable acidity values of 0.39% and 0.42% compared with plants that received either 0 or 5 t ha^{-1} PM that had 7% and 7.46% TA, respectively. From both harvests, the vitamin C contents of 38.02 mg/100ml and 39.01 mg/100ml from sweet orange fruits obtained from plants fertilized with 15 t ha^{-1} PM was higher, compared with values obtained from plants that received 0, 5, and 10 t ha^{-1} PM as soil amendments.

At first harvest, plants that received soil amendments of 10 and 15 t ha^{-1} of PM produced fruits with increased fruit weights of 309.3g and 314.1g, respectively compared with fruits harvested from plants fertilized with 0 and 5 t ha^{-1} PM that had 273.5g and 282.4g. However, at the second harvest, plants that received 15 t ha-^{1} PM produced significantly heavier fruits of 321.6g compared with fruits obtained from 0, 5, and 10 t ha^{-1} PM. Juice volume of 192.2 ml and 232.0 ml was significantly increased in fruits harvested from plants that received 15 t ha^{-1} PM, compared with fruits harvested from plants that received 0, 5 and 10 t ha^{-1} PM from both first and second harvests (Table 4). At both harvests, soil amendments with different rates of

PM did not influence fruit firmness and juice colour of sweet orange fruits. (Tables 4 and 6).). At both harvests, the peel colour of fruits harvested from plants that received 10 t ha^{-1} PM had significant higher amounts of lightness (L*) and yellowness (b*) values when compared with fruits harvested from 0 t ha^{-1} (Table 5).

Table 1: Monthly rainfall, relative humidity, maximum and minimum temperature observed in 2016 and 2017.

Year /Months	Rainfall (mm)	Relative Humidity (%)	Max temp (^{0}C)	Min temp (^{0}C)	Sunshine hours (hours)
2016					
October	155.4	65.3	32.3	22.6	4.9
November	5.9	65.3	32.7	23.5	5.5
December	0.0	56.6	35.3	22.5	5.5
2017					
January	15.9	58.34	35.29	22.39	4.4
February	0.0	55.31	36.36	23.95	4.2
March	34.3	60.28	35.86	24.07	6.0
April	112.8	63.24	33.47	23.75	5.6
May	146.0	69.05	32.40	23.16	5.5
June	111.0	73.83	31.43	21.05	4.3
July	156.1	74.50	29.16	22.80	2.1
August	90.5	77.38	28.18	22.45	1.3
September	50.0	69.10	30.02	22.12	2.1
October	92.2	72.78	31.94	27.62	4.2
Total	970.1	861.01	424.41	301.96	55.6
Mean		66.23	32.65	23.23	4.3

Source: Meteorological Station, Department of Water Management and Agrometeorology. Federal University of Agriculture, Abeokuta.

Table 2: Initial soil chemical and physical properties and poultry manure analysis.

Properties	Soil	Organic manure
pH (H_2O)	7.23	5.91
Organic matter	1.39	15.15
Total organic carbon	0.81%	8.81%
Total nitrogen	0.10%	1.47%
Available phosphorus	42.23 mg kg^{-1}	5.10%
Exchangeable K	0.34 cmol kg^{-1}	1.10%
Exchangeable Ca	4.99 cmol kg^{-1}	2.31%
Exchangeable Mg	1.06 cmol kg^{-1}	1.55%
Exchangeable Na	0.70 cmol kg^{-1}	0.50%
AL + H	0.04 cmol kg^{-1}	-[a]
ECEC	7.13 cmol	-[a]
Base saturation	99.44%	-[a]
Sand	86.8%	-[a]
Silt	7.4%	-[a]
Clay	5.8%	-[a]
Textural class	Sandy loam	-[a]

-[a] = not determined

Table 3: Total soluble solids, vitamin C and Titratable acidity contents of sweet orange fruits as affected by soil amendments

Soil amendments (PM t ha^{-1})	Total soluble solids (^{0}brix)		Vitamin C (mg/100ml)		Titratable acidity (% citric acid)	
	First harvest	Second harvest	First harvest	Second harvest	First harvest	Second harvest
0	8.40	7.00	32.80	33.70	0.17	0.62
5	8.77	7.46	33.50	35.40	0.21	0.56
10	8.90	8.13	36.30	38.30	0.18	0.39
15	8.41	8.10	38.02	39.01	0.25	0.42
LSD (5 %)	ns	0.56	1.10	0.60	Ns	0.07

PM –Poultry manure

Table 4: Fruit weight and juice volume of sweet orange fruits as affected by soil amendments.

Soil amendments (PM t ha^{-1})	Fruit weight (g)		Juice volume (ml)		Fruit firmness (kg $^{-1}$)	
	First harvest	Second harvest	First harvest	Second season	First harvest	Second season
0	273.5	262.5	171.5	186.4	25.32	24.21
5	282.4	288.5	182.2	192.2	24.50	23.42
10	309.3	275.6	186.4	198.9	24.67	28.01
15	314.1	321.6	192.2	232.0	26.22	26.26
LSD (5 %)	4.56	9.65	5.2	8.66	ns	Ns

PM –Poultry manure

Table 5: Peel colour of sweet orange fruits as affected by soil amendments.

Soil amendments (PM t ha^{-1})	L*		a*		b*	
	First harvest	Second harvest	First harvest	Second harvest	First harvest	Second harvest
0	47.8	40.2	-7.70	-11.31	30.7	13.86
5	50.5	48.5	-8.06	-10.3	23.6	20.27
10	41.1	49.8	-7.81	-8.35	21.6	23.40
15	48.4	41.2	-8.84	-10.09	22.2	20.78
LSD (5 %)	Ns	9.37	ns	ns	Ns	6.64

L*= Lightness- lighten (0= maximum darken, 100=maximum lighten).
a*= Redness- red/green coordinate {(-a(green), + a(red)}
b*=Yellowness- yellow/blue coordinate {-b(blue), +b(yellow)}

Table 6: Juice colour of sweet orange fruits as influenced by soil amendments.

Soil amendments (PM t ha^{-1})	L*		a*		b*	
	First harvest	Second harvest	First harvest	Second harvest	First harvest	Second harvest
0	55.38	62.77	0.84	2.29	18.01	17.76
5	57.93	59.20	0.78	0.98	21.56	18.24
10	56.44	61.10	1.55	2.05	18.85	18.45
15	56.43	57.21	1.32	0.36	19.67	18.79
LSD (5 %)	ns	ns	ns	ns	Ns	ns

L*= Lightness- lighten (0= maximum darken, 100=maximum lighten).
a*= Redness- red/green coordinate {(-a(green), + a(red)}
b*=Yellowness- yellow/blue coordinate {-b(blue), +b(yellow)}

Table 7 Total soluble solids, titratable acidity and vitamin C contents of sweet orange fruits as affected by time of harvest

Harvest time	Total soluble solid (brix^{o})	Titratable acidity (%)	Vitamin C (mg/100ml)
First harvest	8.55	0.23	35.42
Second harvest	7.74	0.51	38.27
LSD (5 %)	0.43	0.12	1.24

Table 8: Fruit weight, juice volume and fruit firmness of sweet orange as affected by time of harvest

Harvest time	Fruit weight (g)	Juice volume (ml)	Fruit firmness (kg $^{-1}$)
First harvest	280.1	181.3	25.49
Second harvest	300.4	224.6	26.42
LSD (5 %)	6.7	8.93	ns

Table 9: Peel and juice color of sweet orange fruits as affected by time of harvest

Harvest time	Peel colour			Juice colour		
	L*	a*	b*	L*	a*	b*
First harvest	46.9	-8.1	22.44	56.54	1.12	19.52
Second harvest	46.7	-2.1	19.58	60.09	1.42	18.31
LSD (5 %)	ns	4.9	ns	2.36	ns	ns

L*= Lightness- lighten (0= maximum darken, 100=maximum lighten).
a*= Redness- red/green coordinate {(-a(green)-+ a(red)}
b*=Yellowness- yellow/blue coordinate {-b(blue)+b(yellow)}

Effect of Time of Harvest on Fruit Quality

The effect of time of harvest was significant on TSS contents of the fruits harvested (Table 7). Fruits harvested from the first season had higher amounts of TSS at 8.55% when compared with the values obtained from fruits harvested during the second season at 7.74%. The TA contents were significantly reduced in fruits harvested from the first harvest when compared with fruits from second harvest. Vitamin C content of fruits (38.27 ml/100g) harvested during the second harvest was significantly higher than values obtained from first harvest fruits (35.42 ml/100g). Fruit weight and juice volume of fruits from second harvest were significantly increased compared with values obtained from fruits harvested during the first season. Fruits Firmness was similar in fruits harvested from first and second harvests (Table 8). The lightness (L*) and yellowness (b*) values obtained for the peel colour of fruits for first and second harvest fruits were not significantly different. However, fruits harvested in the first season had more green colouration (a*) as compared with fruits harvested in the second season. There was no significant difference in a* and b* values of the juice colour of fruits harvested in both seasons but the juice colour from the second harvest was lighter (L*) with value of 60.09 compared with fruits harvested in the first season with a value of 56.54 (Table 9).

DISCUSSION

Fruit quality of sweet orange is dependent on several factors which could be external or internal. Ladaniya (2008) stated that the growth of citrus fruits and quality are dependent on climatic conditions, soil type, water availability, cultural practices and nutrient supply. The significant differences observed in the fruit quality from the different rates of poultry manure as soil amendment are due to different nutrient supply and environmental conditions. This is corroborated by Paramasivaram et al, (2000) that application of fertilizer directly affects fruit yield and quality in sweet orange production. Total soluble solid that was increased by application of 10 t ha $^{-1}$ during the second harvest can be attributed to the modest soil K content which is known to help in sugar translocation in plants, thus led to increased TSS contents of sweet orange fruits. This is similar to the findings of Canali et al., (2004) in which the use of organic amendment on Valencia late variety of sweet orange resulted in better fruit quality characteristics. Titratable acidity is an important maturity index for citrus that contributes to flavour and determines consumer's acceptability (Odeyemi, et al, 2018). The titratable acidity in the fruits reduced with increasing TSS, implying a negative correlation. The increase in TSS observed in fruits from the first harvest could be attributed to reduced amount of rainfall during fruit growth. The observed increased concentration of carbohydrates with the dry season harvest is attributable to general reduced soil moisture which will imply low moisture plant intake. With increased moisture content from increasing rainfall before the second harvest, the fruits had reduced TSS due to higher dilution of nutrients.

The increased vitamin C content of fruits harvested from soils amended with 15 t ha^{-1} PM was due to the catalytic activity of several enzymes which participated in the biosynthesis of ascorbic acid and precursor (Garhwal et al., 2014). Vitamin C tends to decrease seasonally. The vitamin C contents of fruits harvested during the first harvest was reduced as similar finding had been made by Davies and Albrigo, (1998) in a study on Hamlin, Pineapple and Valencia cultivars of sweet orange, when high level of vitamin C was observed between September and December while vitamin C level decreased between January and June.

Fruit growth is a function of tree water status, carbohydrate partitioning and temperature. The 15 t ha^{-1} was applied to supply 220 kg N ha^{-1}. Fruit weight that was increased in sweet orange fruits harvested from soils amended with 15 t ha^{-1} PM could be as a result of more availability of N which enhanced vigorous fruit growth. Fruits harvested during the second harvest that were bigger could be as a result of increased rainfall during fruit growth. According to Quaggio (2006), the juice content, total soluble solids and acidity are the most important fruit traits for frozen concentrate orange juice processing, while fruit size, peel texture and colour are valuable for the fresh market because consumers require fruits with superior external characteristics.

Colour is an important attribute in citrus fruit quality which influences consumer perception and acceptability (Lado et al, 2014). The retention of the green colour in the peel colour of the sweet orange fruits produced from first and second harvests was a result of warm temperature recorded in the area of cultivation. In growing regions where the average temperatures remain high such as tropical regions all year, the fruit peel chlorophyll does not degrade, oranges and tangerines remain green (Zekri, 2011;

Ritenour, 2016; Otero, 2011). For these reasons, citrus fruit growing in the tropics show an inability to develop their characteristic colour, acquiring greenish-pale peel coloration. The internal, edible portion of the fruit which is the pulp usually reaches maturity with the external peel green. However, as air and soil temperatures fall below 15^oC, chlorophyll is degraded and chloroplasts are converted to chromoplasts containing yellow, orange or red pigments (Davies and Albrigo, 1998). Sweet oranges require cool temperatures during later stages of fruit development to develop the characteristic good colour and preserve acidity from the lower levels that usually occur. The minimum temperature observed during the study was not cool enough for chlorophyll to be degraded in the fruits to express the inherent characteristic colour.

CONCLUSION

Postharvest quality in Agege 1 variety of sweet orange fruit was affected by soil amendments and the time of harvest during the production seasons. Fruits fertilized with 10 t ha^{-1} PM produced sweeter fruits with reduced acidity, while fruits fertilized with 15 t ha^{-1}produced heavier fruits with more juice content with good amount of vitamin C. Fruits from first harvest were sweeter, with reduced acidity while fruits obtained from second harvest had more juice content, with good amount of vitamin C content. Sweet orange fruit colour remained green at maturity during first and second harvests.

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