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Evaluation of Nine Elite Cassava (Manihot Esculenta Crantz) Genotypes for Tuber and Gari Yields and Gari Quality in Four Locations in Akwa Ibom State, Nigeria

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Abstract: Field experiments were conducted in four locations Ika, Ikot Ekpene, Uyo and Okobo in Akwa Ibom State, Nigeria to evaluate nine elite cassava genotypes for fresh tuber and gari yields and gari quality for pre-release trials. The nine elite cassava genotypes include TMS 30572 (national check), TMS 05/0539, TMS 01/1368, TMS 05/0593, TMS 05/1635, NR 07/0220, NR 04/0053, NR 07/0167 and ULC-1 (Obubit okpo as local check). A land area of 18 m x 20 m was laid out in a randomized complete block design and replicated three times in each location. Plant establishment (%), number of tubers per plants, fresh weight of tubers per plant (kg), weight of gari per plant (g) fresh tuber yield (tha^{-1}) and gari yield (tha^{-1}) were studied. Six gari quality characteristics assessed were gari appearance, swelling, stickiness, aroma, taste and colour. Significant differences ($P<0.05$) were observed for fresh tuber and gari yields. TMS 01/1368 demonstrated superiority over all the genotypes including both the national and local checks in two characters, namely fresh weight of tubers per plant (kg) and weight of gari per plant (g). The genotype was ranked second in three characters, namely tuber yield (tha^{-1}), gari yield (tha^{-1}) and gari colour, and third in plant establishment (%), number of tubers per plant, gari appearance, stickiness, aroma and taste. NR 07/0167 demonstrated superiority in gari yield (tha^{-1}) and gari swelling, second in weight of gari per plant (g) and gari colour and third in tuber yield (tha^{-1}). The two cassava genotypes could be recommended for pre-release trials, while TMS 05/0593 with the lowest performance could be eliminated from the list of cassava genotypes for Akwa Ibom State, Nigeria.

Keywords: *Manihot esculenta*, evaluation, tuber yield, gari yield, gari quality.

Introduction

Cassava (*Manihot esculenta*) is a very popular high energy root crop (Komolafe and Arawande, 2010), and belongs to the spurge family Euphorbiaceae (Makanjuola *et al*., 2012). It is cultivated mainly in the tropical and subtropical regions of the world over a wide range of environmental conditions (Richardson, 2013) in area between latitude 30°N and 30°S. The area encompasses some of the poorest countries of the world (Bokanga, 1996). Cassava is the fourth most important source of food calories for humans in the tropics, after rice, wheat and maize (IFAD/FAO, 2000). It is the seventh most important crop of the world and constitutes a staple food for about 12.5% of the world population and major source of calories for roughly two out of every five Africans (Nweke *et al*., 2002).

Cassava may be the world's least expensive source of calories (Cock, 1990) for over half a billion people (Makanjuola *et al*., 2012), supplying very high yields of energy per unit land area, for example about 13 times more than maize and guinea corn (Achinewhu *et al*., 1998). It is cultivated extensively as a food crop in 39 African countries, stretching through a wide belt from Madagascar in the south-east to Senegal in the north-west (IITA, 1990). Its high productivity under adverse conditions, all-year-round availability as well as wide adaptability to various cropping and food systems, makes it an ideal food security crop and resourceful industries raw material (Awa and Tumanteh, 2001; Okpara *et al*., 2014).

Nigeria is the world's largest producer of cassava with over 54.831 million metric tonnes (mmt), followed by Thailand (30.022 mmt), Indonesia (23.436 mmt), Brazil (23,253 mmt), Ghana (16.524 mmt), Democratic Republic of Congo (14.683 mmt) and Vietnam (10.209 mmt) (FAO, 2014). Despite the increase in production in Nigeria over the years, there has been a steady decline in yield in farmers' plot. For example, an average production of 11.7 tha^{-1} in 1990 declined to 10.7 tha^{-1} in 2005 (FAO, 2006). Cassava growth rates in 2011 and 2012 were estimated at 6.0 and 4.7, respectively. There was also a decline in total national output of cassava in 2015, compared to 2014 (CBN, 2012). The decline in tuber yield could be attributed to production constraints such as unavailability of improved varieties, lack of well-developed and timely distribution of improved varieties and other farm inputs, inadequate processing technology, problem of marketing and problems associated with climatic, edaphic and biotic factors (Aina *et al*., 2007).

Cassava root is normally processed before consumption to detoxify, preserve and provide acceptable quality products for consumption (Odomelan, 2005; Oluwole *et al*., 2004). Processed products of cassava have increased shelf life, and are easier to transport and market, contain less cyanide and are more palatable (Nweke, 1996). Numerous processing methods have been devised including grating, fermentation followed by roasting to reduce the toxicity and at the same time convert the highly perishable fresh roots of cassava to stable products (Oyewole, 1991; Komolafe and Arawande, 2010). By far, its processing into a fermented, dried, granular food products called gari is more popular in sub-saharan Africa than other derivatives (Opara, 1999; Amoah *et al*., 2009). Gari is a cassava based granule obtained by roasting fermented cassava paste (Tshiunza *et al*., 1999). The creamy white partially gelatinous granular flour is a major source of high dietary energy for low-income consumers in many parts of tropical Africa (Ihekoronye and Ngoddy, 1985, Oluwole *et al*, 2004; Sanni *et al*., 2008). Gari is usually consumed by mixing with boiled water to form a stiff paste, called eba and eaten with sauce or soup as complements. It may be sipped alone or with roasted fish, coconut, palm kernel, avocado pear, African pear or groundnut, when mixed with cold water and taken with or without sugar or salt (Makanjuola *et al*., 2012), or eaten dry as snack by adults and children in Nigeria (Arisa *et al*., 2011).

There are over 30 different cassava cultivars in Nigeria (Achinewhu *et al*., 1998) but only a few cultivars are dominant in farmers' field and gari producing areas. High yield of cassava tuber yield may not necessarily translate to gari yield and its quality. The usefulness of any cassava to the consumers could be determined by the quantity and quality of its gari (Komolafe and Arawande, 2010); many consumers of gari depends on the quality attributes (Makanjuola *et al*., 2012) such as poundability, taste, colour and aroma for acceptability of the products (Raji *et al*., 2010). Estimated gari yield ranges from 1.0 tha^{-1} to 6.0tha^{-1} (Nweke, 2002) or more depending on variety, season, age of the plants at harvest and time between harvest and processing into gari and processing equipment (Makanjuola *et al*., 2012). The purpose of this study was to evaluate nine elite cassava genotypes for tuber and gari yields and gari quality for advancement to the pre-release trials in Akwa Ibom State, Nigeria.

Materials and Methods

Field experiments were conducted simultaneously in four locations in Akwa Ibom State, Nigeria namely Ika, Ikot Ekpene, Okobo and Uyo to assess the variability in fresh tuber and gari yields and gari quality characteristics of elite cassava genotypes for advancement to pre-release trials. Akwa Ibom State lies within latitude 04° 33′ and 05° 33′ north and longitude 07° 25′and 08° 25′ east of the Greenwich meridian and altitude 38m above sea level (Edem *et al*., 2008). It lies in the humid high rainfall area of over 2500mm per annum with daily photoperiod of 3.5h. The temperature is generally high, ranging from 23°C to 34°C throughout the year. The average relative humidity is about 76% with the lowest and highest values in January/December and July, respectively (Ekpeh, 1994). The soil is described as a typical acid sand (Edem *et al*., 2008).

The experimental sites were manually cleared and ridged 1m apart and 0.5m high. A land area of 18m x 20m was laid out in a randomized complete block design and replicated three times. There were nine plots per replicate and each plot measured 2m x 6m, with two ridges. Nine elite cassava genotypes evaluated were TMS 30572 (national check), TMS 05/0539, TMS 01/1368, TMS 05/0593, TMS 05/1635, NR 07/0220, NR 04/0053 and NR 07/0167 obtained from Akwa Ibom State Agricultural Development Project (AKADEP) Uyo, while the local cultivar, Obubit Okpo was obtained from cassava farmers in the four experimental locations.

Cassava stems were cut 20 cm long with at least 5 nodes and put into 9 labelled boxes for ease of identification and planting. One stem cutting was planted per stand in an inclined position of about 45° on the crest of the ridges and spaced 1m apart, giving 12 plants per plot and 324 plants in the entire experimental plot per location, equivalent to 10,000 plants per hectare. The cassava stem cuttings were planted simultaneously on 3rd April, 2015 in all the experimental locations. Weeding was done manually three times: 2 Months After Planting (MAP), 4 MAP and 6 MAP. Fertilizer NPK 15:15:15 was applied 400 kg/ha in two split doses, first in May and then August for proper growth and development of the crops.

Five plants were randomly tagged from the net plot for data collection. The parameters studied were plant establishment (%), number of tubers per plant, fresh weight of tubers per plant (kg), fresh weight of tubers (tha^{-1}), weight of gari per plant (g), gari yield (th^{-1}) and gari qualities, namely appearance, swelling, "drawing" (stickiness), aroma and colour, all determined at harvest.

Analysis of variance was conducted per location and significant means separated with the least significant difference (LSD) at 5% probability level. Standard deviation and coefficient of variability were conducted among the cassava genotypes within and across experimental locations. Gari qualities (appearance, swelling, stickiness, aroma, colour and taste) were determined using a scale, 1 – 5 (highest), where 1 = very poor, 2 poor, 3 = good, 4 = very good and 5 = excellent. Cassava tubers from all the genotypes and locations were subjected to similar processing methods: peeling, grating, drying and frying (without the addition of palm oil). A panel of 10 people was set up comprising 5 males and 5 females to assess the appearance (texture), stickiness (drawing), aroma and taste. Gari swelling index was determined by a slight modification of the method of Ukpabi and Ndimele (1990). Fifty grammes of gari sample derived from each cassava genotype was put into a 500 ml measuring cylinder and 300 ml of distilled cold water added to each sample and stirred round two times and allowed to stand for 4 hours. The final level of gari in the cylinder was recorded against the initial level (when the gari finally stopped swelling).

For stickiness (drawing), gari samples measuring 500 grammes from different genotypes were treated with boiled water (100°C), and which was allowed to cool slightly to 90°C and stirred ten times with wooden spoon. Thereafter, the paste was rolled into balls and bonds. The stickiness of each sample was scored using the scale. The overall acceptability of each genotype was also determined.

Results

Significant differences ($p<0.05$) were observed among the nine cassava genotypes for plant establishment (%), number of tubers per plant, fresh weight of tubers per plant (kg), weight of gari per plant (g), gari yield (tha^{-1}) and fresh tuber yield (tha^{-1}). The local cultivar (Obubit Okpo) had the highest number of stands at harvest (%) (93.0), followed by TMS 01/13680 (85.6), TMS 30572 (84.4) and NR 07/0167 (77.1) while the lowest was TMS 05/0593 (58.9). Coefficient of variability across locations ranged from 13.47 – 30.69 for plant establishment. Variability with locations ranged from 11.38% (for TMS 30572) to 80.87% for NR 04/0053.

Number of Tubers Per Plant

The highest number of tubers was produced by TMS 05/0539 (5.6), followed by TMS 30572 (5.2), TMS 01/1368 (4.8), NR 07/0167 (4.1) while the lowest was TMS 05/0593 (2.3). Variability in performance of the cassava

genotypes within and across locations were observed. In ika, the highest number of fresh tubers was produced by TMS 01/1368 (7.2), followed by TMS 05/0539 (6.8), TMS 30572 (6.3) and NR 04/0053 (5.1), while the lowest came from Obubit okpo, with 2.2 fresh tubers. In Okobo, TMS 05/0539 produced the highest number of tubers followed by TMS 01/1368 and NR 07/0220, while the lowest was TMS 05/0593. In Ikot Ekpene, TMS 30572 produced the highest number of fresh tubers (6.0), followed by Obubit Okpo (4.9), NR07/0167 (4.2) and TMS 01/1368 while the lowest was NR 07/0220 (2.2). In Uyo, NR 07/0220 produced the highest number of tubers (7.9), followed by TMS 01/1368 (6.2), TMS 05/0539 (6.0), and obubit okpo (5.5) while the lowest number of tubers came from TMS 05/0593 (3.0). The coefficient of variability (%) across locations ranged 30.04 to 41.94. Similarly, variability within locations for number of tubers ranged from 4.22 for NR 07/0167 to 41.66% for TMS 01/1368.

Fresh Weight of Tubers Per Plant

Result (Table 1) shows significant differences ($P<0.05$) for fresh weight of tubers (kg) among the cassava genotypes. Coefficient of variability across locations ranged from 42.74% for Okobo to 73.32% for Uyo. Also, variability within locations ranged from 9.79% to 37.48%. Two cassava genotypes, namely TMS 01/1368 (2.75kg) and TMS 05/0539 (2.60kg) produced tubers with the highest fresh weight than the national check (TMS 30572), while the lowest fresh tuber weight per plant was recorded by TMS 05/0593 (0.93kg). In Ika, six cassava genotypes produced cassava tubers with higher fresh weight than the national check (TMS 30572), namely TMS 05/0539 (3.1kg), TMS 01/1368 (2.9), NR 04/0053 (2.5kg), NR 07/0167 (2.3kg), NR 07/0220 (1.6kg) and TMS 05/1635 (1.2kg). The lowest in that location was Obubit Okpo (0.8kg). In Okobo, three cassava genotypes produced tuber with fresh weight higher than the national check TMS 30572 (2.5kg) namely TMS 01/1368 (3.0kg), followed by NR 07/0167 (2.8kg) and TMS 05/0539 (2.6kg), while the lowest was produced by Obubit Okpo (1.0kg). In Ikot Ekpene, only NR 04/0053 (3.1kg) produced higher fresh tuber weight greater than the national check, TMS 30572 (2.8kg). In Uyo, two cassava genotypes produced higher fresh tuber weight above the national check TMS 30572 (1.7kg), namely TMS 01/1368 (2.8kg) and TMS 05/0539 (2.7kg).

Fresh Tuber Yield (th^{-1})

Significant difference ($p<0.05$) were observed among the cassava genotypes for fresh tuber yield (th^{-1}). Variability across locations was generally large, and ranged from 42.16% for Okobo to 52.10% for Uyo. Variability within locations however ranged from 6.91% for TMS 05/0539 to 37.40% for NR 07/0167. The highest fresh tuber yield was produced by TMS 05/0539 (27.75 th^{-1}), followed by TMS 01/1368 (27.50 tha^{-1}), NR 07/0167 (21.0 tha^{-1}) and the national check, TMS 30572 (20.23tha^{-1}), while the lowest fresh tuber yield (tha^{-1}) was produced by TMS 05/0593 (9.25 tha^{-1}). The result showed that the three cassava genotypes out yielded the national check in the environment, namely, TMS 05/0539, TMS 01/1368 and NR 07/0167. Significant differences ($p<0.05$) in fresh tuber yield (tha^{-1}) were observed among the cassava genotypes within and across the locations. For examples, in Ika, the highest fresh tuber yield was produced by TMS 05/0539 (31.0 tha^{-1}), TMS 01/1368 (29.0 tha^{-1}), NR 07/0167 (23.0 tha^{-1}) and NR 04/0053 (12.0 tha^{-1}), while the lowest fresh tuber yield was recorded in Obubit Okpo (8.0 tha^{-1}). In Okobo, three cassava genotypes out yielded the national check, TMS 30572 (25.0tha^{-1}), namely TMS 01/1368 (30.0tha^{-1}), followed by NR 07/0167 (28.0tha^{-1}) and TMS 05/0539 (26.0 tha^{-1}) while the lowest fresh tuber yield was obtained from Obubit Okpo (10.0 tha^{-1}). In Ikot Ekpene, the highest fresh tuber yield was produced by the national check, TMS 30572 (28.0 tha^{-1}) while the lowest was produced by TMS 05/0593 (10 tha^{-1}). However, in Uyo, three cassava genotypes produced tuber yields which were higher than the national check, namely TMS 01/1368 (28.0 tha^{-1}), TMS 05/0539 (27.0 tha^{-1}) and NR 07/0167 (18.0 tha^{-1}), while the lowest fresh tuber yield of 5.0tha^{-1} was recorded for TMS 05/0593.

Weight of Gari Per Plant (kg)

Significant differences ($p<0.05$) were observed for weight of gari/plant among the cassava genotypes. The coefficient of variability across locations ranged from 23.43% for Ikot Ekpene to 52.92 for Ika. Variability within locations ranged from 14.68% for TMS 01/1368 to 47.11 for obubit okpo. The highest weight of gari per plant was produced by TMS 01/1368 (0.76kg), followed by NR 07/0167 (0.68kg), NR 07/0220 (0.67kg) and TMS 30572 (0.66kg), while the lowest was in TMS 05/0539 (0.42kg). In Ika, NR 07/0167 produced the highest weight of gari per plant (0.82kg), followed by TMS 01/1368 (0.72kg), NR 07/0220 (0.70kg), TMS 05/0539 (0.65kg) and Obubit Okpo (0.52kg) while the lowest was produced by TMS 05/1635 (0.29kg). The gari weight per plant of NR 07/0167, TMS 01/1368, TMS 05/0593, NR 07/0220, TMS 05/0539 and Obubit Okpo (local check) were greater than TMS 30572 (0.52kg), being the national check. In Ikot Ekpene, a similar trend was observed with the highest produced by two cassava genotypes TMS 01/1368 (0.80kg) and NR 07/0220 (0.80kg), followed by the national check TMS 30572 (0.72kg), NR 07/0167 (0.072kg) and TMS 05/0593 (0.61kg), while the lowest gari per plant were given by NR 04/0053 (0.46kg) and Obubit Okpo (0.46kg). In Okobo the highest weight of gari per plant was produced by NR 07/0167 (0.84kg), followed by TMS 01/1368 (0.79kg), TMS 30572 (0.78kg) and NR 07/0220 (0.70kg) while the lowest gari (kg) per plant was produced by TMS 05/0539 (0.26kg). In Uyo, gari (kg) per plant were lower than those of other locations. The highest gari (kg) per plant was produced by NR 07/0167 (0.68kg), followed by TMS 30572 (0.64kg) and TMS 01/1368 (0.64kg) while the lowest was recorded in TMS 05/0593 (0.25kg) (Table 1).

Gari Yield (tha^{-1})

Gari yield (tha^{-1}) for all the genotypes were significantly different ($p<0.05$). variability across locations for gari yield (t/ha) ranged from 22.39% for Ikot Ekpene to 36.19% for Ika. Similarly, variability within locations was observed and ranged from 8.72% for NR 07/0167 to 38.28% for TMS 05/0539. The highest gari yield was produced by (TMS 01/1368 (7.37tha^{-1}), followed by NR 07/0167 (7.16tha^{-1}), NR 07/0220 (6.70tha^{-1}) and TMS 30572 (5.27tha^{-1}), while the lowest gari yield was produced by Obubit Okpo (4.35tha^{-1}). The location specific performances of the cassava genotypes varied significantly ($p<0.05$). In Ika for example, NR 07/0167 produced the highest gari yield (8.2tha^{-1}), followed by TMS 01/1368 (7.2tha^{-1}), NR 07/0220 (7.0tha^{-1}) and TMS 30572 (5.0tha^{-1}) and TMS 05/0539 (5.0tha^{-1}), while the lowest was produced by TMS 05/1635 (2.90tha^{-1}).

The highest gari yield in Okobo was produced by TMS 01/1368 (7.9tha^{-1}), followed by NR 07/0220 (7.0tha^{-1}) and TMS 30572 (6.1tha^{-1}), while the lowest gari yield was obtained from Obubit okpo (4.4 tha^{-1}). In Ikot Ekpene two cassava genotypes namely NR 07/0220 and TMS 01/1368 produced the highest gari yields (8.0 tha^{-1}), followed by TMS 30572 and NR 07/0167 with 7.20 tha^{-1} while TMS 05/0593 produced 6.10 tha^{-1}. The lowest gari yields of 4.6tha^{-1} were obtained from obubit okpo and NR 04/0053. In Uyo, the highest gari yield was produced by NR 07/0167 (6.8tha^{-1}), followed by TMS 01/1368 and TMS 30572 with 6.4tha^{-1} while TMS 05/0539 and NR 04/0053 produced 5.1tha^{-1} and 5.0tha^{-1} of gari, respectively. The lowest gari yield was obtained from TMS 05/0593 (2.5tha^{-1}) (Table 1).

Gari Quality

Variability in gari quality ($p<0.05$) was observed among the cassava genotypes. Coefficient of variability was observed for appearance (18.15%), swelling (10.71%), stickiness (9.21%), aroma (9.08%), colour (12.68%) and taste (8.65%). TMS 30572 had the best gari appearance (4.50), followed by TMS 05/0539 (4.25) while NR 04/0053, TMS 01/1368 and obubit okpo were rated 4.0. The lowest gari quality appearance (3.0) was obtained from TMS 05/1635 and TMS 05/0593. The phenotypic coefficient of variability (%) was 18.15 which was considered high enough for selection. Gari swelling quality of the genotypes was significant ($p<0.05$). The highest swelling quality gari was obtained from NR 07/0167 (4.50), followed by TMS 30572 and obubit okpo (4.0) while TMS 05/0539, TMS 01/1368 and TMS 01/0593 were rated 3.75. The cassava genotypes with the lowest swelling quality were NR 04/0053 and TMS 05/1635 (3.35).

Similarly, TMS 05/0539 was rated the most sticky gari, followed by TMS 30572 (4.25) while TMS 01/1368 and TMS 05/0593 were both rated 4.0. Cassava genotypes with the lowest stickiness were NR 04/0053 and TMS 05/1635, both rated 3.25 (Table 2).

The cassava genotype considered the best gari aroma was TMS 30572 (4.50), followed by NR 04/0053 and NR 07/0220 with 4.0, while TMS 05/0539, TMS 01/1368 and Obubit Okpo were rated 3.75. The lowest gari aroma was obtained from NR 07/0167 (3.25).

Variability in gari colour was observed among the cassava genotypes ($p<0.05$) with the best quality colour produced by TM 30572 (4.75), followed by NR 07/0167 and TMS 01/1368 (4.25), NR 04/0053 and TMS 05/0593 (4.0), while the lowest quality colour gari was obtained from TMS 05/1635 (3.0). Similarly, the taste quality of the cassava genotypes varied significantly ($P<0.05$). TMS 30572 and NR 07/0220 produced the best gari taste of 4.25, followed by TMS 01/0539 with 4.0, while NR 04/0053, TMS 01/1368 were both rated 3.75. The lowest rated gari taste (3.25) was obtained from TMS 05/1635. In all, the cassava genotype with the highest rating for all the six gari qualities was TMS 30572 in four characters, namely aroma, colour, taste and appearance and as a result was ranked first. This was followed by TMS 05/0539, ranked first for stickiness and second in appearance and taste, and as a result, it was ranked second. TMS 01/1368 was ranked second in colour and third in appearance, stickiness, aroma and taste was ranked third in overall gari quality. Garri with the poorest quality was produced by TMS 05/1635.

Table1. *Plant establishment (%), number of tubers/plant, fresh weight of tubers/plant (kg), fresh uber yield, (tha^{-1}), weight of gari/plant (g) and gari yield (tha^{-1}) of 9 elite cassava genotypes in Akwa Ibom State, Nigeria*

	Establishment (%)						No. of tubers/plant location						Fresh weight of tubers per plant/location (kg)					
	IKA	OKO	IKA	UYO	$\bar{X}$	SD/CV	IKA	OKO	IK	UYO	$\bar{X}$	SD/CV	IKA	OKO	IK	UYO	$\bar{X}$	SD/CV
TMS 30572	77.7	100	94.4	69.4	85.4	9.72 11.38	6.3	3.8	6.0	4.8	5.2	0.99 19.13	1.1	2.5	2.8	1.7	2.5	0.82 32.80
TMS 05/0539	69.4	50	75.0	88.8	70.1	13.49 19.89	6.8	6.8	3.0	6.0	5.0	1.56 27.68	3.1	2.6	2.7	2.7	2.65	0.40 15.23
NR 07/0167	50	83.3	75.0	100	77.1	18.03 23.39	4.2	3.8	4.2	4.1	4.1	0.17 4.22	2.3	2.8	1.3	1.9	1.8	0.701 37.48
NR 04/0053	50	77.7	88.8	58.3	68.7	55.56 80.87	5.1	2.1	3.0	5.3	3.9	1.36 34.96	2.5	1.1	3.1	1.7	2.1	0.58 36.26
TMS 05/1635	50	69.4	69.4	88.8	69.4	13.71 19.76	3.6	3.2	3.4	3.8	3.6	0.24 6.80	1.2	1.1	1.0	0.6	0.97	0.227 23.48
TMS 01/1368	94.4	69.4	75.0	94.4	84.6	11.35 16.36	7.2	5.4	3.5	6.2	4.8	2.0 41.66	2.9	3.0	2.3	2.8	2.75	0.269 9.79
NR 07/0220	50	77.7	58.3	77.7	65.9	9.18 12.79	3.9	4.5	2.2	7.9	3.1	0.99 35.48	1.6	1.7	1.0	1.1	1.35	0.327 24.28
TMS 05/0593	44.4	69.4	69.4	52.7	58.9	10.83 18.38	2.9	1.2	2.2	3.0	2.3	0.71 31.27	1.1	1.1	1.0	0.5	0.9	0.221 224.03
Obubit Okpo	100	88.8	83.3	100	93.0	7.24 53.3	2.2	3.2	4.9	5.5	4.0	1.31 32.88	0.8	1.0	1.2	1.2	1.05	0.164 15.64
CV	30.69	17.52	13.47	20.48	NA	28.45	35.56	41.94	35.20	30.04	NA	26.00	44.35	42.74	68.81	73.32	NA	24.33
LSD	3.54	5.21	4.26	5.06	NA	NA	0.08	0.46	0.64	0.64			0.08	0.03	0.04	0.04	0.04	
X	65.1	76.18	76.51	81.12	74.78		4.68	3.77	3.60	4.51	4.06		1.84	1.87	1.82	1.43	1.79	

CV = Coefficient of variability, SD = Standard deviation, NA = Not applicable; IK = Ikot Ekpene Local Government Area; OK = Okobo Local Government Area; Uyo Local Government Area; Ika Local Government Area

Table1. *Continued*

	Weight of gari/plant (kg)						Gari yield (t/ha)						Fresh tuber yield (t/ha)					
	IKA	OKO	IK	UYO	$\bar{X}$	SD/ CV	IKA	OKO	IK	UYO	$\bar{X}$	SD/ CV	IK	OKO	IK	UYO	$\bar{X}$	SD/CV
TMS 30572	0.50	0.78	0.72	0.64	0.66	0.104 15.89	5.0	7.0	7.2	6.40	5.27	1.04 15.75	11.0	25.0	28.0	17.0	20.23	6.68 33.01
TMS 05/0539	0.65	0.26	0.50	0.28	0.42	0.161 38.39	5.0	5.4	5.0	5.1	5.10	1.61 38.28	31.0	26.0	27.0	27	27.75	1.91 6.91
NR 07/0167	0.82	0.84	0.72	0.68	0.68	0.212 27.91	8.2	8.4	7.2	6.8	7.6	0.66 8.72	23.0	28.0	18.0	18.0	21.0	7.01 37.40
NR 04/0053	0.36	0.49	0.46	0.50	0.45	0.175 38.75	3.0	4.9	4.6	5.0	4.37	0.80 18.41	20.0	11.0	21.0	17.0	17.25	7.61 36.26
TMS 05/1635	0.29	0.61	0.48	0.47	0.45	0.125 27.50	2.9	6.1	4.8	4.7	4.62	1.20 26.08	12.0	11.0	10.0	6.0	9.75	2.27 23.35
TMS 01/1368	0.72	0.79	0.80	0.64	0.76	0.10 14.68	7.2	7.9	8.0	6.0	7.37	1.11 19.63	29.0	30.0	23.0	28.0	27.50	2.69 9.79
NR 07/0220	0.70	0.70	0.80	0.48	0.67	0.117 17.46	7.0	7.0	8.0	4.8	6.70	1.17 17.46	16.0	17.0	10.0	11.0	13.50	3.04 22.52
TMS 05/0593	0.49	0.51	0.61	0.25	0.46	0.129 28.15	4.9	5.1	6.1	2.5	4.65	1.32 28.42	11.0	11.0	10.0	5.0	9.25	2.48 26.89
Obubit Okpo	0.52	0.34	0.40	0.42	0.43	0.204 47.11	4.2	4.4	4.6	4.2	4.35	0.60 13.93	8.0	10.0	12.0	12.0	10.50	1.65 15.79
CV	52.92	37.31	23.43	28.46	27.08	28.43	36.19	32.82	22.39	28.68		20.29	44.28	42.16	45.83	52.10		23.54
LSD	0.02	0.02	0.02	0.03			0.16	0.16	0.14	0.12			2.28	2.26	2.0	2.18		
X	0.56	0.59	0.61	0.41	0.56		5.76	5.91	6.16	4.73	5.58		18.44	18.77	18.22	14.88	17.58	

CV = Coefficient of variability, SD = Standard deviation, NA = Not applicable; IK = Ikot Ekpene Local Government Area; OK = Okobo Local Government Area; Uyo Local Government Area; Ika Local Government Area

Table2. *Gari quality of elite cassava genotypes from 4 locations in Akwa Ibom State, Nigeria*

Cassava genotype	Appearance (texture)	Swelling	Stickiness	Aroma	Colour	Taste	Overall acceptability	Rank
TMS 30572	4.50	4.0	4.25	4.50	4.75	4.25	43.7	1st
TMS 05/0539	4.25	3.75	4.50	3.75	3.75	4.0	4.0	2nd
NR 07/0167	3.75	4.50	3.50	3.25	4.25	3.50	3.79	5th
NR 04/0053	4.0	3.25	3.25	4.0	4.0	3.75	3.79	5th
TMS 05/1635	3.0	3.25	3.25	3.5	3.0	3.25	3.20	9th
TMS 01/1368	4.0	3.75	4.0	3.75	4.25	3.75	3.91	3rd
NR 07/0220	3.75	3.25	3.75	4.0	3.75	4.25	3.79	5th
TMS 05/0593	3.0	3.75	4.0	3.5	4.0	3.50	3.70	8th
Obubit Okpo	4.0	4.0	3.75	3.75	3.5	4.0	3.83	4th
SD	0.61	0.39	0.35	0.34	0.49	0.32	NA	
CV	18.15	10.71	9.21	9.08	12.68	8.65	NA	
X	3.40	3.72	3.86	3.77	3.91	3.80	NA	
LSD	0.116	0.08	0.07	0.08	0.07	0.07	NA	

NA = Not applicable; CV = coefficient of variability; SD = standard deviation

Discussion

Significant differences ($p<0.05$) were observed among the nine cassava genotypes for plant establishment (%), number of root tubers per plant, fresh weight of tubers per plant (kg), weight of gari per plant (g) and gari yield (t/ha). Variability is a desirable characteristic in all selection processes and improvement in the crops.

Six cassava genotypes produced fresh tuber yields which ranged from 13.5ha^{-1} to 27.75tha^{-1}, with TMS 05/0539 giving 27.75tha^{-1}, followed by TMS 01/1368 (27.50tha^{-1}), NR 07/0167 (21.0tha^{-1}), TMS 30572 (20.23tha^{-1}), NR 04/0053 (17.0tha^{-1}) and NR 07/0220 (13.50tha^{-1}). Fresh tuber yields were above the world's average yield of fresh cassava tubers (12.8tha^{-1}) (FAO, 2011). Similarly, three cassava genotypes, namely TMS 05/0539, TMS 01/1368 and NR 07/0167 produced higher fresh tuber yields which were significantly ($p<0.05$) greater than the fresh tuber yield of the national check, TMS 30572 (20.23tha^{-1}). The three cassava genotypes have satisfied the criteria of selection and could be recommended for further selection trials in Akwa Ibom State and for pre-release trials in the area.

Gari yield of the cassava genotypes under study did not follow the exact trend of fresh tuber yield. However, three cassava genotypes produced gari yields which were higher than the estimated gari yield of 6tha^{-1} (Nweke, 2002) namely TMS 01/1368 (7.37tha^{-1}), NR 07/0167 (7.15tha^{-1}) and NR 07/0220 (6.70tha^{-1}). These gari yields were also greater than the gari yield of the national check, TMS 30572 (5.27tha^{-1}). It was observed that TMS 01/1368 and NR 07/0167 which were ranked second (27.50tha), and third (21.0t/ha^{-1}) in fresh tuber yields, came second (7.37 tha^{-1}) and third (7.15 tha^{-1}) in gari yields. The three cassava genotypes produced higher gari yields which were above the national check (TMS 30572) and therefore satisfied the criteria of selection for further trials in Akwa Ibom State and for pre-release trial in Nigeria (Komolafe and Arawande, 2010).

Selection of cassava based on gari yield is more appropriate since the usefulness of any cassava genotype to the processor and the ultimate consumers would be determined by the quantity and quality of gari produced (Komolafe and Arawande, 2010) rather than fresh tuber yields. The differences in gari yields among the cassava genotypes in the area could be attributed to varietal differences since the cassava tubers of the genotypes were subjected to the same processing techniques. However, the observed differences in gari quality among the cassava genotypes indicate that the desired quality characteristics could not be found in one cassava genotype and therefore suggests for further recombination through breeding and selection. For example, TMS 01/1368 which produced the highest gari yield of 7.37 tha^{-1} was ranked third in four gari quality, namely appearance, stickiness, aroma, taste and second in colour preference and finally ranked 3rd in overall quality gari. Similarly, NR 07/0167 which was ranked second highest gari producer with 7.15tha^{-1} was ranked first in gari swelling and second in colour preference and 5th in overall gari quality. Richardson (2013) observed a large variation among cassava genotypes in agronomic and sensory properties and noted that a proper understanding of such variations and correlations could assist breeders in the selection and breeding of cassava for both fresh tuber and gari yields.

Conclusion

A large variability ($p<0.05$) was observed among the nine cassava genotypes for yield components, tuber and gari yields in four locations in Akwa Ibom State, namely Ika, Ikot Ekpene, Uyo and Okobo. Three cassava genotypes, namely TMS 05/0539, TMS 01/1368 and NR 07/0167 produced higher fresh tuber yields of 27.75 tha^{-1}, 27.50tha^{-1} and 21.0tha^{-1}, respectively which were greater than the national check (20.23tha^{-1}) and also above the world's average tuber yield of 12.8tha^{-1} and could be recommended for further trials and selection to pre-release trials in Uyo, Akwa Ibom State. Similarly, three cassava genotypes, namely TMS 01/1368 (7.37tha^{-1}), NR 07/0167 (7.15tha^{-1}) and NR 07/0220 (6.70tha^{-1}) produced gari yields which were higher than that of the national check (5.27tha^{-1}) and could be recommended for further trials and selection in the area. There is also

need for recombination of traits in the three cassava genotypes for the production of hybrid varieties with superior performance in terms of gari quality. The continuous appearance of TMS 05/0539 and TMS 01/1368 alongside with the national check (TMS 30572) attests to the fact that they are inherently superior to others and could be further develop or selected for advancement to the pre-release trials for the area.

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