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Evaluation of agronomic performance of beta-carotene rich (yellow fleshed) cassava varieties in Nigeria

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Twenty-five yellow fleshed cassava varieties including three checks (two improved and one local) were evaluated in a randomized complete block design with four replications in three locations in Nigeria. Tuber yield, dry matter content, root size, fiber content, harvest index, sprouting and vigor of the varieties evaluated were all significant at 0.05 significant levels across the locations. Taste, color of unexpanded leaves, height at branching, and internode length were not significant. In Ibadan, plant height, vigor and root size were not significant. In Mokwa, plant height was not significant. Traits such as dry matter, mealiness and taste were significant. In Onne, dry matter was not significant. Clones such as 01/1413, 01/1442, 01/1663, 98/2132, 01/1277, and 01/1235 were stable across locations, 94/0330 had the highest dry matter (38%) which was better than the best check 30572 (37%). All clones were resistant to cassava mosaic disease, cassava bacteria blight, cassava green mites and cassava anthracnose disease vector infection and to the spread of the pathogens within the plant and across locations. Clones 01/1115, 011413, 01/1663, and 01/1335 had high beta-carotene content of range 7 on a color chart. Clones 01/1368, 01/1371, 98/2132, 90/01554 and 94/0330 had dry matter values ranging from 30 to 38%; these were acceptable values. In terms of yield, the best clones were 01/1368 (26 t/ha), 98/2132 (25 t/ha) and 01/1663 (24.5 t/ha). For gari yield clone 01/1649 gave 25%; 94/0330 gave 23% and 90/01554 gave 23%. They were better than the best check, with 22% garri yield. Cultivating cassava with yellow pigmented root flesh is a valid strategy to solve the problem of improving the nutritional value of the diet in the region where cassava is a staple food.

Key words: Agronomic performance, beta-carotene, clone, evaluation, cassava, yellow cassava, yield.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a major staple food in Nigeria, consumed daily by more than 100 million people. The global production of cassava in 2014 was 278.7 million tons with an estimate of 281 million tons for 2015 and 288.4 million tons for 2016 (FAO, 2016). From available records, Nigeria still stands out as the world's largest producer of cassava with a progressive production pattern that increased from 42.5 million metric tons

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in 2010 to 54 million metric tons in 2012 with average production output of 12.2 t/ha in 2010 increased to 14.03 t/ha in 2012 (FAOSTAT, 2013). Total area harvested of the crop in 2012 was 3.85 million ha (FAOSTAT, 2013). The diverse uses of cassava largely explain its popularity in the tropics. In Africa, most cassava produced is used for food consumption with 50% in processed form and 38% in the fresh and/or boil form; and 12% is used for animal feed. The diverse uses of cassava largely explain its popularity in the tropics. However, many pathogens and pests reduce cassava yields, especially in Africa including Nigeria. Diseases such as cassava mosaic disease (CMD), transmitted by a whitefly (*Bemisia tabaci*) vector and spread by infected cuttings, cassava brown streak virus disease (CBSD), cassava bacterial blight (CBB; *Xanthomonas axonopodis pv. manihotis*), and anthracnose (CA; *Colletotrichum gloeosporoides*) are among the most important diseases. Pests with a wide African spread are the cassava mealybug (CM; *Phenacoccus manihoti*), African root and tuber scale (*Stictococcus vayssierei*), cassava green mite (CGM; *Mononychellus tanajoa*) and nematodes (particularly *Meloidogyne* species) (Abaca et al., 2014).

Over-dependence on cassava-based diets may result in poor health, stunted growth, reduced capacity for physical activity, and in extreme cases, a high incidence of anaemia, corneal blindness, and compromised immunity (Saltzman et al., 2013). However, while the commonly available white cassava can provide most of the body's daily energy requirements, it does not provide sufficient proteins, essential micronutrients and vitamin A, required for a healthy and productive life. Vitamin A deficiency can impair the body's immunity to infectious diseases and cause eye defect that can lead to partial or complete blindness. Nearly one in three Nigerian children under five and one-quarter of all pregnant women in the country are vitamin A deficient (FAO, 2014). Billions of people around the world suffer from hunger and 'hidden hunger' or micronutrient malnutrition. Around 805 million people were considered chronically undernourished over the 2012 to 2014 period (FAO, 2014).

Those that do not get enough vitamin A and micronutrients (zinc and iron) from the foods they eat face severe health complications and even death. Micronutrient malnutrition can lower intelligence quotient (IQ), cause stunting and blindness in children, lower resistance to disease in both children and adults, and increase risks for both mothers and infants during childbirth. Malnutrition is the underlying cause of 45% of child deaths under the age of 5 (WHO, 2015). In 2013, an estimated 161 children under the age of 5 were stunted (below median height for age) and another 51 million were wasted (below median weight for height) (Thompson et al., 2013).

This is especially true in regions with prolonged dry seasons that limit production and access to alternative sources of micronutrients such as fresh vegetables (Von Grebmer et al., 2014).

Pro-vitamin A varieties that are presently available provide up to 40% of the daily recommended vitamin A intake for children less than 5 years old (De Moura et al., 2015). Nevertheless, new crosses to select varieties with an even higher content of β-carotene varieties are being generated through recurrent selection breeding scheme (Sánchez et al., 2014). This paper reports on the agronomic performance and suitability for quality garri production of adapted beta-carotene rich (Pro-vitamin A) cassava clones in diverse locations (Ibadan, Mokwa, and Onne) in Nigeria.

MATERIALS AND METHODS

The fields were plowed, harrowed and ridged at 1 m apart. Mature stem cuttings (0.25 m long) of 25 genotypes including three checks were planted on plots of four ridges (Table 6). The ridges were about 50 cm high, each 10 m long and spaced 1 m apart. The plot size was 4 m × 10 m (40 m^2). The experimental design was a randomized complete block with four replications. Blocking was done according to the topo-sequence of the field. The plots were weeded six times after planting and no fertilizers were applied. The experiment was conducted in three locations (Mokwa, Ibadan, and Onne) in Nigeria for two seasons (Figure 1). Mokwa (Niger State) is located in the southern Guinea savanna zone with latitude 9°18'N and longitude 5°04'E at about 457 m altitude about sea level (masl) and has a unimodal rainfall pattern with an annual total of 1069 mm, falling between June and October. Radiation is about 450 MJ m^{-2} $year^{-1}$. The soil is alfisols and ultisols. The second environment was Ibadan (Oyo State) with latitude 7°31'N and longitude 3°54'E and is located in the forest savanna transition zone at about 150 masl. It is characterized by a bimodal rainfall also averaging 1300 mm annually, most of which falls between May and October. Radiation is about 5285 MJ m^{-2} $year^{-1}$. The soil is slightly acidic alfisols. The third test environment, Onne (Rivers State), latitude 4° 43'N, longitude 7° 01'E, and 10 masl is in the rainforest zone, has a unimodal rainfall pattern with an annual average of 2400 mm falling between February and December. Relative humidity remains high throughout the year, with average values ranging from 78% in February to 89% in July and September. This site receives an average 4 h of direct sunshine daily, reaching 5060 MJ m^{-2} $year^{-1}$. The soil is representative of highly leached acid ultisols.

Data collection

One month after planting, data was collected on Cassava Mosaic Diseases (CMD). Cassava Bacterial Blight (CBB) was scored monthly until 6 months after planting. Cassava anthracnose disease (CAD) was scored for 6 months after planting and monthly till 9 months after planting. Cassava green mite (CGM) was scored for between January and February. That was when it normally appeared and reached its peak period. The scale used for scoring was 1 to 5 (1= zero attack or resistance; 2 = little attack or little resistance; 3 = medium or moderate resistance; 4 = high attack or susceptible; and 5 = very high attack or highly susceptible).

Number of cassava plants sprouted at 1 MAP was counted and scored as number sprouted or germinated over total number planted.

The plant growth vigor at one month after planting was rated visually, per plot basis, using 3 for low vigor, 5 for intermediate vigor, and 7 for highly vigor cassava plants. Root size was categorized into small, moderate and large with the scale 3 =

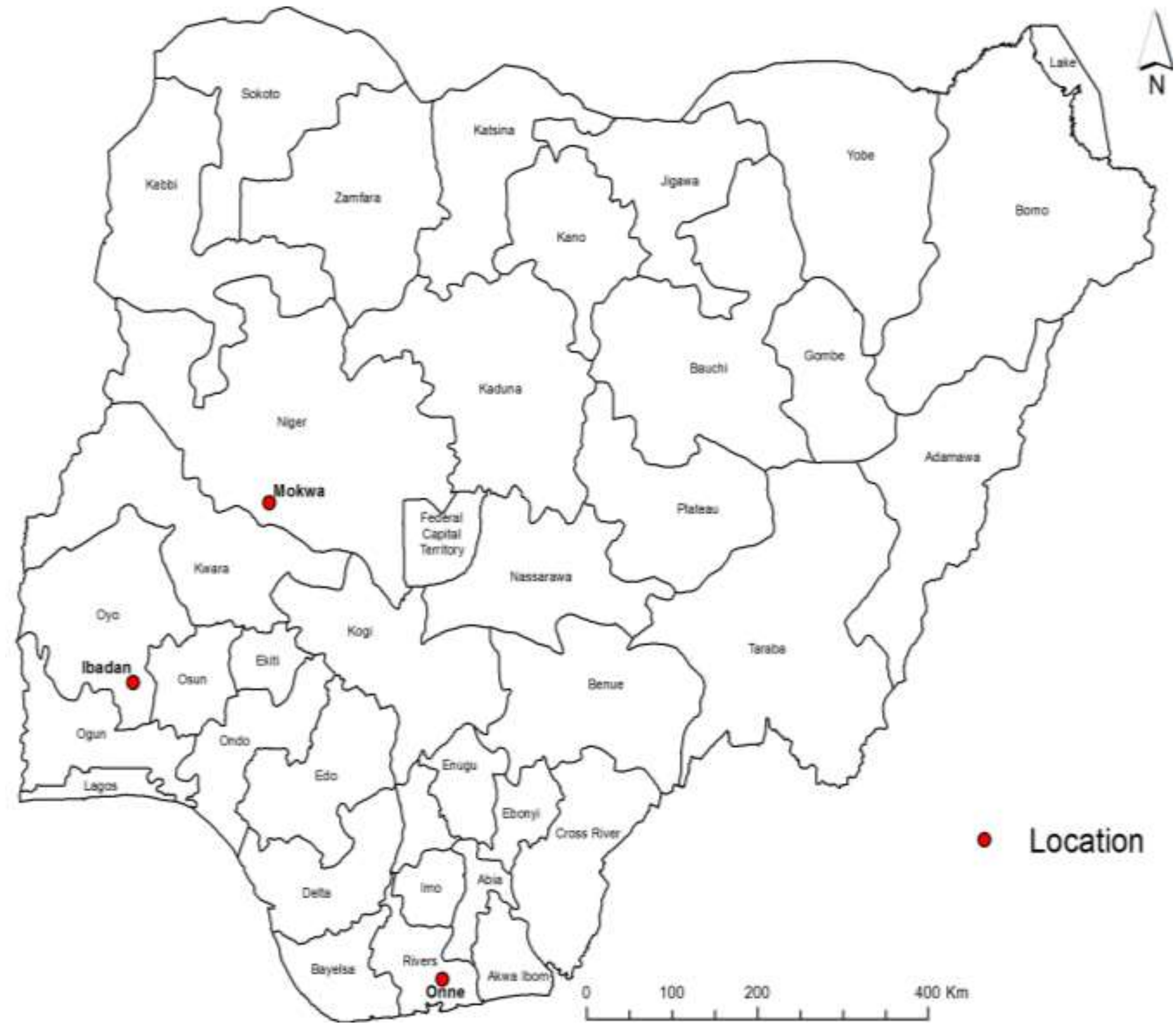

Figure 1. Map of Nigeria showing the three experimental locations.

small, 5 = moderate, and 7 = large. For B-carotene, Provitamin A carotenoids represent precursors to vitamin A in humans. It was scored at harvest with the use of color chart: 1= white, 2= light cream, 3= cream, 4= light yellow, 5= yellow, 6=yellow deep, 7= orange and 8= pink. The root cyanide content was estimated by picrate acid method. It was rated on a 1 to 9 scale based on intensity of red color (higher intensity of higher HCN content of root sample): 1= <10 HCN; 2= 10-15 HCN; 3 = 15-25 HCN; 4 = 25-40 HCN; 5 = 40-60 HCN; 6 = 60-85 HCN; 7 = 85-115 HCN; 8 = 115-150 HCN; and 9 = >150 (Intense red). Taste of boiled roots was examined by panel of five people and the conclusion was recorded. The scale used was 1: sweet, 2: bland, and 3: bitter.

Dry matter content of the tuberous root is an important character for the acceptance of cassava roots by consumers who boil or process them. Fresh sample of 100 g were taken from each clone in each replicate and dried at 70°C in oven and they were re-weighed after 72 h of drying and have attained constant drying. The dried sample was weighed and root dry matter content percentage was calculated as the ratio between fresh weight (FW) and dry weight (DW), that is, DM (%) = (DW/FW) × 100.

For fresh root yield, all the underground roots per plot were weighed in kilogram (kg) and converted to tones per hectare (t/ha).

Garri yield is the weight of garri (a dried granule gotten from 10 kg of fresh cassava roots of each clone, after being peeled, grated, fermented, dewatered, fried and sieved) measured in kilogram.

Harvest index was calculated by (root weight / root weight + shoot weight) × 100.

Statistical analysis

The data collected were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedure for randomized complete block design in statistical analysis system (SAS, 1996) to test for the treatment of effect and significant interaction of the variables considered. The results of the different experiments were subjected to combined analysis of variance to examine genotype by environment interaction (G × E) effect and standard errors were calculated for each trait.

RESULTS AND DISCUSSION

Plant height

Plant height was measured and the mean was calculated. The analysis of variance (Table 4) of the plant height indicated significant differences among the clones at probability level of 0.05 in Onne with CV of 17%, while in Ibadan and Mokwa a non-significant difference was observed.

Vigor

The result of vigor in G × E (Table 5) was very significant with CV of 17.90%. In Ibadan, the CV was 10.66% and not significant. In Onne, the CV was 21% and showed significance and in Mokwa it was 18% and significant. This result shows that vigor is a stable trait and not affected by the environment (Table 4).

Fresh tuber yield

This was very significant among the clones. From G × E analysis, the CV (31.28%) from combined analysis (Table 3) indicated a wide spread of the difference in the mean of the yield among the genotypes and across the locations. The yield could be considered stable at Onne with a high yield of about 24 t/ha. While Ibadan and Mokwa had yield of 15 t/ha (Table 4).

Dry matter

Dry matter content is a very important trait for acceptability of the cassava by consumers. It was significant in Ibadan at 0.05 (Table 4), with CV of 11.17%. In Onne, it was not significant. However, in combined analysis it was significant at a probability level of 0.001 with a CV of 12.88% and has a mean ranged from 28 to 35 across the locations (Table 5). This shows high dry matter percentage. Edoh et al. (2018) also reported higher dry matter percentage of 33.5% in one of her findings.

Cultivating cassava with yellow-pigmented root flesh is a valid strategy to solve the problem of how to improve the nutritional value of the diet in the regions where cassava is a staple food.

From the analysis of the 25 accessions, a significant (p=0.01) carotene content was determined within the range of variability for carotene concentration in the roots. A few genotypes were high up to 7 when a color chart that ranges from 1 to 8 was used. Olapeju et al. (2013) also reported higher carotene concentration in some of the varieties.

Locations accounted for most of the G × E interaction significance (p=0.001) which reflects the differences in soil types in which the clones were grown. This suggested that for the evaluation of cassava clones, it might be more appropriate to test genotypes over space rather than over time. This experiment was able to identify stable clones across locations such as 01/1413, 01/1442, 01/1663, 98/2132, 01/1277, and 01/1235.

Tuber yield, dry matter content, root size, fiber content, harvest index, sprouting and vigor of the varieties evaluated were all significant among the clones in the combined analysis (Table 5). Taste color of unexpanded leaves, height at branching, leaf area, and internode length were not significant. Overall, dry matter content showed that clone 94/0330 (yellow root) had the highest dry matter (38%), which was better than the best check 30572 (37%), followed by the clones 90/01554, 01/1335, 01/1368 and 01/1371 with values ranged from 30 to 35% (Table 3). However, in Ibadan (Table 4), plant height, vigor, mealiness and root size were not significant. In Mokwa (Table 4), sprouting and plant height were the only traits that were not significant. In Onne (Table 4), dry matter, sprouting, mealiness and taste were not significant.

In terms of disease resistance, all the clones evaluated were resistant to CMD and CBB vector infection and to the spread of the pathogen within the plant and across the locations (Tables 1 and 2).

Conclusion

The results showed that all clones were resistant to CMD, CGM and CAD vector infection and to the spread of the pathogen within the plant and across the locations. In terms of beta-carotene, clones 01/1115, 01/1413, 01/1663, and 01/1335 had high beta-carotene content, indicating the best genotypes for recommendation. In terms of dry matter content, clone 94/0330 (yellow root, 38%) was better than the best check 30572 (37%), clones 90/01554, 01/1335, 01/1368 and 01/1371 had dry matter values ranged from 30 to 35%, which were acceptable values. In terms of garri yield; yield per 50 kg of fresh root submitted for garri showed that clones 01/1649 (25%), 94/0330 (23%), and 90/01554 (23%) were better than the check 30572 (22%). Most of the clones evaluated were sweet, some were bland and non-was bitter in terms of taste.

In terms of yield, the best clones were 01/1368 (26 t/ha), 98/2132 and 01/1663 (25 t/ha). Clones 01/1412, 01/1115, 01/1235, 01/1610, 01/1649, and 95/0379 gave between 21 and 22 t/ha. In terms of the cyanide level, clones 01/1442, 01/1413, 01/1115, and 01/1663 were

Table 1. Mean from analysis of variance showing the reaction of 25 yellow root of Cassava genotype to CMD, CBB, CAD and CGM severity and incident at Ibadan, Mokwa and Onne.

Trait	Range	Ibadan			Mokwa			Onne		
		Mean	CV (%)	Sig.	Mean	CV (%)	Sig.	Mean	CV (%)	Sig.
CMD (S)	1-5	1.7	28.8	**	1.42	14.51	**	1.7	15.1	**
CBB (S)	1-5	1.8	22.03	*	2.45	14.31	***	1.49	7.14	*
CMD (I)	1-5	2.02	30.36	Ns	1.11	58.55	***	1.19	59.2	***
CBB (I)	1-5	1.18	39.74	Ns	1.9	18.49	**	1.07	93.58	**
CGM	1-5	4.04	24.6	**	2.9	15.05	**	2.34	6.57	Ns
CAD	1-5	18.8	26.64	Ns	1.89	25.6	ns	1.84	18.29	**

*,**,*** indicate 0.05, 0.01 and 0.001 levels of significance and ns means not significant. CMD: Cassava Mosaic Disease, CBB: cassava bacterial blight, CAD: cassava anthracnose disease, CGM: cassava green mite, S: severity, I: incident. 1: Zero attack or resistance, 2: little attack or little resistance, 3: medium or moderate resistance, 4: high attack or susceptible, and 5: very high attack or highly susceptible.

Table 2. Mean performance of (combined analysis) G × E of beta-carotene in cassava genotypes evaluated for multilocation trial at Ibadan, Mokwa and Onne for disease pest effects.

Trait	Range	Mean	CV (%)	MS between clone (df=24)	Sig. level
CMD (S)	1-5	1.14	21.32	3.2	***
CBB (S)	1-5	1.35	10.64	0.1	***
CMD (I)	1-5	0.28	30.36	0.6	*
CBB (I)	1-5	1.17	39.74	1.6	***
CGM	1-5	3.86	12.2	2.1	***
CAD (S)	1-5	2.11	35.97	0.2	*
CAD (1)	1-5	3.27	36.69	0	***

*,**,*** indicate 0.05, 0.01 and 0.001 levels of significance and ns means not significant. CMD: Cassava Mosaic Disease, CBB: cassava bacterial blight, CAD: cassava anthracnose disease, CGM: cassava green mite, S: severity, I: incident. 1: Zero attack or resistance, 2: little attack or little resistance, 3: medium or moderate resistance, 4: high attack or susceptible, and 5: very high attack or highly susceptible.

Table 3. Mean performance of G × E beta-carotene in cassava genotypes evaluated for multilocational trial at Ibadan, Mokwa and Onne for agronomic traits effect.

Clone	Fresh yield	H.I.	DM (%)	Beta carotene	Cyanide	Root size	Taste	Garri yield/50 kg	Garri yield
01/1115	21.21	1.2	29.53	7	3.5	7	1.8	8	16
01/1224	17.96	0.5	34.17	6.8	4.75	7	1.5	10.5	21
01/1235	21.4	0.59	28.99	6	4.5	7	1.3	6	12
01/1273	16.21	0.5	28	6.8	4.75	7	1.7	7.2	14.4
01/1277	16.2	0.5	34.12	6.5	4.5	6.3	1.7	7.5	15
01/1331	9.28	0.36	30.84	6.3	5.5	5.3	2	7.3	14.6
01/1335	18.5	0.53	31.88	7	4.25	7	1.5	8.5	17
01/1368	26.13	0.05	30.12	6	5.25	7 .0	1.8	7	14
01/1371	17.86	0.52	30.04	6.8	4.5	6.7	2	6.5	13
01/1412	21.96	0.58	28.08	6.5	4.5	7	1.8	10	20
01/1413	19.06	0.52	28.97	7	3.25	5.8	1.5	2	4
01/1442	16.58	0.53	30.44	6.3	3	6.3	1.7	7	14
01/1610	20.61	0.52	27.52	6.8	4.75	6.7	1.8	10	20
01/1646	18.1	0.45	31.58	5.5	4	6.3	1.7	7.7	15.4
01/1649	20.88	0.56	32.19	6.3	4.25	7	1.5	12.5	25
01/1662	16.38	0.46	29.9	5.5	4	6.5	1.8	10.6	21.2
01/1663	24.54	0.54	29.02	7	3.5	7	2	10	20
30572	26.83	0.55	37.18	1	3.75	6.7	1.5	11	22
90/01554	19.95	0.49	34.97	4.3	4.25	7	1.8	11.5	23

Table 3. Contd.

91/02324	24.66	0.6	35.3	1	3.25	7	1.3	8.2	16.4
94/0006	20.84	0.6	35.19	4.3	4.25	6.7	1.7	7.4	14.8
94/0330	13.89	0.41	38.35	4.5	5.25	6.3	1.7	11.5	23
95/0379	20.81	0.55	29.59	6	4	6.7	1.8	6.5	13
98/2132	25.02	0.69	35.78	6	4.25	7	2	7	14
TME 1	18.01	0.54	33.62	1	3.25	6.8	1.5	8.2	16.4
G.MEAN	19.73	0.55	31.81	5.5	4.23	6.68	1.7	8.4	-
STDEV	3.91	0.15	3.09	1.9	0.67	0.43	0.2	2.23	-
Stderr	0.01	0.03	0.62	0.4	0.13	0.12	0.06	0.64	-
CV%	31.28	0.6	12.88	7.5	2.69	12.49	12.9	9.78	-
F-Ratio	***	***	***	***	***	***	ns	ns	-

*,**,*** indicate 0.05, 0.01 and 0.001 levels of significance and ns means not significance. H.I: Harvest index, DM: Dry matter

Table 4. Mean square from analysis of variance showing various agronomic traits of 25 yellow root cassava genotypes evaluated for multilocational trail at Ibadan, Mokwa and Onne.

Trait	Ibadan				Mokwa				Onne			
	Mean	CV (%)	MSBC (Df=24)	SL	Mean	CV (%)	MSBC (df=24)	SL	Mean	CV (%)	MSBC (Df=24)	SL
FYLD	15.2	35.8	86.83	**	15.1	42	258.4	***	24.1	25	116	***
Sprout	95.67	7.79	337.1	*	18.16	66	221.6	Ns	93.9	9.4	205	Ns
Vigor	6.25	10.66	1.78	Ns	5.64	18	1.88	**	4.4	21	1.7	*
LA	11697	228.5	6736	Ns	15222	58.4	54428	Ns	26598	66.4	46798	Ns
Plant H.	63.26	41.28	428	ns	59.7	30	277	Ns	117	17	695	*
DM	35.26	11.17	37.4	Ns	34.5	15	34.56	*	28	18	35	Ns
Mealy	1.05	119.7	2.5	Ns	2.64	14	0.53	***	0.5	131	0.82	Ns
Cyanide	5.68	20.47	3.22	**	5.68	20	3.22	***	4.2	20	4.21	*
B.carotene	5.45	9.88	10.55	**	5.43	9	11.61	**	4.6	19	3.23	*
Rt. size	6.68	12.06	0.57	Ns	6.64	11	1.38	**	6.6	13	2.6	***
Taste	1.65	24.63	0.44	**	1.68	20	1.06	*	1.8	27	0.3	Ns
Garri	20.65	15.23	20.68	**	19.65	24	15.65	*	19	9.8	19	***

*, **,*** indicate 0.05, 0.01 and0.001 levels of significance and ns means not significance. FYLD: Fresh yield, LA: leaf area, Plant H.: plant height, DM: dry matter, B.carotene: beta carotene, Rt. size: root size, MSBC: mean square between clones, SL: significant level.

Table 5. Mean performance of G × E of 25 beta-carotene cassava evaluated for multilocational trail at Ibadan, Mokwa and Onne for agronomic traits effect.

Trait	Mean	CV (%)	MS between clone (df=24)	Sig. level
Fresh yield	19.63	31.28	125	***
Sprout	1.92	11.19	0.06	***
Vigor	9	17.9	3.03	***
H.I	0.51	14.55	0.02	***
Root size	6.63	12.49	1.74	***
Fiber	2.37	9.36	0.16	***
Dry matter	32.91	12.88	50.1	***
Taste	69	25.09	0.24	Ns
Leaf shape	13	12.03	1.17	***
Color of unexpanded leaf	65	34.65	11.47	Ns
Pubescent of young leaf	2.78	45.77	5.5	**

Table 5. Contd.

Petiole length	12.33	34.36	35.21	*
Petiole Color	3.5	29.37	6.5	***
Flowering	1.7	35.79	0.31	**
Fruit	1.2	89.35	0.37	*
Height at branching	26.91	81.5	799.9	ns
Stem/plant	1.19	27.31	0.44	**
Internode length	1.21	18.87	0.05	Ns
Stem color	2.5	23.85	1.26	**
D. of anthocyanine pigment	1.81	60.62	6.64	*

*,**,*** indicate 0.05, 0.01 and 0.001 level of significance and ns mean not significant.

Table 6. Characteristics of 25 yellow root cassava clones evaluated for agronomic performance during 2003/2004 cropping season.

Clone	Leaf length (cm)	Color of unexpanded leaf	Petiole length (cm)	Plant height (cm)	Petiole color	Flower	No. of stem Plant^{-1}	Internode length (cm)	Stem	Height at branch (cm)
01/1115	10.7	Light-green	12.7	91.5	Light-green	Present	2	1.5	Silver-green	25
01/1224	13.8	Green-purple	18.2	105.5	Dark-green	Present	2	2	Dark-green	26.9
01/1235	11.2	Green-purple	27.1	68.3	Dark-green	Present	3	2	Silver-green	59.6
01/1273	11.1	Green-purple	16.5	69.5	Light-green	Present	2	1.5	Light-brown	40
01/1277	14.6	Purple	20.9	122.8	Light-green	Absent	3	2	Light-brown	73.2
01/1331	15.2	Green-purple	14.7	105.1	Light-green	Present	2	2	Dark-brown	35.2
01/1335	13.5	Green-purple	13.4	120.3	Dark-green	Present	2	2	Dark-green	26.8
01/1368	12.8	Green-purple	18.9	127.2	Light-green	Present	3	2	Light-brown	23.2
01/1371	8.4	Green-purple	15	131.3	Light-green	Present	2	2	Dark-green	54
01/1412	12.2	Dark-green	17.8	112.9	Light-green	Present	3	2	Silver-green	22
01/1413	12.5	Green-purple	17	108.2	Dark-green	Present	3	1.5	Silver-green	16.3
01/1442	13	Dark-green	12	130.1	Light-green	Present	3	2	Dark-green	23.3
01/1610	14	Dark-green	18.8	97	Light-green	Present	3	1.5	Light-brown	25
01/1646	14.7	Green-purple	24.1	143.9	Light-green	Absent	2	2	Light-brown	29.8
01/1649	14.2	Purple	18.3	117.9	Light-green	Present	2	2	Light-brown	55.8
01/1662	15.8	Dark-green	20.5	142	Dark-green	Present	2	2	Dark-green	31.3
01/1663	15	Dark-green	25.2	141.4	Dark-green	Absent	3	1.5	Dark-brown	0
30572	10.4	Green-purple	24.2	62.3	Dark-green	Present	2	2	Dark-brown	74.8
90/01554	15.7	Green-purple	17	104.9	Dark-green	Present	3	2	Dark-green	21.9
91/02324	15.2	Green-purple	25.3	87.6	Dark-green	Absent	2	2	Dark-brown	0
94/0006	13	Light-green	19.8	112.4	Dark-green	Present	2	2	Dark-brown	30
94/0330	13	Purple	23.7	125.5	Red	Present	2	1.5	Dark-brown	31
95/0379	14.3	Dark-green	19	128.3	Dark-green	Present	1	2	Dark-brown	45
98/2132	10.2	Green-purple	23	60	Dark-green	Present	2	2	Dark-brown	25
TME 1	16	Purple	26	250	Purple	Absent	1	1.5	Dark-brown	150

very low, clones 01/1224, 01/1235, 01/1371, 95/0379, 98/2132, 94/0006, 01/1662, and 01/1412 were moderate.

None of them was high in cyanide level. Most of the root sizes were large and some were moderate while none were small among the clones evaluated.

In terms of harvest index, clone 01/1115 had the highest index of about 120% of the total yield. Clones 98/2132 (69%), 01/1235 (59%), 01/1412 (58%), and 95/0379 (55%) were acceptable. Clones 01/1115 and 98/2132 were better than the best check (91/02324) with a harvest index of 60%. Clones 01/1235, 01/1412, 98/2132, 01/1115, 94/0006, and 01/1649 were better than the most popular check 30572 (55%).

Four of the clones used in this experiment were already released varieties in Nigeria. Three of them (01/1368, 01/1412 and 01/1371) were released in the year 2011, while one (98/2132) was released in the year 2012.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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