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Agronomic performance of pro vitamin a cassava varieties in three locations in Nigeria

Adetoro, N. A.[1*], Ogunbayo, S. A.[1,2], Akinwale, M. O.[3]

[1]International Institute of Tropical Agriculture (IITA), PMB 5320, Ibadan, Oyo State, Nigeria.
[2]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), BP 320, Bamako, Mali.
[3]International Institute of Tropical Agriculture (IITA), P. O. Box 30258, Lilongwe, Malawi.

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In an early yellow root cassava study in 2003 to 2004, we investigated agronomic performance of pro Vitamin A (yellow fleshed) cassava genotypes in three locations in Nigeria (Ibadan, Mokwa, and Onne). Twenty-two clones and three checks were evaluated. A randomized complete block design was used with four replications. Characteristics showing significant differences among genotypes across all locations included sprouting, vigor, harvest index, root size, storage root yield, dry matter content and fiber content. Plant height, root mealiness and taste were different in only selected locations. Six clones showed stable performance across locations including IITA TMS I011413, IITA TMS I011442, IITA TMS I011663, IITA TMS I982132, IITA TMS I011277 and IITA TMS I011235. Clones IITA TMS I940330 showed the highest dry matter content of 38%. All clones exhibited good resistant to cassava mosaic disease, cassava bacterial blight, cassava green mite, and cassava anthracnose disease. These genotypes ranged in total carotenoid content from 3.4 to 8.2 µg/g fresh weight. In terms of yield, the best clones were IITA TMS I011368 (26 t/ha), IITA TMS I011663 (22 t/ha) and IITA TMS I982132 (25 t/ha). For gari yield clone IITA, TMS I011649 gave 25%, IITA TMS I940330 gave 23%, and IITA TMS I9001554 gave 23%. They were better than the best check IITA TMS I30572, with 22% gari yield. This study showed the potential for biofortification of cassava as a valid strategy to approach the problem of micronutritient deficiencies of the population in the region where cassava is a staple food.

Key words: cassava varieties, biofortification, pro Vitamin A, Nigeria, agronomic performance.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the third most important source of calories after rice and maize in the tropics. About 60% of the world's cassava production is concentrated in five countries which are Nigeria, Brazil, Thailand, Indonesia and the Democratic Republic of Congo (DRC). Nigeria which is the leading producer with 19% is followed by Brazil with 13 %, Indonesia with 10 %, Thai land with 8% and DRC with 7% while the rest of the world accounts for the remaining 43%. (Ohimain, 2015) 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). It is a major staple food in Nigeria, consumed daily by more than 100 million people. 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

*Corresponding author. E-mail: naadetoro@gmail.com.

million metric tons in 2010 to 54 million metric tons in 2012 with average production output of 12.2 t/ha in 2010 increased to 14.03t/ha in 2012 (FAOSTAT, 2013). Total area harvested of the crop in 2012 was 3.85 million ha (FAOSTAT, 2013). 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. 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). Nearly one in three Nigerian children under five and one-quarter of all pregnant women in the country are vitamin A deficient (HarvestPlus 2014).

People who 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). 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).

There is need to work on the Pro Vitamin A cassava clones to understand their performance agronomically. This paper reports on the agronomic performance (diseases and pests, plant height, plant vigor and sprout, root size and numbers root cyanide and dry matter contents, root yield and harvest index) and suitability for quality gari production of adapted beta-carotene rich (Pro-vitamin A) cassava clones in diverse locations (Ibadan, Mokwa, and Onne) in Nigeria.

MATERIALS AND METHODS

The study was conducted at three locations, Mokwa (latitude 9°18'N and longitude 5°04'E; 457 masl; unimodal rainfall pattern with an annual total of 1069 mm, falling between June and October; Radiation is about 450 MJ m^{-2} yr^{-1}. The soil is Alfisols and Ultisols in the southern Guinea savanna zone), Ibadan (latitude 7°31'N and longitude 3°54'E; 150 masl; 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} yr^{-1}. The soil is slightly acidic alfisols;, in the forest savanna transition zone), and Onne (latitude 4° 43'N, longitude 7° 01'E; 10 masl; unimodal rainfall pattern with an annual average of 2400 mm falling between February and December; relative humidity average values range from 78% in February to 89% in July and September; receives an average four hours of direct sunshine daily, reaching 5060 MJ m^{-2} yr^{-1}. The soil is representative of highly leached acid ultisols in the rainforest zone) in Nigeria, following a northern-south gradient of rainfall and vegetation types.

Plant materials and plant establishment

Stem cuttings, each 25 cm long with at least four nodes, were planted in ridges about 50 cm high, 10 m long and spaced 1 m apart in a randomized complete block design with four replications. These sites; Ibadan was planted on the 1st August, 2003, Mokwa on 27th July, 2003, and Onne on 10th August, 2003. The fields were plowed, harrowed and ridged at 1 m apart. 25 clones (23 pro-vitamin A-yellow root and 2 checks- white roots: TME 419 and TME 1) were planted in the basic plot consisted of four rows, making a plot size of 40 m square. The plots were weeded six times after planting. No fertilizers were applied.

One month after planting, data was collected on Cassava Mosaic Diseases (CMD). Cassava Bacterial Blight (CBB) was scored for 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 mites (CGM) were 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

This 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.

Plant height was measured, and the mean was calculated

Root size was categorized into small, moderate and large with the scale 3 = small; 5 = moderate and 7 = large.

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 1-9 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

The 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 (per cent) = (DW/FW) × 100.

Fresh root yield

All the underground roots per plot were weighed in kilograms (kg) and converted to tones per hectare (t/ha).

Gari yield

Gari yield is the weight of gari (a dried granule gotten from ten kilograms of fresh cassava roots of each clone, after peeled, grated, fermented, dewatered, fried and sieved) measured in kilograms.

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

Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedure 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 G × E effect and standard errors were calculated for each trait.

RESULTS AND DISCUSSION

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. The soil variation observed justified the effects of blocks on the performance of most traits, showing the importance of conducting and blocking genotype trials across various environments for selecting genotypes presenting general and/or specific adaptation to those environments. The findings on G × E interaction agreed with the findings of Tumuhimbise et al. (2015) showing that G × E interaction analysis is important for identifying genotypes with adequate adaptation to target environments.

Plant height

There were significant differences among the clones in Onne with CV of 17%, while in Ibadan and Mokwa a non-significant difference was observed (Table 1).

Vigor

The effect of G × E on vigor was very significant (Table 1) with CV of 17.90%. The effect was not significant only in Ibadan. This shows that vigor is a stable trait and not affected by the environment.

Fresh tuber yield

Tuber yield vary significantly among the clones and G × E analysis (p = 0.001) was also significant (Table 1). There was wide spread of the difference in the mean of the yield among the genotypes and across the locations. Osekita et al. (2014) also had a wide spread of difference in the mean of the yield among the genotypes and across the locations in his findings. The yield could be considered stable in Mokwa and Onne with a high yield of about 20 t/ha. In terms of fresh root yield, the best clones were 01/1368 (26 t/ha), 98/2132 and 01/1663 (25 t/ha). Clones 01/1412, 01/1115, 01/2135, 01/1610, 01/1649. 95/0379 gave between 21 and 22 t/ha.

Dry matter

Dry matter content is a very important trait for acceptability of the cassava by consumers. It was significant in Ibadan, 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%. The significant effect of the clone on cassava dry matter agrees with the findings of Athanase et al. (2017)

The dry matter percentage mean ranged from 27.5 to 38 across the locations (Table 3). This shows high dry matter percentage. Edoh et al. (2018 also reported higher dry matter percentage of 33.5% in one of her findings.

Beta- carotenoid

Beta- carotenoid content ranged from 1.0 to 7.0 µg/g fresh weight Table 3.

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 and high beta- carotene across locations among the clones used: 01/1413, 01/1442, 01/1663, 98/2132, 01/1277, and 01/1235. A few

Table 1. Mean square from analysis of variance showing various agronomic traits of 25 yellow root cassava genotypes evaluated for multilocational traits at Ibadan, Mokwa and Onne during cropping season.

Trait	Mean	CV%	MS btw clone df = 24	Sig	Mean	CV%	MS btw clone df =24	Sig. level	Mean	CV%	MS btw clone df =24	Sig. level
F.Yield	15.20	35.8	86.83	**	15.10	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	*
Leaf area	11697	228.5	6736	ns	15222	58.4	54428	ns	26598	66.4	46798	ns
Plant height	63.26	41.28	428	ns	59.70	30	277	ns	117	17	695	*
Dry matter	35.26	11.17	37.40	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	*
R.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
Gari	20.65	15.23	20.68	**	19.65	24	15.65	*	19	9.8	19	***

*, ** &*** indicate 0.05, 0.01 and 0.001 levels of significance and ns means not significance.

genotypes were high up to7 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. 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 2). Taste color of un-expanded 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 (36%), followed by the clones 01/1115, 01/1413, 01/1663, with values ranged from 30 to 35%. However, in Ibadan plant height, vigor, mealiness and root size were not significant (Table 1). In Mokwa; sprouting and plant height were the only traits that were not significant (Table 1). In Onne dry matter, sprouting, mealiness and aste were not significant (Table 1).

The significant effect of Cassava Mossaic disease (CMD) indicated that genotypes respond differently to CMD in various environments, explaining the need for specific adaptation analysis for the trait, as reported by Athanase et al. (2017). In terms of disease and Pest resistance, all the clones evaluated were resistant to CMD, CBB and CGM vector infection and to the spread of the pathogen within the plant and across the locations (Table 4).

Conclusion

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, 01/2135, 01/1610, 01/1649. 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 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 (60%), 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, 95/0379, 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

Table 2. Mean performance of G × E of 25 beta-carotene cassava evaluated for multilocational trails at Ibadan, Mokwa, onne for agronomic traits effect during 2004 cropping season.

Traits	Mean	CV%	MS btw clone df = 24	Sig.level
F.Yield	19.63	31.28	125	***
Sprout	1.92	11.19	0.06	***
Vigor	09	17.90	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	***
C. of unexp Leaf	65	34.65	11.47	Ns
Pub.of young leaf	2.78	45.77	5.50	**
Petiole length	12.33	34.36	35.21	*
Petiole C	3.5	29.37	6.5	***
Flowering	1.7	35.79	0.31	**
Fruit	1.2	89.35	0.37	*
Height at B	26.91	81.50	799.9	ns
Stem/plant	1.19	27.31	0.44	**
Internode L	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 levels of significance and ns means not significance.

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 during 2004 cropping season.

Clones	F. Yield	H.I.	DM	B-Carotene	Cyanide	Root Size	Taste	Gari Yield/50 kg	Gari yield
01/1115	21.21	1.2	29.53	7.00	3.50	7	1.8	8.0	16
01/1224	17.96	0.5	34.17	6.75	4.75	7	1.5	10.5	21
01/1235	21.40	0.59	28.99	6.00	4.50	7	1.3	6.0	12
01/1273	16.21	0.5	28.00	6.75	4.75	7	1.7	7.2	14.4
01/1277	16.20	0.5	34.12	6.50	4.50	6.3	1.7	7.5	15
01/1331	9.28	0.36	30.84	6.25	5.50	5.3	2	7.3	14.6
01/1335	18.50	0.53	31.88	7.00	4.25	7	1.5	8.5	17
01/1368	26.13	0.05	30.12	6.00	5.25	7	1.8	7	14
01/1371	17.86	0.52	30.04	6.75	4.50	6.7	2	6.5	13
01/1412	21.96	0.58	28.08	6.50	4.50	7	1.8	10	20
01/1413	19.06	0.52	28.97	7.00	3.25	5.8	1.5	2.0	4
01/1442	16.58	0.53	30.44	6.25	3.00	6.3	1.7	7.0	14
01/1610	20.61	0.52	27.52	6.75	4.75	6.7	1.8	10	20
01/1646	18.10	0.45	31.58	5.50	4.00	6.3	1.7	7.7	15.4
01/1649	20.88	0.56	32.19	6.25	4.25	7	1.5	12.5	25
01/1662	16.38	0.46	29.90	5.50	4.00	6.5	1.8	10.6	21.2
01/1663	24.54	0.54	29.02	7.00	3.50	7	2	10	20
30572	26.83	0.55	37.18	1.00	3.75	6.7	1.5	11	22
90/01554	19.95	0.49	34.97	4.25	4.25	7	1.8	11.5	23
91/02324	24.66	0.60	35.30	1.00	3.25	7	1.3	8.2	16.4
94/0006	20.84	0.60	35.19	4.25	4.25	6.7	1.7	7.4	14.8
94/0330	13.89	0.41	38.35	4.50	5.25	6.3	1.7	11.5	23

Table 3. Contd.

95/0379	20.81	0.55	29.59	6.00	4.00	6.7	1.8	6.5	13
98/2132	25.02	0.69	35.78	6.00	4.25	7	2	7.0	14
TME 1	18.01	0.54	33.62	1.00	3.25	6.8	1.5	8.2	16.4
G.MEAN	19.73	0.55	31.81	5.51	4.23	6.68	1.7	8.4	
STDEV	3.91	0.15	3.09	1.88	0.67	0.43	0.20	2.23	
Stderr	0.01	0.03	0.62	0.38	0.13	0.12	0.06	0.64	
CV%	31.28	0.60	12.88	7.52	2.69	12.49	12.88	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 = Matter; F. Yield; R. Size = Root size.

Table 4. 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.

Traits	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; 5: very high attack or highly susceptible.

year 2012. All clones were resistant to CMD, CGM and CAD vector infections across the locations. Clones 01/1115, 01/1413, 01/1663, and 01/1335 had higher beta-carotene content than others. For gari yield, clone 01/1649 gave 25%, 94/0330 gave 23%, 90/01554 gave 23%. They were better than the best check 30572, with 22% gari yield.

This study showed the understanding of agronomic performance of the early potential for biofortification of cassava as valid strategy to approach the problem of micronutrient deficiencies of the population in the region where cassava is a staple food.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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