Agronomic traits and tuber quality attributes of farmer grown cassava landraces in Nigeria

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Abstract

Eleven Nigerian cassava landraces with desirable pest and disease resistance were evaluated for 18 agronomic and tuber quality traits along with two popularly grown cultivars including an improved genotype. The improved cultivar TMS 30572 gave the highest yield, but had certain undesirable quality attributes such as high cyanogenic potential (12.86 mg HCN equivalent/100g fresh tuber weight) and low mealiness (non-poundable). Conversely, the landraces had lower cyanogenic potential (1 to 5 mg HCN equivalent/100g fresh tuber weight, considered non-toxic) and high mealiness (2.0 to 2.5 scored on a scale of 0 to 3) of boiled tubers. All cultivars exhibited relatively high dry matter percentage (33.2 to 39.2%). Taste, colour, and fibre content of boiled tubers were generally sweet to bland, white to cream, and low to moderate respectively for all cultivars. Although the landraces gave less yield than the elite cultivars, they carried genes for adaptation to local conditions, and have preferred tuber quality attributes that can be introgressed into elite germplasm development.

Keywords: Africa, Cyanogenic potential, Cassava germplasm, Mealiness.

Introduction

Locally adapted cassava landraces constitute an important part of the traditional diet of more than 600 million people in sub-Saharan Africa, Asia, and Latin America (FAO, 2002). Some African germplasm also have been used as sources of resistance to major pest and diseases particularly the African cassava mosaic disease (ACMD), cassava bacterial blight (Mignouna and Dixon, 1997) and more recently, the cassava brown streak disease (CBSD). However, these landraces are often low yielding and thus cannot compete with improved cultivars of major crops for arable lands. Nonetheless, a number of African cassava landraces have been reported to possess certain agronomic and food quality characteristics that could be potentially utilized for tuber quality and productivity improvement (Raji, 2003). Despite this, the use of African genetic resources for cassava improvement has been limited compared to the resources from Latin America and Asia. One of the factors impeding the development of African landraces has been their shy flowering habit. Other major constraints include lack of information on tuber quality and agronomic traits (Ceballos et al., 2004; Chavez et al., 2005), and details on the extent of available genetic diversity for most traits of economic importance in the African germplasm. Hence, there is a need to explore more African landraces for other end-user preferred traits, particularly tuber quality and agronomic parameters. In the present study, we examined the important tuber quality parameters of selected farmer-grown cassava landraces in Nigeria and the extent of genetic diversity of these landraces based on the traits evaluated.

Materials and Methods

This study was conducted at the International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria

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($7^{o}31'$ N; $3^{o}45'$ E; 210 m above sea level) on a ferric Luvisol soil. The site experiences a mean annual rainfall of 1305 mm having a bimodal rainfall distribution pattern with mean minimum and maximum annual temperatures of 20 to 23 and 27 to 34°C, respectively. The wet season occurs in March and early August, with a short break of two weeks in between. Rainfall resumes in late August and extends up to November (Jagtap et al., 1994).

Eleven African adapted landraces with resistance to cassava mosaic disease (CMD), and cassava green mite (CGM) were used in this study, besides an improved and widely grown cultivar (TMS 30572) as well as a popular landrace of West African origin (Table 1). Planting was done at the onset of rains in a randomized complete block design having four replications. The plot size was 40 m^2 and consisted of 40 plants of each genotype in a 4 x 10 (column by row) arrangement with 1 m spacing between plants. No fertilizers or herbicides were applied throughout the experiment; however, weeds were manually removed as and when necessary.

The morphometric parameters evaluated at periodic intervals included sprouting ability (proportion of germinated plants) at one month after planting (MAP), height to the first apical branch (ground level to the base of the first crown-forming branch) at 7 MAP, angle of first apical branch (between the vertical line of the main stem and the first branch), number of branch whorls at harvest (12 MAP) and leaf area (using a leaf area meter: Model LI 3000A, LI-COR, USA) at 3, 8, and 12 MAP, which coincides with the mid-rainy, mid-dry and early rainy seasons (i.e., at harvest) respectively, and plant height at 7, 8, 10, and 12 MAP.

Table 1. Cassava landraces and a widely grown improved cultivar (TMS 30572) evaluated and their sources of collection in Nigeria.

Cultivar	Location	State
2nd agric	Omi Alfa Camp	Ondo
Alice local	Ibadan	Oyo
'Amala'	Iruekpen	Edo
'Atu'	Iwo	Kwara
'Bagi wawa'	New Bussa	Niger
'Lapai-1'	Lapai	Niger
MS 20 ('Idiogbayepe')	Oba Akoko	Ondo
'Ofege'	Badagry	Lagos
'Oko iyawo'	New Lapai	Niger
TME 1 ('Antiota')	Egbeyemi	Ogun
'Tokunbo'	IAR&T (Moor Plantation)	Oyo
'Isunikankiyan'	Ibadan	Oyo
TMS 30572	IITA (Ibadan)	Oyo

Tuber traits were evaluated at harvest on per plot basis from the two inner rows and included fresh tuber number, tuber weight, tuber dry matter percentage, and pre-harvest deterioration ratio of tubers (i.e., proportion of rotten tubers to healthy tubers at harvest). The dry matter percentage of tubers was determined from a random bulk sample of four plants selected from the two inner rows of each plot. Whole tubers were shredded after brushing off soil from the tubers. Duplicate samples of 200 g each were dried at 70°C for 72 h (until constant weights) in a forced air-drying oven to estimate the dry weights. The cyanogenic potential of tubers was determined by enzymatic assay (Cooke, 1978). Tubers were boiled for approximately 45 min. and evaluated for poundability (mealiness) through a sensory evaluation panel on a scale of 0 to 3 (0= non-poundable, 1= fairly poundable, 2 = poundable and 3 = very poundable); taste on a scale of 1 to 3 (1 = sweet, 2 = bland, and 3 = bitter); colour on a scale of 1 to 3 (1 = white, 2 = cream, and 3 = yellow); and fibre content on a scale of 1 to 3 (1 = low fibre, 2 = moderate fibre, and 3 = high fibre).

The data were subjected to analysis of variance (ANOVA) using SAS (2004). Fisher's protected least significant difference (LSD) was used when the *F* test was significant. Principal component analysis was conducted using the correlation matrix of 18 traits (SAS, 2004). The principal component scores for the first two principal axes that accounted for most of the variations were used to generate a plot to examine the genetic variability among cultivars.

Results and Discussion

As expected, the improved cultivar TMS 30572 had the highest dry tuber yield (7.1 t ha^{-1}), which was significantly higher than the landraces (Table 2). Cultivars such as

2nd Agric, Atu, and Tokunbo gave moderate yields. The landraces, however, possessed superior tuber quality and agronomic characteristics; cyanogenic potential (CNP) was particularly low ($p<0.05$). The CNP values ranged between 4.0 mg HCN/100g fresh tuber weight for the landrace 'Isunikankiyan' to 12.86 mg HCN /100 g for the improved cultivar (TMS 30572). Making allowance for the standard error, CNP values of 'Isunikankiyan', 'Ofege', 'Atu', Alice Local, MS 20, 2nd Agric, 'Lapai-1', and TME 1 were in the range of 1 to 5 mg HCN/100 g fresh tuber weight, which is considered non-toxic (Coursey, 1970). Poundability (mealiness) of the boiled tubers ranged between 1.5 (fairly poundable) and 2.5 (poundable). The taste generally varied from sweet to bland, colour from white to cream, and fibre content from low to moderate; however, these differences were not statistically significant (data not shown). The dry matter percentage ranged from 33.2 to 39.2%. Three landraces (Amala, BagiWawa, and Oko Iyawo) and TMS 30572 had high dry matter content while TME 1, 'Lapai-1', 'Ofege', 'Isunikankiyan', and Alice Local were on the lower side of the range. Pre-harvest deterioration (ratio of rotten tuber to healthy tubers) was low for all cultivars evaluated and not statistically significant (data not shown).

Morphological parameters such as levels of branching (whorls), angle of branching, height at branching, and plant height varied significantly among cultivars (Table 2). The landrace 'Amala' branched the most, while Alice Local, 'BagiWawa', and TME 1 branched the least. The landrace 'Lapai-1', possessed a fresh storage yield of 43125 tubers/ha, a number considered high for landraces and comparable to that of the improved cultivar, TMS 30572 (59750/ha). Noteworthy also is the fact that some landraces used in this study (Alice Local, 'Tokunbo', 'BagiWawa', and 2nd Agric) were either low branching or have a wide angle of branching comparable to that of TMS 30572. This is significant as it helps in suppressing the weed flora, especially spear grass (*Imperata cylindrica*) by forming a dense canopy (Melifonwu et al., 2000).

Genetic variability of cultivars as determined by PCA

The eigen values (as proportion of the total variance)

Table 2. Agronomic and tuber quality characteristics of some farmer-grown cassava landraces and a widely grown improved cultivar (TMS 30572) in Nigeria.

Cultivar	Dry yield (t ha^{-1})	Root number/ha	Dry matter (%)	Leaf area (cm^2)	Plant height (cm)	Branching height (cm)	Level of branching	Angle of branching	CNP (mg HCN/100g fresh root wt)	Mealiness (boiled roots)
2nd Agric	4.6	36750	37.7	150.4	166.4	89.1	3.0	70.0	5.68	1.5
TMS 30572	7.1	59750	39.2	124.2	184.1	157.3	3.5	70.0	12.86	0.0
Alice Local	3.1	22000	33.2	211.0	200.4	59.0	2.5	35.0	4.86	0.0
'Amala'	2.2	18250	38.0	102.7	166.9	104.7	3.8	61.3	9.38	0.0
'Atu'	4.4	37000	36.2	96.4	169.6	89.0	3.0	68.8	4.53	0.5
'Bagi Wawa'	3.0	25875	38.8	140.0	191.3	109.0	2.3	70.0	7.18	2.0
'Isunikankiyan'	2.6	23875	33.9	76.7	192.5	163.8	3.0	40.0	4.01	2.5
'Lapai-1'	4.9	43125	37.0	108.9	183.4	112.0	3.0	47.5	5.69	2.5
MS 20	2.4	19625	34.1	121.9	181.3	83.7	3.0	35.0	5.63	0.0
'Ofege'	2.8	21250	34.6	109.6	189.1	93.8	3.0	35.0	4.49	0.0
'Oko Iyawo'	2.6	23125	38.5	115.4	160.9	94.3	3.0	61.3	7.25	2.5
TME 1	3.5	25250	34.2	103.3	190.1	87.5	2.3	63.8	5.85	0.0
'Tokunbo'	4.3	41000	37.5	149.8	166.9	94.7	3.0	72.5	6.66	1.5
F-test	*	**	*	**	**	**	**	**	*	**
$LSD_{0.05}$	2.51	17996	4.02	25.45	18.48	26.8	0.5	10.5	4.24	2.0

CNP: Cyanogenic potential.

are listed in Table 3 for the first three principal components, which accounted for 65% of the total variation of all the traits. PC1, PC2, and PC3 accounted for 35, 16, and 14% respectively of the total variability. Traits that accounted for most of the observed variations of the first and second principal components were leaf area, final plant stand, tuber number, dry tuber yield, fresh tuber yield, dry matter, plant height angle of branching, height of branching, and sprouting ability. The first and second principal components accounted for more than 50% of the total variability and organized the cultivars into five distinct clusters (Fig. 1), while the third principal component accounted for only 14% of the variation. Regarding the clustering pattern, clusters 1 to 4 had four ('Ofege', 'Amala', 'Isunikankiyan', and 'Oko Iyawo'), three (MS 20, TME 1, and 'BagiWawa'), and four cultivars ('Lapai-1', 2nd Agric, 'Tokunbo', and 'Atu') respectively. The landrace Alice Local (cluster 4) and the improved cultivar TMS 30572 (cluster 5) formed separate clusters with one entry each.

Overall, the landraces in our study exhibited considerable genetic variations, which could be further explored and utilized in combination with the recent knowledge on

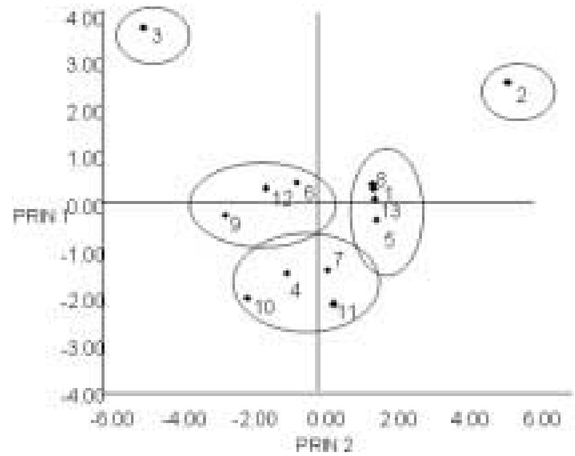

Figure 1. Genetic relationship among Nigerian cassava landraces and a widely grown improved cultivar (TMS 30572) as determined by principal component analysis of 18 agronomic and tuber quality traits (1 = 2nd Agric, 2 = 30572, 3 = Alice Local, 4 = 'Amala', 5 = Atu, 6 = 'BagiWawa', 7 = 'Isunikankiyan', 8 = 'Lapai-1', 9 = MS 20, 10 = 'Ofege', 11= 'Oko Iyawo', 12 = TME 1, and 13 = 'Tokunbo').

Table 3. Principal component eigenvectors and eigenvalue (%) of agronomic and food quality characteristics of cassava landraces and a widely grown improved cultivar (TMS 30572) in Nigeria.

Trait	Prin 1	Prin 2	Prin3
Sprouting ability (stem cuttings at 1 MAP)	0.23	-0.34	-0.03
Leaf area (cm^2)	-0.14	0.43	-0.11
Canopy retention capacity	-0.27	0.24	0.33
Plant height	-0.17	0.27	-0.00
Height of first branching	0.26	-0.07	0.00
Levels of branching	0.19	-0.16	0.37
Angle of branching	0.26	0.03	-0.15
Final plant stand at harvest (per 20 m^2 at 12 MAP)	0.32	-0.11	-0.05
Root number per ha	0.34	0.26	0.04
Fresh storage root yield per ha	0.29	0.35	0.10
Dry matter percentage	0.28	-0.04	-0.04
Dry storage root yield per ha	0.31	0.32	0.08
Cyanogenic potential (mg/100g fresh root weight)	0.22	0.15	0.24
Pre-harvest deterioration	-0.24	-0.23	0.30
Poundability (mealiness of boiled storage roots)	0.12	-0.18	-0.48
Taste of (boiled) storage roots	0.03	-0.25	0.47
Color of (boiled) storage roots	-0.11	0.22	-0.08
Fiber content of (boiled) storage roots	0.21	0.06	0.30
Eigenvalue (% of total variance)	36	16	15

Prin= principal component; MAP= months after planting.

genomics, cloning, and marker assisted selection (Nassar and Ortiz, 2007), besides capturing the heterotic effects for yield and quality improvement. Another striking observation is that the African landraces clustered separately from the popular improved cultivar TMS 30572, which signifies the differential origin of these varieties. This is also consistent with the observations of Mignouna and Dixon (1997) in a study conducted to assess the extent of genetic diversity in some elite and landrace cultivars of cassava resistant to ACMD using molecular markers.

Overall, farmers maintain diverse cassava populations on their farms in view of their superior agronomic and tuber quality attributes, which may not necessarily translate into high yields. This high genetic diversity available at the farmer's level (Mignouna and Dixon, 1997) may also aid in developing trait-specific cassava populations with emphasis on tuber quality (for food, animal feed and industrial purposes). This study also revealed some new sources for low cyanogenic potential and high mealiness, in addition to providing information about the desirable agronomic and food quality characteristics of cassava landraces in Nigeria. Evaluation of a more extensive collection of African cassava landraces is currently in progress at the International Institute of Tropical Agriculture.

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