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GENETIC ASSESSMENT OF 23 CASSAVA, *MANIHOT ESCULENTA* CRANTZ,  
GENOTYPES AT TWO AGRO-CLIMATIC ZONES IN NIGERIA

ABSTRACT

This study investigated genetic diversity among 23 cassava genotypes in two-agro-ecological zones (Ibadan and Mokwa), Nigeria. The experiment was conducted using a randomized complete block design with three replicates. The cassava genotypes were evaluated for tuber yield, fresh weight of tuber, number of tubers, tuber girth and length, dry matter and chlorophyll concentration. The data collected were subjected to analysis of variance and differences among the genotypes were computed using Duncan's multiple range test. Single linkage cluster and FASTCLUS analysis were used to group the cassava genotypes. Genotypic and phenotypic coefficient of variability, heritability and genetic advance were also evaluated. Genotype, environment and genotype  $\times$  environment interaction (GEI) were significant ( $P < 0.01$ ) for most of the traits evaluated. The magnitude of the environment was higher compared to genotype and GEI. Comparative mean performance varied from location to location. Tuber yield ranged from 0.32 for 92/0325 to 0.90 kg for 99/3073 with mean of 0.58 kg, and 0.16 kg for 82/00058 to 0.67 kg for 98/0581 with mean of 0.35 kg in Mokwa. Higher genotypic and phenotypic coefficients of variability were observed in Ibadan than Mokwa, for most of the characters. The interrelationships among the characters revealed the superiority of some cassava genotypes for a character in one location and not in the other location. However, breeding potentials exists among the cassava genotypes across the two environments.

Key word: cassava, FASTCLUS, morphological performance,  $G \times E$  interaction

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial shrub widely grown in tropical Africa, Asia and Latin America (Olsen and Schaal, 2001). Nigeria

is the highest cassava producer in the world, producing a third more than Brazil and almost double the production capacity of Thailand and Indonesia. She produces about 38 million metric tonnes (MT) per annum, a figure expected to double by 2020 (FAO, 2002).

Cassava is the developing world's fourth most important crop, with production in 2006 estimated at 226 million tones (FAO, 2006). It produces bulky storage roots with a heavy concentration of carbohydrates. Apart from food, cassava derivatives and starch are used as confectionery, sweeteners, glues, plywood, textiles, paper, biodegradable products, monosodium glutamate and drugs.

In Nigeria, cassava is one of the most important staple foods, and the cheapest main source of dietary food energy for nearly one-third of the population of sub-Saharan Africa (Nweke *et al.*, 2002; Tsegia *et al.*, 2002). Currently, the government of Nigeria considers a transition from the present status of usage to the level of industrial raw material and livestock feed as a development goal that can spur growth with increase in employment. This consideration, therefore, emphasized the need for various research geared towards cassava improvement and production. The objectives of this study are to assess the influence of environment and genotypic differences on root yield and related traits.

#### MATERIALS AND METHODS

The experiment was conducted at two locations in Nigeria, Ibadan (Derived savanna) and Mokwa (Southern guinea savanna) Table 1. Twenty-three cassava genotypes from International Institute of Tropical Agriculture (IITA), Nigeria were used for the study. The experimental design was a randomized complete block design with three replicates at each site under rain-fed conditions. Each plot consisted of 60 plants in ten-plant rows. The ridges were 1 m apart, 30 cm high and 6 m long. Spacing between plants was 1 m. Weeding was done as necessary. At harvest (12 months after planting), data were collected from the inner plants within a plot for tuber length and diameter, fresh tuber yield, number of tubers and dry matter weight. Dry matter weights of tuberous roots were determined from a random bulk sample of five plants selected from the inner rows. The roots were peeled and shredded after washing. One hundred grams of fresh root (cortex) was taken in the form of chips and dried at 60°C for 48 h in a forced air oven. The dried samples were then reweighed to obtain the dry weights. Dry tuber yield was estimated by multiplying fresh storage tuber yield by dry matter content (Kawano *et al.*, 1987). Chlorophyll concentration was measured using a Minolta chlorophyll meter.

Table 1

Description of the agro-ecologies of the trial locations

Geographical data	Ibadan	Mokwa
Ecological zone	Forest savannah transition	Sub-humid Southern Guinea savannah
Longitude	3°01'W	11°30'E
Latitude	7°29'N	7°22'S
Altitude [m.a.s.l.]	215	161
Minimum temperature [°C]	12	13
Maximum temperature [°C]	34	36
Mean annual rainfall [mm]	1300	1150
Soil type	Ferric-luvisols	Ferric-luvisols

Analysis of variance was performed using the GLM procedure of Statistical Analysis System (SAS, 9.2) and differences among the genotypes were computed using Duncan's multiple range test. The genetic and phenotypic variance components were used to compute the genotypic and phenotypic coefficients of variability, heritability (in the broad-sense) and genetic advance (Kumar *et al.*, 1985; Allard, 1960)

$$\text{Genotypic coefficient of variability} = \frac{\delta_g}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variability} = \frac{\delta_{ph}}{\bar{X}} \times 100$$

$$H_B = \frac{\delta_g^2}{\delta_g^2 + \delta_e^2}$$

$$\text{Genetic advance} = H_B \times K \times \delta_{ph}$$

where

$\delta_g$  — genotypic standard deviation

$\delta_{ph}$  — phenotypic standard deviation

$H_B$  — heritability

$\bar{X}$  — grand mean for the character under consideration.

$\delta_g^2$  — genotypic variance

$\delta_e^2$  — environmental variance.

$K$  is selection differential = 2.06 (assuming 5% selection)

## RESULTS

The combined analysis of variance across two environments (Table 2) showed significant ( $P \leq 0.01$ ) genotype and location effects for chlorophyll concentration, tuber diameter and length, number of tubers, dry matter and dry tuber yield. Genotype  $\times$  environment interaction (GEI) showed significant mean squares ( $P \leq 0.01$ ) for all traits evaluated except number of tubers and fresh weight of tubers. Also, the table revealed that the relative magnitude of the environmental effect (as a proportion of the total sum of squares) was higher compared to genotype and GEI effects.

Table 2

Mean squares from combined analysis of variance of yield and related characters in 23 cassava genotypes across two locations

Source	DF	Chlorophyll concentration	Tuber diameter [cm]	Tuber length [cm]	Number of tubers/plant	Fresh weight of tubers per plant [kg]	Dry matter [kg]	Tuber yield per plant [kg]
Block	4	6.56	3.42**	950.81**	13.97**	2.14**	0.0003**	0.15**
Genotype (G)	22	28.70**	1.25**	229.77**	5.27**	1.49**	0.0002**	0.07**
Environment (E)	1	290.73**	144.54**	497.42**	230.83**	2.08	0.0085**	1.90**
G $\times$ E	22	18.61**	1.34**	192.78**	3.09	0.81	0.0002**	0.06**
Error	88	5.83	0.44	42.83	2.26	0.62	0.00003	0.02
CV (%)		6.82	12.46	23.88	25.97	33.89	13.96	32.27

Block = block within location; \*\* significant at 1% probability level

Tables 3 and 4 showed the mean performance for the 23 cassava genotypes at Ibadan and Mokwa, respectively. Tuber yield ranged from 0.32 for 92/0325 to 0.90 kg for 99/3073 with mean of 0.58 kg, and 0.16 kg for 82/00058 to 0.67 kg for 98/0581 with mean of 0.35 kg in Mokwa. Thirteen (13) of the genotypes had above average yield in Ibadan and eleven (11) in Mokwa. Genotypes 96/0289 and TME419 had the highest tuber weight of 3.70 kg and dry matter of 0.067 kg, respectively, at Ibadan. However, genotypes 98/0581 and 96/1089A had the highest tuber weight (4.40 kg) and dry matter (0.050 kg), respectively at Mokwa. The average number of tubers varied significantly among the genotypes at Mokwa and ranged from 4 (98/0510) to 9 (97/4769) with average number of 7 tubers. However, it varies from 3 (90/0325) to 7 (96/0289) with average number of 5 tubers per plant in Ibadan.

Table 3  
 Mean performance of the 23 cassava genotypes evaluated for root yields and its component at Ibadan

Variety	Chlorophyll concentration	Tuber diameter [cm]	Tuber length [cm]	Number of tubers per plant	Fresh weight of tubers/plant [kg]	Dry matter [kg]	Tuber yield/plant [kg]
99/3073	35.57 <sup>a-d</sup>	6.30 <sup>de</sup>	29.00 <sup>le</sup>	6.34 <sup>a-c</sup>	3.24 <sup>ab</sup>	0.056 <sup>b-d</sup>	0.90 <sup>a</sup>
TME419	34.47 <sup>b-d</sup>	6.35 <sup>de</sup>	33.33 <sup>cf</sup>	4.40 <sup>b-d</sup>	2.46 <sup>a-f</sup>	0.067 <sup>a</sup>	0.82 <sup>ab</sup>
95/0289	38.63 <sup>a</sup>	8.20 <sup>a</sup>	56.00 <sup>ab</sup>	7.22 <sup>a</sup>	3.70 <sup>a</sup>	0.044 <sup>bj</sup>	0.81 <sup>ab</sup>
82/00058	33.93 <sup>b-d</sup>	8.60 <sup>a</sup>	32.00 <sup>f</sup>	6.82 <sup>ab</sup>	3.22 <sup>ab</sup>	0.042 <sup>bj</sup>	0.68 <sup>a-c</sup>
96/1565	34.00 <sup>b-d</sup>	7.60 <sup>a-c</sup>	40.67 <sup>de</sup>	4.11 <sup>b-d</sup>	3.02 <sup>a-d</sup>	0.044 <sup>bj</sup>	0.67 <sup>a-c</sup>
M98/0040	39.40 <sup>a</sup>	6.35 <sup>de</sup>	22.33 <sup>gh</sup>	4.70 <sup>a-d</sup>	2.62 <sup>a-c</sup>	0.050 <sup>c-g</sup>	0.65 <sup>a-c</sup>
30572	28.37 <sup>ef</sup>	6.20 <sup>de</sup>	25.67 <sup>le</sup>	5.88 <sup>a-c</sup>	3.15 <sup>a-c</sup>	0.041 <sup>ij</sup>	0.64 <sup>a-c</sup>
98/0581	33.38 <sup>b-d</sup>	7.65 <sup>a-c</sup>	52.67 <sup>a-c</sup>	5.41 <sup>a-d</sup>	2.86 <sup>a-d</sup>	0.045 <sup>ej</sup>	0.64 <sup>a-c</sup>
96/1632	36.40 <sup>a-c</sup>	6.67 <sup>c-e</sup>	41.33 <sup>de</sup>	4.23 <sup>b-d</sup>	2.03 <sup>b-f</sup>	0.063 <sup>ab</sup>	0.64 <sup>a-c</sup>
97/4769	26.27 <sup>f</sup>	6.43 <sup>de</sup>	28.33 <sup>le</sup>	3.95 <sup>cd</sup>	2.20 <sup>b-f</sup>	0.058 <sup>bc</sup>	0.64 <sup>a-c</sup>
98/0510	38.73 <sup>a</sup>	8.00 <sup>ab</sup>	45.67 <sup>cd</sup>	4.09 <sup>b-d</sup>	2.66 <sup>a-c</sup>	0.046 <sup>ej</sup>	0.63 <sup>a-c</sup>
4(2)1425	31.70 <sup>de</sup>	7.00 <sup>b-e</sup>	57.67 <sup>a</sup>	3.79 <sup>cd</sup>	2.26 <sup>b-f</sup>	0.053 <sup>c-g</sup>	0.60 <sup>b-d</sup>
92B/00068	34.53 <sup>b-d</sup>	7.00 <sup>b-e</sup>	15.33 <sup>h</sup>	3.67 <sup>cd</sup>	2.48 <sup>a-f</sup>	0.048 <sup>ej</sup>	0.60 <sup>b-d</sup>
91/02324	33.17 <sup>b-d</sup>	6.00 <sup>ef</sup>	45.00 <sup>cd</sup>	5.29 <sup>a-d</sup>	2.71 <sup>a-c</sup>	0.042 <sup>bj</sup>	0.56 <sup>b-d</sup>
96/1089A	37.00 <sup>ab</sup>	6.33 <sup>de</sup>	49.00 <sup>b-d</sup>	5.64 <sup>a-c</sup>	2.76 <sup>a-c</sup>	0.041 <sup>hj</sup>	0.56 <sup>b-c</sup>
98/0505	28.53 <sup>ef</sup>	6.43 <sup>de</sup>	31.67 <sup>f</sup>	3.64 <sup>cd</sup>	2.00 <sup>b-f</sup>	0.045 <sup>ej</sup>	0.53 <sup>b-c</sup>
97/0162	33.10 <sup>b-d</sup>	7.00 <sup>b-e</sup>	30.67 <sup>le</sup>	3.91 <sup>cd</sup>	2.11 <sup>b-f</sup>	0.045 <sup>ej</sup>	0.47 <sup>c-g</sup>
94/0034	33.97 <sup>b-d</sup>	6.23 <sup>de</sup>	29.00 <sup>le</sup>	4.93 <sup>a-d</sup>	2.23 <sup>b-f</sup>	0.038 <sup>j</sup>	0.43 <sup>cd</sup>
96/0603	32.38 <sup>c-e</sup>	6.43 <sup>de</sup>	29.00 <sup>le</sup>	5.44 <sup>a-d</sup>	1.93 <sup>c-f</sup>	0.043 <sup>hj</sup>	0.42 <sup>cd</sup>
96/1642	31.63 <sup>de</sup>	6.40 <sup>de</sup>	33.00 <sup>cf</sup>	5.36 <sup>a-d</sup>	1.54 <sup>ef</sup>	0.054 <sup>c-e</sup>	0.41 <sup>cd</sup>
92/0067	31.43 <sup>de</sup>	7.10 <sup>b-e</sup>	30.00 <sup>le</sup>	4.02 <sup>cd</sup>	1.81 <sup>d-f</sup>	0.043 <sup>hj</sup>	0.39 <sup>cd</sup>
M98/0028	34.10 <sup>b-d</sup>	5.07 <sup>f</sup>	28.67 <sup>le</sup>	4.37 <sup>b-d</sup>	1.83 <sup>d-f</sup>	0.042 <sup>hj</sup>	0.38 <sup>cd</sup>
92/0325	31.70 <sup>de</sup>	6.40 <sup>de</sup>	26.33 <sup>le</sup>	2.73 <sup>d</sup>	1.31 <sup>f</sup>	0.049 <sup>dh</sup>	0.32 <sup>d</sup>
Mean	33.58 ± 0.45	6.76 ± 0.11	35.32 ± 1.39	4.78 ± 0.19	2.44 ± 0.10	0.05 ± 0.001	0.58 ± 0.02

Means followed by the same letter within the column are not significantly different ( $P \leq 0.05$ ) using DMRT

The highest concentration of chlorophyll was recorded for genotypes M98/0040 (39.40), 98/0510 (38.73) and 95/0289 (38.63) at Ibadan while 99/3073 had the highest chlorophyll concentration of 41.70 at Mokwa.

Table 4  
Mean performance of the 23 cassava genotypes evaluated for root yields and its component at Mokwa

Variety	Chlorophyll concentration	Tuber diameter [cm]	Tuber length [cm]	Number of tubers per plant	Fresh weight of tubers/plant [kg]	Dry matter [kg]	Tuber yield/plant [kg]
99/3073	41.70 <sup>a</sup>	4.77 <sup>a-c</sup>	35.67 <sup>a</sup>	7.14 <sup>a-d</sup>	2.10 <sup>bc</sup>	0.036 <sup>cd</sup>	0.38 <sup>b-c</sup>
TME 419	37.37 <sup>ab</sup>	4.57 <sup>a-c</sup>	32.67 <sup>a</sup>	8.84 <sup>ab</sup>	2.66 <sup>b</sup>	0.018 <sup>h</sup>	0.23 <sup>d-e</sup>
95/0289	37.63 <sup>ab</sup>	4.37 <sup>bc</sup>	32.00 <sup>a</sup>	7.00 <sup>a-d</sup>	2.60 <sup>bc</sup>	0.029 <sup>ef</sup>	0.36 <sup>c-e</sup>
82/00058	31.93 <sup>c</sup>	3.97 <sup>bc</sup>	26.00 <sup>a</sup>	7.57 <sup>a-c</sup>	1.94 <sup>bc</sup>	0.017 <sup>h</sup>	0.16 <sup>e</sup>
96/1565	38.00 <sup>ab</sup>	4.90 <sup>a-c</sup>	41.00 <sup>a</sup>	7.00 <sup>a-c</sup>	2.23 <sup>bc</sup>	0.033 <sup>df</sup>	0.38 <sup>b-c</sup>
M98/0040	38.67 <sup>ab</sup>	4.77 <sup>a-c</sup>	29.67 <sup>a</sup>	9.17 <sup>ab</sup>	2.35 <sup>bc</sup>	0.026 <sup>ef</sup>	0.29 <sup>b-c</sup>
30572	35.50 <sup>bc</sup>	5.00 <sup>a-c</sup>	39.00 <sup>a</sup>	8.48 <sup>a-c</sup>	2.07 <sup>bc</sup>	0.031 <sup>df</sup>	0.32 <sup>c-e</sup>
98/0581	37.63 <sup>ab</sup>	4.53 <sup>a-c</sup>	29.33 <sup>a</sup>	7.00 <sup>abc</sup>	4.40 <sup>a</sup>	0.032 <sup>df</sup>	0.67 <sup>a</sup>
96/1632	35.30 <sup>bc</sup>	4.67 <sup>a-c</sup>	31.33 <sup>a</sup>	7.67 <sup>a-c</sup>	1.86 <sup>bc</sup>	0.043 <sup>b</sup>	0.39 <sup>a-e</sup>
97/4769	39.07 <sup>ab</sup>	5.20 <sup>a-c</sup>	31.33 <sup>a</sup>	9.27 <sup>a</sup>	2.89 <sup>bc</sup>	0.044 <sup>ab</sup>	0.66 <sup>ab</sup>
98/0510	38.57 <sup>ab</sup>	5.30 <sup>ab</sup>	26.33 <sup>a</sup>	4.17 <sup>d</sup>	0.97 <sup>c</sup>	0.032 <sup>df</sup>	0.15 <sup>e</sup>
4(2)1425	35.13 <sup>bc</sup>	4.53 <sup>a-c</sup>	31.33 <sup>a</sup>	6.00 <sup>b-d</sup>	2.06 <sup>bc</sup>	0.034 <sup>de</sup>	0.36 <sup>c-e</sup>
92B/00068	37.27 <sup>ab</sup>	4.97 <sup>a-c</sup>	28.67 <sup>a</sup>	6.50 <sup>a-d</sup>	1.76 <sup>bc</sup>	0.027 <sup>ef</sup>	0.23 <sup>d-e</sup>
91/02324	35.37 <sup>bc</sup>	5.27 <sup>ab</sup>	32.33 <sup>a</sup>	8.00 <sup>a-c</sup>	2.52 <sup>bc</sup>	0.033 <sup>df</sup>	0.41 <sup>a-e</sup>
96/1089A	37.76 <sup>ab</sup>	4.33 <sup>bc</sup>	38.33 <sup>a</sup>	7.20 <sup>a-d</sup>	2.22 <sup>bc</sup>	0.050 <sup>a</sup>	0.44 <sup>a-e</sup>
98/0505	36.47 <sup>bc</sup>	5.77 <sup>a</sup>	35.00 <sup>a</sup>	7.25 <sup>a-d</sup>	2.15 <sup>bc</sup>	0.044 <sup>ab</sup>	0.47 <sup>a-d</sup>
97/0162	35.17 <sup>bc</sup>	4.87 <sup>a-c</sup>	33.33 <sup>a</sup>	6.55 <sup>a-d</sup>	2.04 <sup>bc</sup>	0.027 <sup>ef</sup>	0.26 <sup>c-e</sup>
94/0034	35.50 <sup>bc</sup>	4.40 <sup>a-c</sup>	28.33 <sup>a</sup>	9.14 <sup>ab</sup>	2.58 <sup>bc</sup>	0.042 <sup>bc</sup>	0.53 <sup>abc</sup>
96/0603	35.20 <sup>bc</sup>	5.07 <sup>a-c</sup>	29.67 <sup>a</sup>	7.05 <sup>a-d</sup>	2.01 <sup>bc</sup>	0.023 <sup>gh</sup>	0.22 <sup>d-e</sup>
96/1642	36.20 <sup>bc</sup>	3.93 <sup>bc</sup>	25.00 <sup>a</sup>	7.51 <sup>a-c</sup>	1.93 <sup>bc</sup>	0.029 <sup>ef</sup>	0.27 <sup>c-e</sup>
92/0067	37.93 <sup>ab</sup>	4.60 <sup>a-c</sup>	32.00 <sup>a</sup>	6.00 <sup>a-d</sup>	2.05 <sup>bc</sup>	0.032 <sup>df</sup>	0.32 <sup>c-e</sup>
M98/0028	34.00 <sup>bc</sup>	3.87 <sup>c</sup>	27.33 <sup>a</sup>	8.00 <sup>a-c</sup>	1.66 <sup>bc</sup>	0.034 <sup>de</sup>	0.28 <sup>c-e</sup>
92/0325	31.83 <sup>c</sup>	4.87 <sup>a-c</sup>	29.33 <sup>a</sup>	5.36 <sup>cd</sup>	1.39 <sup>bc</sup>	0.033 <sup>df</sup>	0.22 <sup>d-e</sup>
Mean	36.50 ± 0.37	4.72 ± 0.10	31.52 ± 1.28	7.37 ± 0.24	2.19 ± 0.12	0.03 ± 0.001	0.35 ± 0.02

Means followed by the same letter within the column are not significantly different ( $P \leq 0.05$ ) using DMRT

The estimate of phenotypic and genotypic coefficients of variability, heritability (broad-sense) and genetic advance expressed as percentage of grand mean is presented in the Table 5. Generally, the GCV are lower in magnitude than the PCV. Although the magnitude of the variability differed

from location to location for each character, higher GCV and PCV were recorded for most of the characters at Ibadan compared to Mokwa. The genotypic coefficients of variability ranged from 8.96 for chlorophyll concentration to 30.52 for tuber length in Ibadan and 4.61 for leaf chlorophyll concentration to 31.51 for tuber yield in Mokwa. Heritability estimates (broad-sense) above 60% was observed for chlorophyll concentration, tuber diameter and length, weight of tuber, dry matter and tuber yield at Ibadan and only dry matter and tuber yield at Mokwa. Low value of genetic advance was observed for chlorophyll concentration (7.09), tuber diameter (4.91) and tuber length (6.09) at Mokwa.

Table 5

**Estimates of phenotypic and genotypic coefficient of variability, heritability and genetic advance of yield and its components**

Cultivar	Location	Phenotypic coefficient of variability	Genotypic coefficient of variability	Heritability [%]	Genetic advance [%]
Chlorophyll Concentration	Ibadan	9.74	8.96	84.64	16.99
	Mokwa	6.17	4.61	55.74	7.09
Tuber Diameter	Ibadan	11.93	10.64	79.56	19.54
	Mokwa	9.80	4.83	24.31	4.91
Tuber Length	Ibadan	31.48	30.52	93.99	60.95
	Mokwa	13.18	6.24	22.43	6.09
Number of Tubers	Ibadan	22.44	14.76	43.26	20.00
	Mokwa	16.70	11.11	44.26	15.23
Weight of Tubers	Ibadan	24.46	19.21	61.70	31.09
	Mokwa	29.13	16.44	31.86	19.12
Dry Matter	Ibadan	15.69	14.68	87.60	28.31
	Mokwa	24.98	24.08	92.90	47.80
Tuber yield	Ibadan	26.23	21.62	67.96	36.71
	Mokwa	40.11	31.51	61.70	50.98

Table 6 shows the qualitative description of the 23 cassava genotypes used in the study across the two environments. The observation revealed variability among the cassava genotypes for growth pattern and colour. The growth pattern ranged from short genotypes (< 2 m) with and without branches to tall genotypes ( $\geq$  2 m) with and without branches. The number of leaf lobes varied from five to six and seven. Leaf, stem and petiole colour ranges from green to greenish-red, reddish-green and purple. Most of the genotypes with above mean tuber yield at Ibadan were related to

branching growth pattern while there is no specific association of growth pattern with tuber yield in Mokwa.

Table 6

**Qualitative characters of the 23 genotypes of cassava across two environments**

Variety	Growth habit	Leaf colour	Leaf vein colour	Stem colour	Petiole colour	Number of lobes	Lobe shape
99/3073	Tall with branches	Dark green	Green	Silver green	Greenish-red	Seven	Lanceolate
TME419	Tall without branches	Purple-green	Green	Light brown	Green	Five	Lanceolate
95/0289	Tall without branches	Purple	Reddish-green	Dark brown	Greenish-red	Six	Elliptic
82/00058	Tall with branches	Purple	Reddish-green	Light brown	Greenish-red	Five	Lanceolate
96/1565	Tall with branches	Purple-green	Green	Silver green	Green	Five	Elliptic
M98/0040	Short without branches	Purple-green	Green	Silver green	Purple	Six	Lanceolate
30572	Tall with branches	Purple	Reddish-green	Dark brown	Green	Five	Lanceolate
98/0581	Short without branches	Purple-green	Green	Silver green	Purple	Six	Elliptic
96/1632	Short without branches	Purple-green	Green	Light brown	Green	Five	Lanceolate
97/4769	Short with branches	Purple	Reddish-green	Dark brown	Purple	Five	Lanceolate
98/0510	Short with branches	Purple-green	Green	Silver green	Green	Six	Lanceolate
4(2)1425	Short with branches	Purple-green	Green	Light brown	Green	Six	Lanceolate
92B/00068	Short with branches	Purple	Reddish-green	Dark brown	Purple	Six	Lanceolate
91/02324	Tall with branches	Purple-green	Green	Dark brown	Greenish-red	Five	Elliptic
96/1089A	Short with branches	Purple	Reddish-green	Silver green	Green	Five	Elliptic
98/0505	Short without branches	Purple-green	Green	Light brown	Greenish-red	Five	Lanceolate
97/0162	Tall without branches	Dark green	Green	Silver green	Greenish-red	Five	Elliptic
94/0034	Tall without branches	Dark green	Green	Light brown	Green	Six	Lanceolate
96/0603	Tall without branches	Dark green	Green	Light brown	Green	Seven	Lanceolate
96/1642	Tall with branches	Light green	Green	Silver green	Purple	Five	Elliptic
92/0067	Tall without branches	Purple-green	Green	Dark brown	Purple	Seven	Lanceolate
M98/0028	Short without branches	Purple	Reddish-green	Light brown	Purple	Six	Lanceolate
92/0325	Short with branches	Purple	Reddish-green	Dark brown	Purple	Seven	Lanceolate

Short (< 2 m), Tall ( $\geq$  2 m)

The dendrogram generated from single linkage cluster analysis is presented in Fig. 1. The resultant dendrogram grouped the twenty-three cassava genotypes into four and six main clusters at Ibadan and Mokwa, respectively. The cluster order in the dendrograms was not absolutely identical at the two locations. Genotypes M98/0040 and 92B/0006 were distinct from the other cassava genotypes at Ibadan while 92B/0006, 96/1642,



92/0325 and 98/0505 were unique at Mokwa. Also, genotypes 96/0289, 96/1565, 96/1632, 91/02324, 98/0510, 98/0581 and 4(2)1425 were grouped together in cluster II and cluster I at Ibadan and Mokwa, respectively.

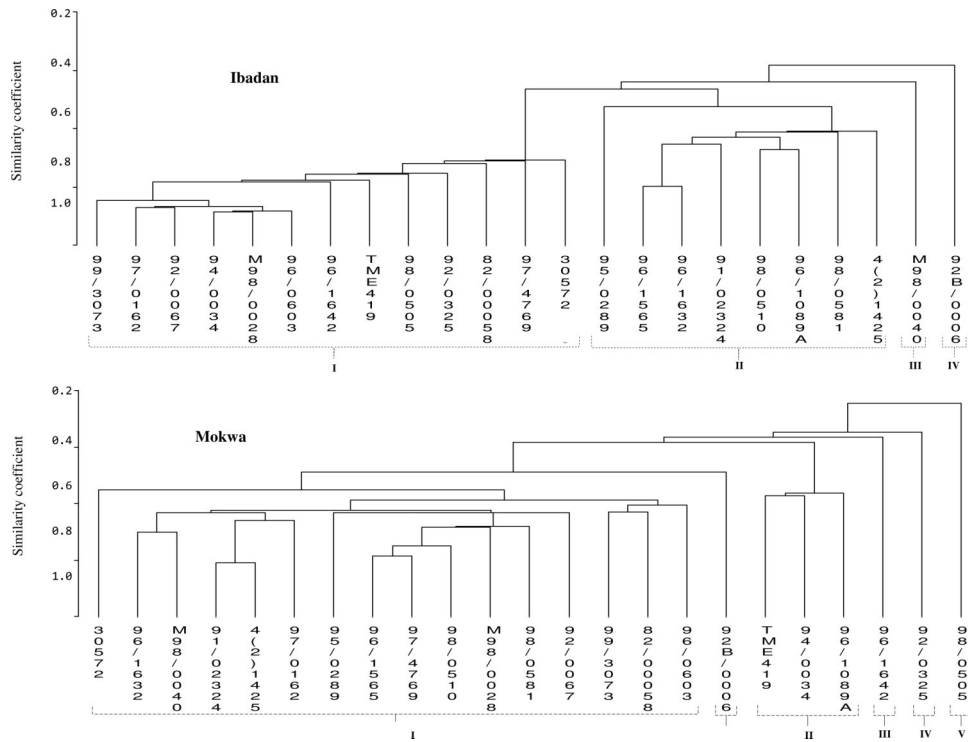


Fig. 1. Cluster analysis dendrogram of the 23 cassava genotypes at the two locations

The means of six cluster groups generated by the FASTCLUS analysis is presented in Table 7. The pattern of association among the cassava genotypes revealed unique information about their morphological characteristic, and varies across the locations. The range of means revealed a higher performance for most of the characters at Ibadan than Mokwa, however, the means revealed that chlorophyll concentration, tuber length and number of tubers contributed the largest proportion of morphological variation at both locations. At Ibadan, mean value of fresh weight of tubers and tuber yield ranged from group I (2.16 and 0.52 kg, respectively) with nine cassava genotypes to group III (3.70 and 0.81 kg, respectively) with genotype 95/0289 while at Mokwa, it ranged from group IV (0.97 and 0.15 kg, respectively) with two genotypes to group II (2.48 and 0.39 kg, respectively) with ten genotypes. The character pattern also reveals that 95/0289 had the highest value for most of the characters evaluated in the study at Ibadan while group II which included 95/0289 and 98/0581 had the highest value for tuber girth, fresh weight of tubers and tuber yield at Mokwa. Also, the

morphological arrangement at Mokwa reveals a relationship between chlorophyll concentration and dry matter yield. Group III with the highest value of chlorophyll concentration was also characterized with high dry matter while group IV had the lowest value of chlorophyll concentration and dry matter.

Table 7

Characteristics pattern of six groups of cassava genotypes at the two locations

Parameters	Group I	Group II	Group III	Group IV	Group V	Group VI	Range of means
	Ibadan						
	82/00058, 92/0067, 92/0325, 94/0034, 96/0603, 96/1642, 97/0162, 99/3073, TME419	4(2)1425, 98/0581	95/0289	30572, 97/4769, 98/0505	91/02324, 96/1089A, 96/1565, 96/1632, 98/0510	92B/0006, M98/0040	
Chlorophyll concentration	33.23 (1.40)	32.54 (1.19)	38.63 (-)	27.72 (1.26)	35.86 (2.26)	36.97 (3.44)	10.91 (3.89)
Tuber girth	6.59 (0.89)	7.33 (0.46)	8.20 (-)	6.35 (0.13)	6.92 (0.85)	6.68 (0.46)	1.85(0.67)
Tuber length	30.10 (2.18)	55.17 (3.54)	56.00 (-)	28.56 (3.01)	44.33 (3.41)	18.83 (4.93)	37.17 (15.32)
Number of tubers	4.70 (1.16)	4.50 (0.71)	7.00 (-)	4.67 (1.15)	4.60 (0.89)	4.50 (0.71)	2.50 (0.99)
Fresh weight of tubers	2.16 (0.64)	2.56 (0.42)	3.70 (-)	2.47 (0.65)	2.64 (0.37)	2.55 (0.09)	1.54 (0.53)
Dry matter	0.048 (0.01)	0.045 (0.01)	0.040 (-)	0.050 (0.01)	0.046 (0.01)	0.050 (-)	0.008 (0.21)
Yield	0.52 (0.20)	0.62 (0.03)	0.81 (-)	0.60 (0.06)	0.61 (0.05)	0.63 (0.04)	0.29 (0.10)
	Mokwa						
	TME419	30572, 4(2)1425, 91/02324, 92/0067, 95/0289, 96/1565, 96/1632, 97/4769, 98/0510, 98/0581	94/0034, 96/1089A	92/0325, 92B/0006	98/0505	82/00058, 96/0603, 96/1642, 99/3073, M98/0040,	
Chlorophyll concentration	34.41 (1.88)	37.08 (1.34)	41.70 (-)	38.57 (-)	37.10 (1.39)	34.05 (1.92)	7.65 (2.82)
Tuber girth	4.04 (0.24)	4.87 (0.41)	4.77 (-)	5.30 (-)	4.73 (0.38)	4.82 (0.27)	1.26 (0.41)
Tuber length	26.67 (1.46)	31.61 (1.85)	35.67 (-)	26.33 (-)	39.44 (1.39)	30.11 (1.07)	13.11 (5.14)
Number of tubers	8.25 (0.50)	7.64 (1.03)	7.00 (-)	4.00 (-)	7.33 (0.58)	6.00 (1.00)	4.25 (1.52)
Fresh weight of tubers	2.03 (0.39)	2.48 (0.73)	2.10 (-)	0.97 (-)	2.17 (0.09)	1.82 (0.37)	1.51 (0.52)
Dry matter	0.030 (0.01)	0.032 (0.01)	0.040 (-)	0.030 (-)	0.037 (0.01)	0.027 (0.01)	0.005 (0.01)
Yield	0.31 (0.16)	0.39 (0.16)	0.38 (-)	0.15 (-)	0.38 (0.06)	0.27 (0.08)	0.07 (0.09)

Standard deviation in parentheses

## DISCUSSION

The significant mean square values obtained from the combined analysis of variance for the environmental effect revealed that the conditions in the two locations used in the study were not similar and thus the possibility of having different effect on the performance of the cassava genotypes. The significant genotype x environment interaction (GEI) observed in most characters also indicated the influence of the environmental condition on the performance of the genotypes. Similar results was observed by Aina *et al.* (2009) and Akinwale *et al.* (2011) when they evaluated eighteen and forty-three cassava genotypes, respectively, at different locations in Nigeria.

Comparative performances of the 23 cassava genotypes at the two locations revealed the response of the genotypes to the different agro-climatic conditions. The superiority of some genotypes for a character in one location and not in the other location is a clear indication of the environmental effect. However, breeding potential exists for genotypes 99/3073, TME419, 95/0289, M98/0040, 96/1565, 98/0581, 97/4769, 91/02324, 96/1089A, 94/0034, 96/1632 and 4(2)1425 with above average for yield and most of its related characters in either or both locations. Akinwale *et al.* (2011) reported the highest value of dry matter yield (36.45 % - as percentage of fresh weight) and fresh root yield (39.23 kg) for TME419 and 91/02324, respectively, across three agro-climatic zones in Nigeria.

Plant characters show the extent with which selection of genotypes could be based on the phenotype. This study revealed the effect of the environments on genetic diversity and heritability of tuber yield and related traits. Higher GCV and PCV observed in Ibadan for most of the characters showed that the agro-climatic condition in Ibadan reveals more diversity among the cassava genotypes for these characters. This also suggested the reason why higher heritability estimates and genetic advance were recorded for most of the traits at Ibadan. Therefore, the agro-climatic condition in Ibadan allows efficiency of selection through the expression of good cassava genotypes. Varma and Mathra (1993) observed that a high selection gain is expected from dry tuber yield and fresh weight of tubers per plant

In conclusion, the current study revealed genetic variability and differential yield performance among the cassava genotypes across the environments due to the presence of GEI. The interrelationships among the yield and related traits also allowed for the identification of optimal genotypes within each environment. Genotypes 95/0289, 99/3073 and TME419 with high tuber yield in Ibadan and 98/0581, 94/0034 and 97/4769 in Mokwa can be specifically adapted to these agro-climatic zones.

The character pattern among the cassava genotypes can be exploited to improve and develop new cassava genotypes. Also, to optimize the avail-

able resources, the climatic condition at Ibadan, which favours high genotypic selectivity, should be considered for cassava breeding programmes while cassava genotypes with relatively stable yield across the environments, for instance 95/0289 and 98/0581, can be used for cassava production in the agro-climatic zone.

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