Performance of selected cassava improved genotypes at different harvest periods and environments in Guinea

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Abstract

Multilocational trials were conducted for two cropping seasons (2000/01 and 2001/02) in three agro-ecological zones in Guinea to assess the relative performance of selected cassava genotypes at different harvest periods and environments and identify the best cassava genotypes with wide and specific adaptation for high fresh and dry storage root yield.

To assess the relative growth performance of cassava genotypes at different harvest periods and environments, data were collected throughout the vegetative cycle from planting to harvest in all trials using a randomized complete block design with three replications. The data collected were subjected to statistical analysis using the general linear model of SAS. Combined analysis of variance was conducted with genotypes and locations considered as fixed effects, and years (cropping seasons) as a random effect. The F-test and significance of the various main effects and interactions were determined using the appropriate error terms and degrees of freedom. Mean separation was done by Fisher's protected least significant difference (LSD) test at the 0.05 probability level. Results obtained from the study showed that cassava genotypes performed differently across and within locations for all the traits evaluated. Growth and productivity of cassava was greatest at Foulaya compared to the other locations. The same location showed the highest tuberous root dry weight followed by Bordo station during both cropping seasons, and presented the highest severity of CMD and CGM. The genotype most resistant to CMD across locations in this study was *Lapai-1*, which could be a successful parent for resistance for CMD, a major disease of economic importance in sub-Saharan Africa. This study also showed that the Foulaya experimental site was the most suitable location to select for CMD resistance. During the first cropping season, *Tokunbo* was the highest fresh tuberous root yielder at Foulaya while *Alice local* presented the highest fresh tuberous root yield at Bareng and Bordo locations. During the second cropping season, the highest yielders at Foulaya were 91/00458 and *Oko Iyawo. Alice local* was still the highest yielder at Bareng, 91/02312 gave the highest fresh tuberous root yield at Bordo. The most stable and high yielding genotypes for fresh and dry tuberous roots were *Alice local* and 92/0057.

Introduction

Cassava improvement programs in sub-Saharan Africa have targeted widening and improving the genetic base of the crop to maintain its adaptability to diverse agro ecologies (Dixon *et al*. 1992). The Institute of Agronomic Research of Guinea (IRAG) in collaboration with the International Institute of Tropical Agriculture (IITA) in Nigeria and the Institute of Agricultural Research (IAR) in Sierra Leone have made efforts in developing improved varieties with characteristics including desirable consumer qualities, root yield and resistance to diseases and pests. Also several improved cassava genetic stocks and breeding materials (which may also be used directly as varieties) have been developed at IITA for a range of agro ecologies (humid forest, moist and dry savannas, and the mid-altitudes). The improved germplasm is shared with National Programs within the region as specific genotypes (certified as virus-tested) or improved seed populations for evaluation and selection under local environmental conditions. National programs that have received breeding materials have developed or selected and released varieties that outperform the local varieties. These improved varieties have been widely adopted by farmers (Nweke *et al*., 2002; Haggblade and Zulu, 2003; Haggblade *et al*., 2004; Dixon *et al*., 2003; 2007a; 2007b). Consequently cassava yields have increased by 40% in much of sub-Saharan Africa (SSA) even without the use of fertilizer (Manyong *et al*., 2000; Nweke *et al*., 2002, Dixon *et al*., 2003, Johnson, *et al*., 2003).

In Guinea, cassava constitutes a very important crop in the farming system. In 2007, the national production was estimated at 1.122.171 tonnes produced from 139.836 ha with a mean fresh storage root yield of 8, 02 t/ha (FAO, 2009). This accounts for 11% of the total cultivated area and provides 16% of the calories consumed by each Guinean. Local rice, the major staple, provides 26% of the calories consumed and is grown on 49% of the cultivated area. Imported rice provides the bulk of the remaining calories. Presently, cassava is a major source of calories for the population living in the dry areas of Guinea where soil fertility is low. It is also becoming increasingly important to farmers having problems in producing crops that require external inputs such as fertilizer, which are expensive and often unavailable.

The major constraints to cassava production in Guinea include low soil fertility, cassava mosaic disease (CMD), cassava mealybug (CM), cassava green mite (CGM), termites (in dry areas), cattle damage, and lack of improved varieties (IRAG, 2003). Most of the varieties planted by farmers are local and are highly susceptible to CMD; they succumb within 8 months of planting, resulting in low yields. There is therefore, a need to identify genotypes that can be used efficiently in different environments. The overall objective of this research was to evaluate the relative performance of improved genotypes at different harvest periods and environments of selected genotypes in three agro ecological zones in Guinea.

The specific objectives of this study were to:

1. Assess the performance of selected elite cassava genotypes at different harvest periods and environments;
2. Identify the best cassava genotypes with wide and specific adaptability for high fresh and dry storage root yield.

Materials and Methods

Location and climate

This experiment was conducted for two consecutive cropping seasons (2000/01 and 2001/02) at three locations, representing three agro ecological zones of cassava: Foulaya in the derived savanna zone, Bareng in the mid-altitude savanna zone, and Bordo in the southern Guinea savanna zone of the Republic of Guinea (Fig. 1).

Foulaya is located in the derived savanna region of Guinea between 09° 10' and 10° 40' latitude north and 12° 50' and 13° 20' longitude west at an elevation of 380 m above sea level. The area around Foulaya has two distinct seasons: the dry season that lasts from November to April, and the wet season that extends from May to October. During the 2000/01 cropping season at Foulaya, total rainfall was 2042 mm; mean minimum and maximum monthly temperatures were 18.7 °C and 32 °C, respectively. In the second cropping season (2001/02), total rainfall was 2191.3 mm and the mean minimum and maximum monthly temperatures were 19.1 °C and 31.5 °C, respectively.

Bareng is located between 11° 11' 51" and 11° 05' 48" latitude north and 12° 28' 45" and 12° 33' 33" longitude west at an elevation of 1024 m above sea level. The pattern and duration of rainfall at Bareng is similar to those of Foulaya and Bordo, but relatively less rainfall is recorded at Bareng than at the other two locations. During the 2000/01 cropping season, total rainfall was 1705.6 mm while mean minimum and maximum monthly temperatures were 13.7 °C and 29.6 °C, respectively. In the second season (2001/02), the total rainfall was 1666.1 mm and the mean minimum and maximum monthly temperatures were 13.1 °C and 28.9 °C, respectively.

Bordo is located in the southern Guinea savanna region of Guinea between 10° 21' 27" and 10° 22' 36" latitude north and 9° 21' 11" and 9° 20' 80" longitude west at an elevation of 378 m above sea level. Bordo has a rainfall pattern similar to Foulaya with alternating dry and wet seasons lasting from November to April, and from May to October. However, rainfall is less in Bordo than Foulaya, but the temperature is similar. During the experimental period of the first growing season at Bordo, total rainfall was 1420.7 mm while mean minimum and maximum monthly temperature were 17.7 °C and 33.2 °C, respectively. Total rainfall during the 2001/02 cropping season was 1940.9 mm; mean minimum and maximum

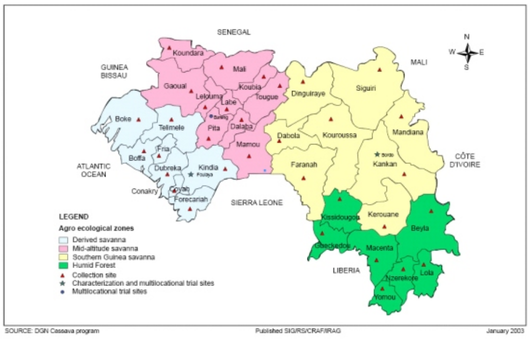

Figure 1. Map of the Republic of Guinea, showing agro ecological zones, areas of germplasm collection, and experimental sites.

Genotypes

A total of 12 cassava genotypes were used in this experiment. The genotypes comprised seven improved (88/02555, 90/0258, 91/02312, 90/0458, 91/0730, 93/0290, and 92/0057), four local (*Oko Iyawo, Lapai-1, Tokounbo,* and *Alice local*) introduced from IITA, and a widely adapted and popularly grown improved variety (check) in Guinea (92B/0033).

Land preparation and experimental design
At each of the locations, soil samples were obtained at a depth of 30 cm and the experimental area was ploughed to a depth of about 20 cm and then harrowed. Ridges 1 m apart and 30 cm high were constructed. These ridges were then demarcated into plots of 100 m^2 (10 m x 10 m), and laid out in a randomized complete block design with three replications.

Planting and management practices
The genotypes were planted in the plots at the beginning of the rainy season in June 2000 and 2001 and harvested in June 2001 and 2002, respectively. Cassava cuttings about 25 cm long were planted inclined at an angle of 45 on the crest of the ridges. The plant spacing was 1 x 1 m giving a population of 10 000 plants/ha. No fertilizer or herbicide was applied during the course of experiment. Manual weeding was done when necessary.

Data collection

Sprouting. The sprouting percentage of the plants was recorded weekly starting from 1 week until 4 weeks after planting. Other observations started at 1 MAP and continued until harvest at 12 MAP.

Diseases and pests. *Cassava mosaic disease (*CMD), and *Cassava green mite (*CGM), were recorded based on phenotypic expression of symptom severity in the field, relying upon natural infection. CMD was recorded at 1, 3, and 6 months after planting (MAP), while CGM was recorded at 6 and 9 MAP. The ratings for reaction to CMD and CGM were based on the following five point-scale scoring systems (IITA, 1990):

CMD:
class 1 = no symptoms observed (highly resistant).
class 2 = mild chlorotic pattern on entire leaflets or mid distortion at the base of leaflets, rest of leaflets appearing green and healthy (resistant).
class 3 = strong mosaic pattern on entire leaf, and narrowing and distortion of the lower one-third of leaflets (moderately susceptible).
class 4 = severe mosaic, distortion of two-thirds of the leaflets and general reduction of leaf size (susceptible).
class 5 = severe mosaic, distortion of four-fifths or more of leaflets, twisted and misshapen leaves (highly susceptible).

CGM:
class 1 = no obvious symptoms (highly resistant).
class 2 = moderate damage, no reduction in leaf size, scattered chlorotic spots on young leaves (resistant).
class 3 = severe chlorotic symptoms, slight reduction in leaf size (moderately susceptible).
class 4 = severe chlorotic symptoms and leaf size of young shoots severely reduced (susceptible).
class 5 = very severe chlorosis and significant reduction in leaf size and young shoot portion; extensive defoliation; candlestick appearance of young shoots (highly susceptible).

Determination of plant characters and destructive sampling: Destructive sampling was carried out on 5 randomly selected plants/genotype from ridges 2, 4, 6 and 8 at each harvest date at 3, 6, 9 and 12 MAP respectively. The plants were separated into lamina and petiole, stem, and roots. The root number and the total fresh weight of roots were taken, and the dry matter content was determined using a standard oven method. A total of 200 g samples were dried for 72 hours in a forced-air drying oven at 70 ^{o}C until weights were constant, and the dried samples were then reweighed to obtain the dry weights expressed on a plant basis.

Fresh yield, dry matter percentage, and dry yield of storage roots. At harvest (12 MAP), the total fresh weight of storage roots/plot was recorded from an area of 16 m^2 (8 x 2 m) in ridges 8 and 9, excluding the end plants. Fresh storage root weight (kg/plot) was converted to storage root yield (t/ha). Dry matter percentage of storage roots was determined from a collection of roots bulked from four randomly selected plants of each genotype. Soil was brushed off the outer skin of the storage roots and whole storage roots, including the peel, were shredded. Two hundred gram duplicate samples of the shredded roots were weighed and dried for 72 hours in a forced-air drying oven at 70 ^{o}C. The dried samples were then reweighed to obtain the dry weights, and the DM percentage was obtained as the proportion of the fresh weight. Dry storage root yield was estimated as the fresh storage root yield multiplied by the percentage DM of the storage roots.

Data analysis
The data collected were subjected to statistical analysis using the general linear model of SAS

(SAS, 1996). The F-test and significance of the various main effects and interactions were determined using the appropriate error term and degrees of freedom (McIntosh, 1983).

Mean separation was done by Fisher's protected least significant difference (LSD) at the 0.05 probability level.

The genotype and genotype x environment (GGE) biplot methodology (Yan and Kang, 2003) was also used to analyses the multi-environment trial data for fresh and dry storage root yields.

Results

Sprouting: Sprouting percentage was generally lower during the first cropping season (2000/01) than in the second cropping season (2001/02), (Table 1). The highest sprouting percentage (88.3 %) was attained by genotype *Lapai-1* at Bareng and genotype *Alice Local* at Bordo during the first cropping season, while during the second cropping season, the highest sprouting percentage (96.3 %) was recorded for genotype 92/0057 at Bareng. sprouting percentage significantly varied among the locations during both cropping seasons while genotype only significantly influenced sprouting percentage during the second cropping season. There was a significant interaction between genotype and location during both cropping seasons.

Genotype 91/02312 did not vary significantly in sprouting percentage across all the locations during both cropping seasons (Table 1). In addition to genotype 91/02312, genotypes 88/02555, 92/0057, and 91/0730 sprouted at a similar rate across the locations during the 2000/01 cropping season, while all the other genotypes sprouted differently across the locations. During the second cropping season (2001/02), three other genotypes (91/00458, *Alice local*, and 90/0258) in addition to genotype 91/02312 sprouted at a similar rate across locations while all the other genotypes exhibited differential sprouting across the locations (Table 1).

Reaction of the genotypes to CMD and CGM

Cassava mosaic disease: At all the stages of assessment (1, 3, and 6 months after planting), CMD disease severity varied significantly among locations and genotypes as well as significantly interacting with both factors during the two cropping seasons (Tables 2, 3, and 4). Also, CMD symptom expression was generally higher during the second cropping season than the first cropping season at all times of monitoring.

At 1 MAP, during both cropping seasons, CMD symptoms did not vary significantly across locations for genotypes *Lapai-1* and 91/0730 (Table 2). In addition to these two genotypes, the following genotypes: Tokunbo, 92/0057, *Alice Local*, 91/02312 and 90/0258 did not vary significantly in CMD symptom expression across locations during the first cropping season; during the second cropping season, only genotype 93/0290, *Lapai-1*, and 91/0730 appeared not to vary significantly in CMD expression across locations (Table 2).

At 3 MAP, CMD disease expression was higher than at 1 MAP (Table 3). There was a significantly lower CMD severity score at Bordo for all the genotypes than at Foulaya and Bareng (Table 3). Also, during the 2000/01 cropping season while there was apparent field resistance at Bordo for all the genotypes except 91/00458, CMD symptom expression significantly varied among the genotypes at both Foulaya and Bareng. During the 2001/02 cropping season, there was a significant variation in CMD infection among the genotypes (Table 3).

At 6 MAP, CMD severity symptoms did not significantly vary among the genotypes during the second cropping seasons at Bordo while at Foulaya and Bareng, CMD severity varied significantly among the genotypes (Table 4). During the 2000/01 cropping season, seven genotypes (Oko Iyawo, 91/00458, 92/0057, *Lapai-1, Alice Local*, 90/0258 and 91/02312) did not exhibit any significant differences in CMD severity symptoms expression across locations.

Table 1. Sprouting of cassava genotypes at 4 weeks after planting at three locations in Guinea during the 2000/2001 and 2001/2002 cropping seasons.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai*	*Alice. local*	91/02312	90/0258	91/0730	Mean
						2000/2001 Cropping season							
Foulaya	80.0	78.3	76.6	85.0	63.3	78.3	73.3	65.0	63.3	70.0	86.6	70.0	74.1
Bareng	45.0	55.0	61.6	58.3	50.0	68.3	50.0	88.3	55.0	55.0	65.6	70.0	60.1
Bordo	76.6	76.0	76.0	75.0	81.6	71.0	81.3	70.0	88.3	71.0	75.0	60.6	75.2
Mean	67.2	69.7	71.4	72.7	65.0	72.5	68.2	74.4	68.8	65.3	75.7	66.2	69.8
CV= 16.8													
			Genotype (G) 11.1 ns										
			Location (L) 5.5**										
LSD (5%)			G x L 18.3**										
						2001/2002 Cropping season							
Foulaya	88.6	83.0	81.3	86.6	82.0	82.3	85.3	84.0	78.6	81.6	63.0	36.6	77.7
Bareng	93.3	92.3	91.3	70.3	91.0	96.3	91.3	96.0	89.3	85.6	74.3	93.3	88.7
Bordo	73.0	75.3	68.6	78.0	79.0	70.6	73.6	75.0	80.3	85.6	68.3	77.0	75.3
Mean	85.0	83.5	80.4	78.3	84.0	83.1	83.4	85.0	82.7	84.3	65.2	69.0	80.6
CV= 10.7													
			Genotype (G) 8.2 ***										
			Location (L) 4.1***										
LSD (5%)			G x L 13.5 ***										

Table 2. Severity of CMD at 1 MAP on 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 and 2001/2002 cropping seasons.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice local*	91/02312	90/0258	91/0730	Mean
						2000/01 cropping season							
Foulaya	1.6	1.3	1.3	1.0	1.0	1.3	1.6	1.3	1.0	1.3	1.3	1.3	1.2
Bareng	1.0	2.0	1.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1
Bordo	1.0	1.0	1.0	1.0	1.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1
Mean	1.2	1.4	1.3	1.0	1.2	1.1	1.2	1.1	1.0	1.1	1.1	1.1	
CV= 27.6			Genotype (G) 0.30 *										
			Location (L) 0.15 **										
LSD (5%)			G x L 0.49 **										
						2001/02 cropp ing season							
Foulaya	3.3	1.6	2.6	2.6	2.3	2.0	1.6	1.6	2.3	2.3	2.3	1.6	2.2
Bareng	1.3	1.3	1.6	1.3	1.0	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.2
Bordo	1.0	1.6	2.0	1.0	1.3	1.3	1.6	1.0	1.0	1.0	1.0	1.3	1.3
Mean	1.8	1.5	2.1	1.6	1.5	1.4	1.5	1.2	1.5	1.4	1.5	1.3	
CV= 31			Genotype (G) 0.46 **										
			Location (L) 0.23 ***										
LSD (5%)			G x L 0.74 **										

Table 3. Severity of CMD at 3 MAP on 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 and 2001/2002 cropping seasons.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice. local*	91/02312	90/0258	91/0730	Mean
						2000/01 cropping season							
Foulaya	2.3	2.0	2.0	1.6	1.0	1.6	2.3	2.0	2.0	2.0	2.0	2.3	1.92
Bareng	1.0	3.0	2.3	1.0	1.0	1.0	2.3	1.0	1.0	1.0	1.0	2.3	1.50
Bordo	1.0	1.0	1.0	1.0	2.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.10
Mean	1.40	2.00	1.70	1.20	1.40	1.20	1.80	1.30	1.30	1.30	1.30	1.80	
CV= 18.8													
LSD (5%)			Genotype (G) 0.26 **										
			Location (L) 0.13 ***										
			G x L 0.43 ***										
						2001/02 cropping season							
Foulaya	2.3	1.3	2.3	2.3	1.6	2.3	1.3	1.3	2.3	1.3	2.6	1.3	1.88
Bareng	1.6	1.6	2.0	2.3	2.0	1.0	2.0	1.0	2.0	1.6	2.0	1.3	1.72
Bordo	1.0	1.0	1.6	1.0	1.0	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.10
Mean	1.60	1.30	200	1.80	1.50	1.40	1.50	1.10	1.80	1.30	2.00	1.20	
CV=31.8													
LSD (5%)			Genotype (G) 0.47 **										
			Location (L) 0.23 ***										
			G x L 0.77 *										

Table 4. Severity of CMD at 6 MAP on 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 and 2001/2002 cropping seasons.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice. local*	91/02312	90/0258	91/0730	Mean
2000/01 cropp ing season													
Foulaya	1.3	1.3	1.0	1.6	1.0	1.0	2.0	1.3	1.6	1.3	1.6	1.6	1.38
Bareng	1.0	2.3	2.6	1.3	1.0	1.0	2.6	1.0	1.3	1.0	1.0	2.3	1.53
Bordo	1.0	1.0	1.6	1.0	1.6	1.0	1.6	1.0	1.3	1.0	1.0	1.3	1.20
Mean	1.10	1.50	1.70	1.30	1.20	1.00	2.10	1.10	1.40	1.10	1.20	1.70	
CV = 30.1			Genotype (G) 0.39 **										
			Location (L) 0.19 **										
		LSD (5%)	G x L 0.65 **										
2001/02 cropping season													
Foulaya	1.6	1.3	3.3	1.6	2.3	2.3	3.3	2.3	2.0	2.3	2.3	1.6	2.20
Bareng	1.6	2.6	1.3	2.0	1.3	1.0	1.0	1.0	2.6	2.3	1.3	2.6	1.75
Bordo	1.0	1.3	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.05
Mean	1.40	2.10	2.00	1.50	1.50	1.40	1.70	1.40	1.80	1.80	1.50	1.70	
CV = 26.1			Genotype (G) 0.41 **										
			Location (L) 0.2 ***										
		LSD (5%)	G x L 0.67 ***										

Cassava green mite (CGM)

The results of CGM damage monitored at 6 and 9 MAP are presented in Tables 5 and 6. At 6 MAP, during the first cropping season (2000/01), no CGM damage was observed on all the genotypes. During the second cropping season (2001/02), CGM damage was seen in the majority of genotypes in all locations (Table 5). Damage from CGM varied significantly with both genotype ($P<0.01$) and location ($P<0.01$) as well as the interaction ($P<0.01$) between genotype and location. At Foulaya, CGM damage varied significantly among genotypes while at both Bareng and Bordo there was no significant variation in CGM damage at each of the locations (Table 5). At 6 MAP, the most severe damage (4.0) was recorded for genotype 91/0730 at Foulaya, followed by genotypes 88/02555 and 91/00458. At 9 MAP, CGM damage also varied significantly among genotypes and locations, and interacted with both factors during the two cropping seasons (Table 6). CGM damage was higher at 9 MAP than at 6 MAP. During the first cropping season, CGM damage was highest (2.6) on genotypes 93/0290 and 90/0258 at the Bordo location. CGM also varied significantly across locations for these genotypes together with the following genotypes: *Oko Iyawo*, 92B/0033, and 91/00458. CGM damage did not vary significantly across locations for the remaining genotypes (Table 6). During the second cropping season (2001/02), there was a significant variation in CGM damage among the genotypes. Genotype 88/02555 at Bareng suffered the greatest CGM damage (5.0). Six genotypes at Bordo did not suffer any CGM damage 88/02555, *Tokunbo*, 91/00458, 92/0057, *Lapai-1*, and 91/02312.

Table 5. Severity of CGM at 6 MAP on 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 and 2001/2002 cropping seasons.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice. Local*	91/02312	90/0258	91/0730	Mean
2000/01 cropping season													
Foulaya	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00
Bareng	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00
Bordo	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.00
Mean	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
				Genotype (G)	-	-							
				Location (L)	-	-							
			LSD (5%)	G x L	-	-							
2001/02 cropping season													
Foulaya	1.3	1.3	3.6	1.6	3.6	1.3	1.0	1.0	1.3	1.0	1.3	4.0	1.80
Bareng	1.0	1.0	1.0	1.0	1.6	1.3	1.3	1.6	1.0	1.6	1.6	1.3	1.30
Bordo	1.6	1.6	1.0	1.0	1.3	1.0	1.6	1.3	1.0	1.6	1.3	1.3	1.30
Mean	1.30	1.30	1.90	1.50	2.10	1.20	1.30	1.30	1.10	1.40	1.40	2.20	
CV = 30.7				Genotype (G)		0.43 ***							
				Location (L)		0.21 ***							
			LSD (5%)	G x L		0.71 ***							

Table 6. Severity of CGM at 9 MAP on 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 and 2001/2002 cropping seasons.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice local*	91/02312	90/0258	91/0730	Mean
						2000/01 cropping season							
Foulaya	1.6	1.3	2.3	2.0	2.3	1.3	1.0	2.0	1.3	1.6	1.3	1.6	1.60
Bareng	1.3	1.6	1.6	1.3	1.0	2.0	1.6	1.3	1.6	1.0	1.0	1.6	1.44
Bordo	2.3	2.3	2.0	1.6	2.0	1.6	2.6	2.0	1.6	1.3	2.6	1.6	2.00
Mean	1.70	1.70	1.60	1.60	1.80	1.60	1.70	1.80	1.50	1.30	1.60	1.60	
CV = 30.2			Genotype (G) 0.48 *										
			Location (L) 0.24 **										
		LSD (5%)	G x L 0.79 **										
						2001/02 cropping season							
Foulaya	1.3	1.6	3.3	2.3	2.6	1.6	1.3	2.0	1.3	1.6	2.3	4.6	2.10
Bareng	3.3	3.6	5.0	3.3	4.0	4.3	4.6	3.6	2.0	4.6	3.6	4.3	3.80
Bordo	1.3	1.6	1.0	1.0	1.0	1.0	1.3	1.0	1.1	1.0	1.3	1.3	1.20
Mean	1.90	2.30	3.10	2.20	2.50	2.30	2.40	2.30	1.40	2.40	2.40	3.40	
CV = 20			Genotype (G) 0.45 ***										
			Location (L) 0.22 ***										
		LSD (5%)	G x L 0.74 ***										

Fresh storage roots weight per plant

The fresh weight of storage roots/plant as affected by genotype and location during the 2000/01 and 2001/02 cropping seasons is presented in Tables 7 and 8. During both cropping seasons, genotypic differences as well as differences for locations were highly significant (P<0.01). During both cropping seasons also, the interaction between genotype and location was highly significant (P<0.01).

Lapai-1 produced the highest storage root yield/plant at 3 MAP (390.9 g/plant) at Bordo and at 9 MAP (3066.7 g/plant) at Foulaya. The highest yielder at 12 MAP was *Tokunbo*, with 6933.3 g/plant at Foulaya. *Oko Iyawo* was the highest yielder at 6 MAP (1,333.3 g/plant) at Foulaya, but was the lowest yielder at 9 MAP (480 g/plant) at Bareng (Table 7).

At 3 MAP during the second cropping season (2001/02), storage root yield/plant varied significantly only among genotypes at Foulaya, where *Tokunbo* was the highest yielder (1966.7 g/plant) and *Oko Iyawo* was the lowest yielder (10.0 g) per plant (Table 8). At 3 MAP, storage root yield/plant did not vary significantly with genotypes at either Bareng or Bordo. At 12 MAP, *Oko Iyawo* was the highest yielder (8083.3 g/plant) at Foulaya; 91/0730 was the lowest.

Table 7. Fresh storage root weight (g)/plant at different harvesting periods of 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 cropping season.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice. local*	91/02312	90/0258	91/0730	Mean
							3 MAP						
Foulaya	97.0	38.3	59.0	77.0	71.6	49.5	55.0	95.5	46.6	34.3	204.1	28.5	71.3
Bareng	19.8	10.6	20.2	21.8	10.3	24.5	19.6	11.9	19.0	14.8	31.5	16.8	18.4
Bordo	112.2	80.3	130.4	101.6	66.0	27.7	64.0	390.9	146.6	122.4	134.0	101.9	123.1
Mean	76.3	43.1	69.9	66.8	49.3	33.9	46.2	166.1	70.7	57.2	123.2	49.0	
CV = 13.8							Genotype (G) 9.26 ***						
					LSD (5%)		Location (L) 4.63 ***						
							GxL 15.28 ***						
							6 MAP						
Foulaya	1333.3	883.3	1083.3	583.3	450.0	710.0	366.6	450.0	333.3	566.6	466.6	533.3	646.6
Bareng	402.8	140.9	216.6	140.7	318.0	182.9	190.9	579.3	99.8	381.6	397.0	96.3	259.2
Bordo	513.9	367.2	133.8	436.0	161.3	330.3	383.6	373.7	132.0	226.1	400.1	310.5	314
Mean	750.0	451.8	477.9	386.7	309.7	407.7	313.7	467.6	188.4	391.4	421.3	313.4	
CV = 18.5							Genotype (G) 70.81 ***						
							Location (l) 35.4 ***						
					LSD (5%)		GxL 116.84 ***						
							9 MAP						
Foulaya	1583.3	1543.3	1183.3	1050.0	2193.3	1003.3	906.7	3066.7	2350.0	1166.7	1010.0	673.3	1477.5
Bareng	480.0	486.7	933.3	1766.7	583.3	776.7	933.3	1165.0	1980.0	1966.7	1280.0	1016.7	1114
Bordo	926.7	1083.3	1210.0	1810.0	1043.3	1223.3	1770.0	1983.3	3433.3	2170.0	853.3	1450.0	1579.7
Mean	996.7	1037.8	1108.9	1542.2	1273.3	1001.1	1203.3	2071.7	2587.8	1767.8	1047.8	1046.7	
CV = 16.7							Genotype (G) 219.06 ***						
							Location (L) 109.5 ***						
					LSD (5%)		GxL 361.45 ***						
							12 MAP						
Foulaya	3000.0	2900.0	2333.3	6933.3	2633.3	4216.7	2433.3	2166.7	3966.7	1666.7	2100.0	2850.0	3100.0
Bareng	650.0	1900.0	1000.0	1800.0	1193.3	1666.7	966.7	1466.7	2433.3	2066.7	2266.7	1366.7	1564.7
Bordo	1156.7	1336.7	1388.3	1993.3	1360.0	2946.7	2200.0	2433.3	3583.3	2813.3	976.7	2017.0	2017.1
Mean	1602.2	2045.6	1573.9	3575.6	1728.9	2943.3	1866.7	2022.2	3327.8	2182.2	1781.1	2077.8	
CV = 11.7							Genotype (G) 246.4 ***						
							Location (L) 123.2 ***						
					LSD (5%)		GxL 406.56 ***						

Table 8. Fresh storage root weight (g)/plant at different harvesting periods of 12 cassava genotypes grown at three locations in Guinea during the 2001/2002 cropping season.

	Genotypes												
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice. local*	91/02312	90/0258	91/0730	Mean
							3 MAP						
Foulaya	803.3	1193.3	716.7	1966.7	1016.7	536.7	1316.7	313.3	1196.7	1100.0	196.7	516.7	906.1
Bareng	187.1	117.1	12.8	47.3	74.4	27.5	15.7	30.1	22.9	35.1	49.4	41.9	55.1
Bordo	10.0	70.3	39.3	93.6	71.3	144.0	29.6	58.3	14.0	42.3	8.0	189.3	64.1
Mean	333.4	460.2	256.2	702.5	387.4	236.0	454.0	133.9	411.2	392.4	84.7	249.3	
CV = 49.7													
				LSD (5%)	Genotype (G) 159.89 ***								
					Location (L) 79.94 ***								
					G x L 263.81 ***								
							6 MAP						
Foulaya	2200.0	3300.0	826.7	3100.0	2016.7	1666.7	2000.0	1700.0	2233.3	583.3	3166.7	1460.0	2021.1
Bareng	308.6	431.9	212.7	156.0	433.5	486.2	144.2	460.9	372.3	469.7	138.3	310.7	327.1
Bordo	880.0	576.6	793.3	1200.0	602.6	560.0	723.3	606.6	786.6	990.0	986.6	610.0	776.3
Mean	1129.5	1436.1	610.9	1485.3	1017.6	904.2	955.8	922.5	1130.7	681.0	1430.5	793.5	
CV = 16.7													
					Genotype (G) 164.42 ***								
					Location (L) 82.21 ***								
				LSD (5%)	G x L 271.3 ***								
							9 MAP						
Foulaya	4466.7	4666.7	3933.3	2916.7	6993.3	6800.0	3833.3	3900.0	4133.3	4240.0	2443.3	6733.3	4588.3
Bareng	743.4	810.9	303.7	873.6	529.4	748.0	937.4	766.5	840.0	1049.2	1008.4	261.7	739.3
Bordo	706.0	1043.3	777.3	715.0	1824.7	382.3	514.7	774.3	503.0	925.7	761.3	582.7	792.5
Mean	1972.0	2173.6	1671.5	1501.7	3115.8	2643.4	1761.8	1813.6	1825.5	2071.6	1404.4	2525.9	
CV = 16.1													
					Genotype (G) 310.22 ***								
					Location (L) 155.11 ***								
				LSD (5%)	G x L 511.88 ***								
							12 MAP						
Foulaya	8083.3	6850.0	5116.7	5050.0	7900.0	6200.0	5423.3	4266.7	4133.3	2833.3	4640.0	3633.3	5344.1
Bareng	1154.8	1402.0	869.0	1399.2	1065.3	1560.0	1644.4	776.0	1694.6	1581.7	1274.4	850.7	1272.6
Bordo	1231.0	1881.0	861.7	1594.7	1326.0	1743.7	1004.7	1682.0	1742.7	2586.0	1205.0	880.0	1478.1
Mean	3489.7	3377.7	2282.4	2981.3	3430.4	3167.9	2690.8	2241.6	2523.5	2333.7	2373.1	1788.0	
CV = 11.05													
					Genotype (G) 280.57 ***								
					Location (L) 140.29 ***								
				LSD (5%)	G x L 462.95 ***								

Dry storage root weight

Similar to that of fresh storage roots, the dry weight of storage roots/plant varied significantly ($P<0.01$) among genotypes and locations during both cropping seasons (Tables 9 and 10). During both cropping seasons also, the interaction between genotype and location was also highly significant ($P<0.01$).

During the 2000/01 cropping season, the same genotypes with the highest fresh storage root yield also had the highest dry storage root yield, except at 9 MAP when *Alice local* was the highest yielder for dry storage root weight, and *Lapai-1* was the highest yielder for fresh storage root weight. At 12 MAP *Tokunbo* had 2617.3 g of dry storage roots/plant while the lowest yielder *Oko Iyawo* had 211.7 g/plant (Table 9).

Generally, there was a similar relationship between fresh storage root yield and dry storage root yield during the second cropping season (2001/02) (Tables 8 and 10). *Tokunbo* was the highest dry storage root yielder at 3 and 6 MAP with 361.8 and 1097.4 g/plant, respectively (Table 10). At 9 and 12 MAP, the highest dry storage root yielders were 92/0057 and 91/00458 with (2305.2 g/plant) and 2429.2 g/plant), respectively. The lowest dry storage root yield was 0.7 g/plant (*Alice local*, 3 MAP), 34.3 g/plant (93/0290, 6 MAP), 92.1 g/plant (91/0730, 9 MAP) and 183 g/plant (*Lapai-1*, 12 MAP).

Table 9. Dry weight of storage roots (g)/plant at different harvesting periods of 12 cassava genotypes grown at three locations in Guinea during the 2000/2001 cropping season.

						Genotypes							
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai-1*	*Alice. local*	91/02312	90/0258	91/0730	Mean
							3 MAP						
Foulaya	19.6	5.9	10.2	17.9	11.1	8.6	10.2	20.5	9.9	6.9	37.1	4.9	13.6
Bareng	2.2.0	1.6	2.9	4.0	2.0	4.6	3.0	1.7	2.7	2.5	8.3	3.0	3.2
Bordo	20.3	13.5	22.4	17.0	10.8	4.9	8.8	58.5	29.7	20.5	28.6	21.1	21.3
Mean	14.0	7.0	11.8	13.0	8.0	6.0	7.3	26.7	14.1	10.0	24.7	9.7	
CV = 15													
							Genotype (G) 2 ***						
							Location (L) 1 ***						
					LSD (5%)		G x L 2.9 ***						
							6 MAP						
Foulaya	423.3	256.1	403.5	226.0	101.2	191.7	131.0	120.3	89.1	196.0	166.8	141.3	203.9
Bareng	114.0	30.5	63.9	26.3	92.0	45.2	48.4	187.9	31.4	104.4	115.1	23.4	73.5
Bordo	129.0	120.8	33.4	106.8	33.8	86.5	78.2	106.1	38.9	54.0	128.0	88.8	83.7
Mean	222.1	135.8	166.9	119.7	75.7	107.8	85.9	138.1	53.2	118.1	136.6	84.5	
CV = 19													
							Genotype (G) 21 ***						
							Location (L) 10 ***						
					LSD (5%)		G x L 34.6 ***						
							9 MAP						
Foulaya	636.5	517.0	453.8	437.0	769.8	351.1	337.7	1074.8	705.0	408.3	450.4	227.9	530.8
Bareng	174.7	148.4	282.3	634.0	176.8	222.8	352.7	404.8	658.7	752.8	493.7	360.2	388.5
Bordo	354.9	427.9	388.4	577.3	307.7	415.9	488.5	745.7	1225.7	661.8	317.4	537.9	537.4
Mean	388.7	364.4	374.8	549.4	418.1	329.2	292.9	741.8	863.1	607.6	420.5	375.3	
CV = 16													
							Genotype (G) 80 ***						
							Location (L) 40 ***						
					LSD (5%)		G x L 132.0 ***						
							12 MAP						
Foulaya	1099.5	817.8	740.8	2617.3	855.8	1437.8	792.0	795.1	1164.6	569.1	751.8	689.7	1027.6
Bareng	211.7	474.2	298.3	571.8	245.7	399.0	304.0	451.2	636.0	602.2	796.7	404.8	449.6
Bordo	375.9	411.6	356.8	540.1	296.4	1113.8	442.2	708.1	1092.9	739.9	294.9	631.2	583.6
Mean	562.3	567.9	465.3	1243.1	466.0	983.5	512.7	651.5	964.5	637.1	614.5	575.2	
CV = 11													
							Genotype (G) 72 ***						
							Location (L) 36 ***						
					LSD (5%)		G x L 119.1 ***						

Table 10. Dry weight of storage roots (g)/plant at different harvesting periods of 12 cassava genotypes grown at three locations in Guinea during the 2001/2002 cropping season.

						Genotypes							
Locations	*Oko Iyawo*	92B/0033	88/02555	*Tokunbo*	91/00458	92/0057	93/0290	*Lapai*	*Alice. local*	91/02312	90/0258	91/0730	Mean
							3 MAP						
Foulaya	171.1	230.3	153.3	361.8	190.1	98.7	260.7	59.2	208.2	192.5	37.7	103.3	172.2
Bareng	26.5	23.3	2.0	10.0	14.0	5.4	2.1	5.2	3.8	9.1	9.8	9.1	10
Bordo	1.0	11.4	6.5	20.9	12.0	30.0	6.1	11.6	0.7	8.0	1.6	37.8	12.3
Mean	66.2	88.3	54.0	130.9	72.0	44.7	89.6	25.3	70.9	69.9	16.4	50.1	
CV = 48													
					Genotype (G) 29 ***								
					Location (L) 15 ***								
				LSD (5%)	G x L 48.7 ***								
							6 MAP						
Foulaya	631.4	873.1	247.1	1097.4	467.0	500.0	640.0	442.0	540.4	218.1	868.6	421.9	578.9
Bareng	74.0	101.9	47.0	41.1	119.6	125.9	34.3	135.9	92.3	131.0	37.4	74.2	84.6
Bordo	215.6	184.5	218.1	384.0	144.6	162.4	217.0	154.7	200.6	252.4	276.2	186.0	216.3
Mean	30.7	286.5	170.7	507.5	243.7	262.7	297.1	244.2	277.8	200.5	394.1	227.4	
CV = 17													
					Genotype (G) 48 ***								
					Location (L) 24 ***								
				LSD (5%)	G x L 79.4 ***								
							9 MAP						
Foulaya	1539.2	1381.8	1182.4	1087.9	2174.2	2305.2	1439.0	1318.2	1104.8	1836.8	823.2	2154.7	1528.9
Bareng	255.7	336.5	114.8	276.0	197.4	279.7	265.2	290.4	290.6	291.6	289.4	92.1	248.3
Bordo	229.4	391.2	233.2	275.2	647.7	128.0	180.1	278.7	178.5	296.2	243.6	189.3	272.6
Mean	674.8	703.1	510.1	546.4	1006.4	904.3	628.1	629.1	524.6	808.2	452.0	812.0	
CV = 16													
					Genotype (G) 105 ***								
					Location (L) 53 ***								
				LSD (5%)	G x L 173.8 ***								
							12 MAP						
Foulaya	2344.1	1517.2	1233.1	1363.5	2429.2	1844.5	1971.3	1158.4	973.4	1002.4	1245.8	1090.0	1514.4
Bareng	329.1	480.8	258.9	359.5	336.6	503.8	335.4	183.9	547.3	317.9	256.1	282.4	349.3
Bordo	363.1	573.7	216.2	507.1	401.7	533.5	255.1	403.6	400.8	724.0	343.4	249.9	414.3
Mean	1012.1	857.2	569.4	743.4	1055.8	960.6	854.0	582.0	640.5	681.4	615.1	540.7	
CV = 10.7													
					Genotype (G) 76.61 ***								
					Location (L) 38.3 ***								
			LSD (5%) G x L	126.4 ***									

GGE biplot for best cultivars in different environments (which- won- where) for fresh and dry storage root yields

The GGE biplot model (environment-centered) accounted for 77.9% of total variation of the data for fresh storage root yield, consisting of 48.3 and 29.6% of variance attributable to primary and secondary effects (PC1 and PC2), respectively (Fig. 2).

In Figure 2, even though there were five sectors in all, three mega-environments were identified for fresh storage root yield. E6 was one mega-environment with genotype G3 as the winning genotype. The winning genotype for E5, E1, E2, and E3 (second mega-environment) was genotype G12. The third mega-environment E4 has no winning genotype. Vertex genotypes without any environment in the sectors were not the highest yielding genotypes at any environment; moreover, they were the poorest at all or some sites. Genotypes within the polygon, particularly those located near the plot origin, were less responsive than the vertex genotypes.

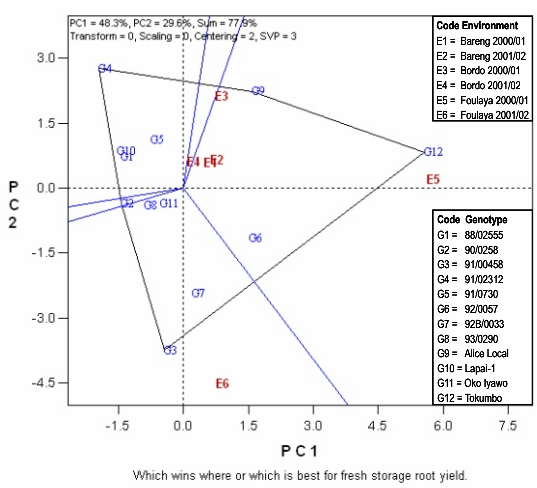

Figure 2. GGE biplot for best cultivars in different environments for fresh storage root yield.

In Figure 3, even though there were four sectors in all for dry storage root yield, three mega-environments were identified. E6 was one mega-environment with genotype G3 as winning genotype; the winning genotype for E5, E4, E3, and E2 (second mega-environment) was genotype G12. The third mega-environment E1 had G9 as the winning genotype.

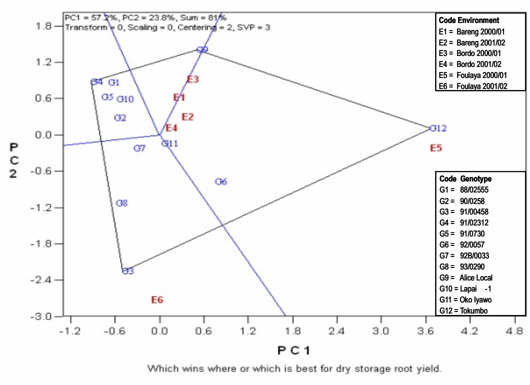

Figure 3. GGE biplot for best cultivars in different environments for dry storage root yield.

Discussion

Environmental conditions are known to be important in determining the realization of the genetic potential of any particular genotype. Farmers, therefore, in addition to providing the required management conditions which they have the option to provide, ensure that the natural soil and climatic conditions are favorable for the growth and productivity of a particular crop.

The three locations in Guinea (Foulaya, Bareng and Bordo) used in this study to evaluate the productivity of 12 cassava genotypes are in three different agro-ecologies with varying agro climatic conditions that will influence the growth and productivity of cassava. Foulaya is in the derived savanna zone and receives more rainfall than Bareng and Bordo. Bordo is in the southern Guinea savanna zone and receives the second highest rainfall but had temperature regime similar to Foulaya. Bareng is in the mid-altitude savanna zone and receives the least rainfall.

The quality of planting stakes exerts great effects on the establishment of cassava and depends on age, thickness, number of nodes/stem cutting, and health. Control of these factors is essential for the sprouting of vigorous plants capable of producing a good number of roots (Ghosh *et al*., 1988; IITA, 1990). The high percentage of sprouting exhibited at Bareng experimental site by the genotypes *Lapai-1*, 91/0730, and 92/0057, at Foulaya experimental site by the genotypes *Tokunbo* and *Oko Iyawo*, and at Bordo experimental site, by the genotypes *Alice local*, 91/0458, 91/02312 and 92B/0033 is an indication that these genotypes have good sprouting potential. Consequently, they could be used as parent material for enhanced performance in succeeding generations.

Sprouting had a very low heritability value.

However, this does not imply that cassava cannot be bred for sprouting potential. High heritability only indicates the effectiveness of selection based on good phenotypic performance, but does not necessarily mean a high genetic gain for a particular trait (Kamalan et al., 1977). These results are in agreement with the observation of Wholey (1974) who reported that the rate of sprouting and the initial vigor of cassava plants are dependent on the varieties used. Cock and Rosas (1975) also observed large clonal differences in the rate of sprouting.

In this study, the growth and productivity of cassava was greatest at Foulaya than in the other locations. Storage root yield was greater at Foulaya than at Bareng and Bordo. The performance of the genotypes at Bordo was the lowest, compared to Foulaya and Bareng. In general, the superior performance at Foulaya could be attributed to the greater rainfall, better soil texture (sandy loam), and nutrient status). Githunguri *et al*. (1998) noted that TMS 4(2)1425 performed best at Ibadan (derived savanna zone with bimodal annual rainfall of 1253 mm), but poorly at Kano (Sudan savanna with unimodal annual rainfall of 844 mm), while Manrique (1990) obtained greater root yield during summer (mean air temperature of 27.0 °C) than in winter (mean air temperature of 22.5 °C) in Hawaii. The significance of adequate rainfall is also demonstrated by the higher productivity recorded during the 2001/02 cropping season compared to the 2000/01 cropping season, probably due to the higher rainfall in 2001/02 than the 2000/01 cropping season.

Temperatures were also higher at Foulaya and Bordo than at Bareng. At Bareng, apart from the relatively lower rainfall, average minimum temperature during both cropping seasons was below 15 °C. High temperatures up to 30 °C tend to open the stomata of cassava (El-Sharkawy and Cock, 1990), while temperatures below 20 °C close stomata (Osiru *et al.,* 1995). High temperature regimes of 25-35 °C resulted into significantly ($P<0.05$) higher storage root number, storage root dry weight, leaf area, and total biomass than the low regime of 15-25 °C (Akparobi, 1992). Osiru *et al.* (1995) reported that cassava has limited potential as a crop when mean temperature is less that 20 °C.

Cassava does not thrive in hydromorphic soils although it does well in a variety of soils; muddy, alluvial, or ferralitic, provided they have good aeration and drainage (Alaux and Fauquet, 1990) and does best in light sandy, loamy soils (Onwueme and Sinha, 1991). The sandy loam soil at Foulaya compared to the clay loam and sandy clay soils in Bareng and Bordo could partly account for productivity at Foulaya being better than the other two locations.

In this study also, genotypic differences were exhibited within and across locations. There were significant differences among genotypes in all the characters measured in this study. Such genotypic differences enhanced the adaptability and productivity of certain genotypes.

The results showed that the difference in reaction of CMD, CGM, and storage root yield among the 12 cassava genotypes was highly significant ($P<0.001$). Several studies have shown that leaf production and root production are important yield-contributing factors in cassava. The genotypes 92/0057, *Tokunbo*, 92B/0033, *Oko Iyawo* and *Alice local* that produced superior storage root yield all had produced large numbers of leaves and storage roots. In addition to contributing to storage root yield, genotypes with large numbers of leaves will be attractive to leaf sellers in the regions were cassava leaves are eaten particularly in the Mano River Union countries and Central Africa.

Conclusions and Recommendation

Cassava genotypes perform differently across and within locations for all the traits evaluated.

The yield potential of genotypes varied widely across and within locations indicating significant variability among genotypes and environments.

These results suggest the need for a study on ACMD pressure on the improved cassava genotypes at Foulaya, Bareng and Bardo locations to elucidate the epidemiology of the disease.

The cassava genotypes used in this study performed better at Foulaya experimental site for all the parameters observed.

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