UDS International Journal of Development [UDSIJD]
Volume 3 No. 1, August, 2016
http://www.udsijd.org

YIELD AND EARLINESS IN BULKING OF SOME INTRODUCED CASSAVA GENOTYPES UNDER MOIST SAVANNA

***Adu-Gyamfi, R., **Osei, C. and **Anadumba, E.**

**University for Development Studies, Tamale; **Savannah Agriculture Research Institute, Tamale.*

Abstract

Over the years several genotypes of cassava have been abandoned due to late bulking. It is necessary to select early bulking, high yielding genotypes for marginal rainfall areas with rising population densities as pertains in Sub-Sahara Africa. It is based on this that a study was conducted with two introduced cassava genotypes; TME225 and 92/0057 (test), and compared with two adapted varieties Afisiafi and Biabasse (control) to determine which genotypes are early and high yielding. The growth and yield parameters considered were the leaf production and canopy spread, stem size and development, root development and yield. The control genotypes produced more leaves at 24 weeks after planting (WAP) than the introduced genotypes. This reflected in the canopy spread with the introduced genotypes having lower canopy spread. The introduced genotypes, however, were higher in branching than the control genotypes by 16 WAP and the trend continued throughout the plant life. Cluster analysis identified one introduced genotype and a control variety to have a mean dry matter yield above the average of the four genotypes. Generally, the introduced genotypes were significantly earlier than the check varieties at 32 WAP in root initiation and yield. The study recommends TME225 for farmers in the Guinea savannah ecology.

Keywords: Cassava *Manihot esculenta,* Bulking, Earliness, Savannah, Root storage

Introduction

Cassava (*Manihot esculenta* Crantz) is a dicotyledonous perennial shrub widely produced in Africa. It belongs to the family *Euphorbiaceae* that has some 300 genera and about 5000 species. The edible portion of the crop is the root. It is a staple food and is ranked second after maize in terms of calories consumed (Nweke, 2004). Cassava is Africa's security crop as it has the ability to grow and produce reliable yields in places where other crops produce nothing at all (Dixon *et al*., 2003). A total of 80 million metric tons of cassava are produced annually in sub-Saharan Africa where agriculture is based on rain-fed systems of farming (Dorosh, 1988).

Cassava plays a central role in the per capita income of the producing countries. The tuberized roots are higher in carbohydrates than rice or maize. It provides job opportunities to those who are into its production and processors. Producers of the crop get income from the sale of the produce and products. About 70% of cassava tubers are processed into a variety of produce like gari, tapioca, eba (fried grated cassava flour prepared with hot water) (Lancaster *et al.,* 1982) and the remaining 30% is boiled and consumed in different dishes (Nweke and Lynam, 1997). The leaves are eaten as vegetables as pertains in the Democratic Republic of Congo, Congo Republic, Gabon, Central Africa Republic, Angola, Sierra Leone, and Liberia, and are rich in vitamin A and C (Hahn *et al*., 1989). Cassava tubers can be prepared into chips for export. The fresh roots of cassava contain 70-85% starch and serves as raw materials for industrial starch production (Cock, 1985). It is a potential foreign exchange earner for countries that produce it. Many derived sugar products such as glucose, fructose, maltodextrin and mannitol are obtained from cassava.

Cassava has no specific maturation point and harvest can take place 8-24 months after planting. Studies have shown that late bulking is the single most important factor responsible for the rejection and abandoning of cassava genotypes in sub-Saharan Africa owing to demographic and market pressures (Nweke *et al*., 1994). The Guinea Savanna zone is characterized by short rainfall periods (of up to five month) and long dry periods (of up to seven months) coupled with bushfires. Livestock are released during the long dry period to graze around and they tend to destroy any crop still found green unless protected by fencing which adds up to the production cost. Cassava genotypes that can bulk faster and yield maximum dry matter and escape these threats mentioned would bring benefit and relief to farmers. It is therefore necessary to develop early bulking and high yielding genotypes for marginal rainfall areas like Sub-Saharan Africa.

The objective of the study was to evaluate the earliness in root bulking among two promising genotypes introduced from the International Institute for Tropical Africa (IITA).

Materials and Methods

The experiment was conducted in the Guinea savannah ecological zone in Northern region of Ghana. The area lies on latitude 9º25'41"N and longitude 00º 58' 42"W and on altitude of 183 m above sea level. The soil is brown in colour, moderately drained loam and free from concretions. It is an alfisol under USDA system of classification and a Savanna Ochrosol under Ghana system of classification and belongs to the Nyankpala series. The mean annual rainfall is 1063 mm and it is monomodal in pattern. The annual temperature in the area is 28.3^{O}C with a mean annual day time humidity of 54%.

Cassava materials and treatments

The genotypes used for the study were TME 225, 92/0057, Afisiafi and Biabasse (Figure 4). TME 225 and 92/0057 are improved genotypes originally introduced from IITA. Afisiafi and Biabasse were introduced as control. Afisiafi is an improved variety whilst Biabasse is a local land race.

Land preparation and experimental design

The stumps and shrubs were removed and the field was ploughed with a disc plough and harrowed. The design used was split-plot design with five replications. Monthly harvests (nine) were assigned to nine main plots whilst the four genotypes were assigned to four subplots. The sub-plot size was 4x4 m. Mounds were made using a hoe at 1 m x 1 m, giving a plant population density of 10,000 plants per hectare. The mounds were made about 30 cm high. Planting was done in May using 25 cm cuttings. They were planted in a slanted position with about two-thirds of the cutting buried. The area was fenced to prevent destruction by animals. Weed control was carried out twice at the 8th and 16th WAP.

Data collection and analysis

Starting from 6 weeks after planting (WAP) harvesting of cassava was carried out every four weeks from one of the nine main plots in a replication. The final harvest was done 36 WAP. Canopy width was recorded from five tagged plants and was taken from 6 WAP using a meter rule. The measurements were taken from the largest width on top of the canopy from one edge to the next. The leaves were detached from each of the five sampled plants and counted. Measurement taken on stem was length of stem to apical branching. Measurement of length of stem to apical branching was recorded from 12 WAP using a graduated wooden rule (m). The measurement was taken from the top of the mound to the point of forking. Data were taken on adventitious roots number by uprooting the roots and the adventitious roots counted.

The storage roots were counted after each harvesting starting from 12 WAP. The fresh and dry root weights were taken using an electronic sensitive scale (KERN). During the first three harvests, both mean fresh and dry root weights were recorded from the total sample because of their small weights at that period. Thereafter, in order to ensure accuracy two sub-samples of 100 g each were taken from the fresh weight and oven dried in order to determine dry weight and dry matter content. The mean value of the two subsamples was used to extrapolate for the dry weight of the total fresh weight obtained. The samples were dried at 90^{O}C for 48 hours.

Root harvest index was determined after final harvest at 36 WAP. Weights of total fresh shoot and storage roots were recorded and the harvest index calculated as weight of storage root over total biomass. The data taken were subjected to analysis of variance (ANOVA) using SATTISTIX 7.0 software package and the means were compared using Fisher's Least Significant Difference (LSD). Correlation analysis was done to find the relationships between yield components. Scatter plot analysis was done using dry storage root weight at 16 and 32 WAP.

Results

Leaf production and canopy width of the cassava genotypes

The results showed an increase in the number of leaves per plant from 20 leaves at 6 WAP to 160 leaves at the peak occasion at 24 WAP (Figure 1). Leave production was not significantly different among the genotypes between 6 and 16 WAP. However, there were differences after16 WAP. Afisiafi and Biabasse, the control varieties had significantly higher number of leaves ($P<0.05$) than the introduced genotypes, TME 225 and 92/0057from 20 to 32 WAP.

The width of the canopy increased from a mean of 0.6 m at 8 WAP to a peak of about 1.7 m at 28 WAP (Figure 2). The trend and pattern among the genotypes was similar to that obtained for leaf production. The results showed evidence of decline in canopy width after 28 WAP for all the genotypes. However, there were no significant differences ($P> 0.05$) in canopy width among the genotypes from 8 – 16 WAP. Thereafter, the genotypes showed significant differences (Figure 2). On these occasions, the introduced genotypes, TME 225 and 92/0057 had the narrowest canopy at all sampled occasions and were consistently significantly narrower than Afisiafi and Biabasse.

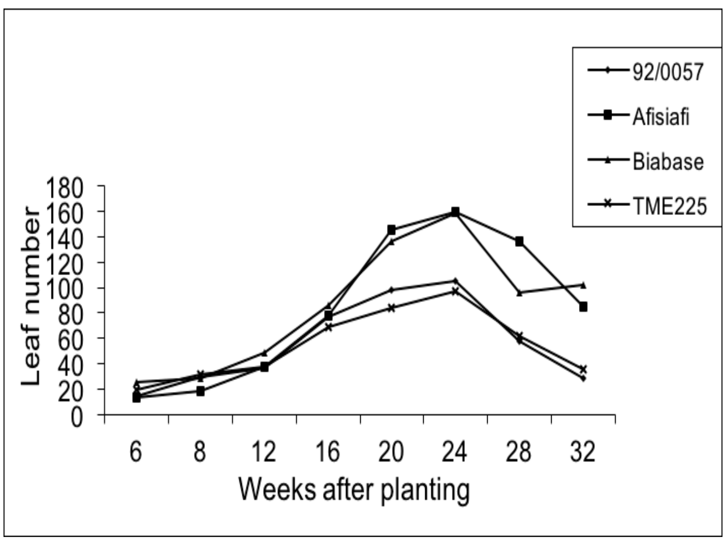

Figure 1. The trend in leaf production among four cassava genotypes.

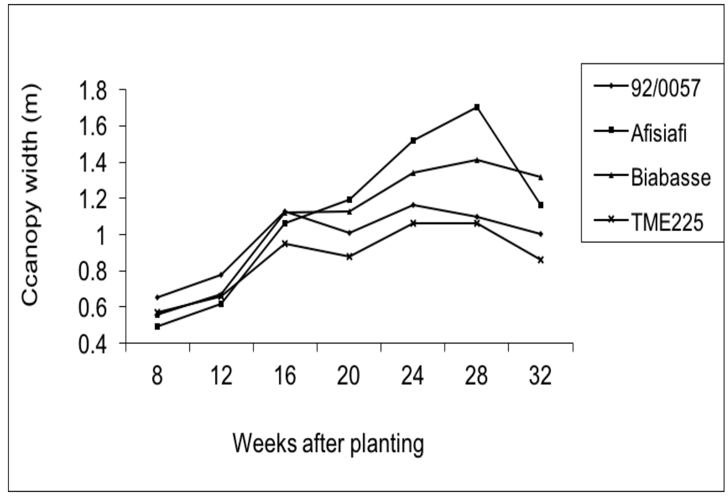

Figure 2. Canopy width of four cassava genotypes at different sampling periods.

Length of stem to apical branching

There were significant differences among the genotypes from 16, 24, up to 32 WAP in length to apical branching. Generally, the introduced genotypes had consistently higher length to apical branching than the control genotypes. The reduction in height at 32 WAP was due to differences in block from which the harvesting was done each time.

Table 1. Length of stem to apical branching of four cassava genotypes from 16 – 32 WAP.

	Length (cm)			
Genotype	**16 WAP**	**24 WAP**	**28 WAP**	**32 WAP**
92/0057	73.6	76.4	80.0	69.2
TME 225	73.7	77.8	71.6	73.6

Afisiafi	42.6	46.0	46.0	40.6
Biabasse	56.4	62.2	49.0	56.4
L.S.D	**4.2**	**12.2**	**0.5**	**0.6**

Field Data, 2014

Root development

Generally, the number of adventitious roots decreased progressively from 6 – 32 WAP with the exception of 16 WAP. Significant differences in adventitious roots (P<0.05) occurred at 16, 20 and 24 WAP (Table 2). During the period 16 – 24 WAP, the genotype 92/0057 produced significantly more adventitious roots than the rest of the genotypes. The three genotypes Afisiafi, Biabasse and TME 225 did not show significant differences in adventitious root formation (Table 2).

Table 2. Number of adventitious roots per plant formed by four cassava genotypes

Genotype	**Period of growth (WAP)**						
	6	**12**	**16**	**20**	**24**	**28**	**32**
92/0057	19	13	31	26	14	16	12
TME 225	19	12	21	17	9	13	10
Afisiafi	19	11	22	13	8	11	8
Biabasse	24	11	20	14	5	13	10
Mean	20	12	23	18	9	13	10
LSD (0.05)	**7**	**4**	**6**	**5**	**4**	**6**	**5**

Field Data, 2014

Number of storage roots per plant

There were no significant differences detected among the genotypes with respect to number of storage or tuberous roots at any stage of sampling. This was in spite of the local variety Biabasse having twice the number of storage roots as Afisiafi or 92/0057 at 12 WAP (Table 3). By 12 WAP most of the genotypes had formed their storage roots and the number did not vary much in subsequent harvests except Afisiafi and 92/0057 which had formed 50 and 57% of the final number of roots respectively. The number of storage roots formed by 6 months after planting (24 WAP) was not different from those at 8 months after planting (32 WAP).

Table 3. Number of storage roots per plant produced by four cassava genotypes.

Genotype	**Period of growth (WAP)**					
	12	16	20	24	28	32
92/0057	3	7	6	5	6	6
TME 225	5	7	7	6	8	7
Afisiafi	3	7	6	7	9	7
Biabasse	6	7	6	7	9	8
Mean	4	7	6	6	8	7
LSD (0.05)	4	2	2	2	3	2

Field Data, 2014

Data recorded at 6 and 8 WAP is omitted due to a mix-up in labelling.

Dry weight of storage roots

Storage roots were first detected in the plants during sampling at 12 WAP. At that time the dry storage root weight of an introduced genotype, TME 225, was significantly higher (P<0.05) than the control variety Afisiafi. The same genotype, TME 225, at 24 WAP produced significantly more dry storage roots than other genotypes except the control variety Biabasse (Table 4). By 28 WAP, the dry weights of storage roots of the genotypes were at par and did not significantly change at 32 WAP (Table 4).

Yield components of the cassava genotypes

At the final harvest the fresh and dry root yield of one of the introduced genotypes, TME 225, was significantly (P<0.05) higher than the rest of the genotypes. A control variety Biabasse and the other introduced genotype, 92/0057, produced more fresh and dry tuberous roots than Afisiafi (Table 5). The tuberous root size of Afisiafi was significantly lower than the rest of the genotypes (Table 5). In terms of the number of storage roots the control variety, Afisiafi, was superior over Biabasse and 92/0057 but not TME 225 (Table 5).

Table 4. Dry weight (kg/plant) of storage roots of cassava genotypes between 12 and 32 WAP.

Genotype	Period of growth (WAP)					
	12	16	20	24	28	32
92/0057	0.09	0.27	0.32	0.42	0.52	0.52
TME 225	0.12	0.26	0.36	0.62	0.70	0.68
Afisiafi	0.07	0.08	0.26	0.38	0.53	0.47
Biabasse	0.10	0.22	0.31	0.49	0.57	0.57
Mean	0.10	0.22	0.31	0.49	0.57	0.57
LSD (0.005)	0.03	0.10	0.15	0.12	0.18	0.15

Field Data, 2014

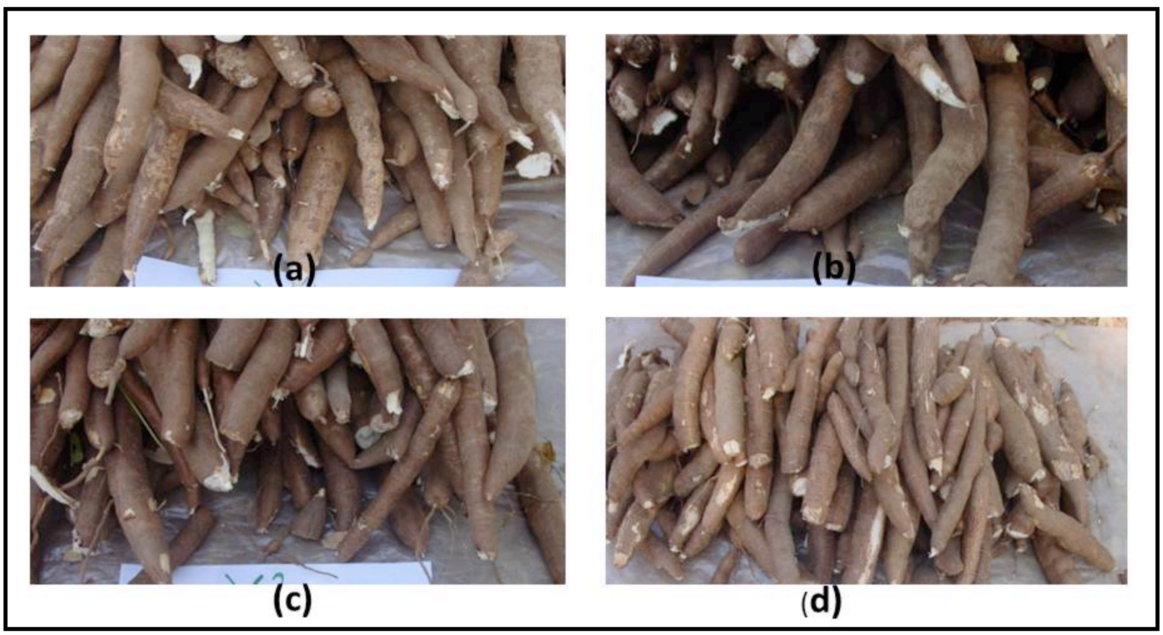

Figure 4: Yield of cassava storage roots 32 WAP, (a) 92/0057, (b) TME 225, (c) Biabasse and (d) Afisiafi

Table 5. Yield components of four genotypes of cassava harvested at 36 WAP

Genotype	FRY (t/ha)	DSR (t/ha)	SRS (kg/root)	NSR roots	DMC (%)	HI (%)
92/0057	11.71	4.81	0.24	5.3	41.3	61.9
TME 225	14.42	6.19	0.24	6.4	43.1	65.6
Afisiafi	8.42	3.55	0.15	6.6	42.0	59.2
Biabasse	11.54	4.60	0.23	5.7	39.7	63.7

Mean	11.52	4.79	0.22	6.0	41.6	62.6
L.S.D (0.5%)	2.56	0.94	0.05	0.8	3.5	6.6

Field Data, 2014

FRY = fresh root yield, DSR= dry storage root, SRS= storage root size, NSR= number of storage root, DMC= dry matter content and HI=harvest index.

The dry weight of storage roots of Afisiafi was significantly lower (P<0.05) than the other genotypes (Table 5). The dry matter content of the cassava roots was not significantly different among the genotypes. On the average, dry matter content was about 41% of the storage roots (Table 5). The harvest index, which is indicative of the efficiency of partitioning of dry matter, did not differ significantly among the genotypes.

Factors that correlate with tuber yield

The results of correlation analysis of the harvest at 32 WAP indicated that root size, shoot fresh weight and harvest index significantly correlated positively to both fresh and dry root weights (Table 6). However, parameters such as root number, diameter of roots and percent dry matter did not correlate significantly to yield in terms of fresh and dry root weight (Table 6).

Table 6. Correlation analysis of yield components of cassava genotypes harvested at 36 WAP

	Fresh root weight (kg/ha)		**Dry root weight (kg/ha)**	
Yield component	**Correlation coefficient r**	**P value**	**Correlation coefficient r**	**P value**
Root size (kg)	0.822	0.000	0.770	0.000
Roots number	0.354	0.125	0.3951	0.0847
Diameter of roots	0.387	0.091	0.3166	0.1738
Shoot fresh weight	0.660	0.001	0.6450	0.0021
Harvest index	0.714	0.000	0.6918	0.0007
% dry matter	0.027	0.908	0.2051	0.3856

Field Data, 2014

Earliness of the cassava genotypes

The relationship between the dry root yield at 16 and 32 WAP had a significant relationship, as can be seen from the scatter plot (Figure 3). Two genotypes, TME 225 and Biabasse produced root yields above the mean yield at the two harvests at 16 and 32 WAP. However, the yields of Afisiafi in both instances were below the mean of all the genotypes. The introduced genotype 92/0057 produced above the mean yield at 16 WAP but by 32 WAP its yield was below average.

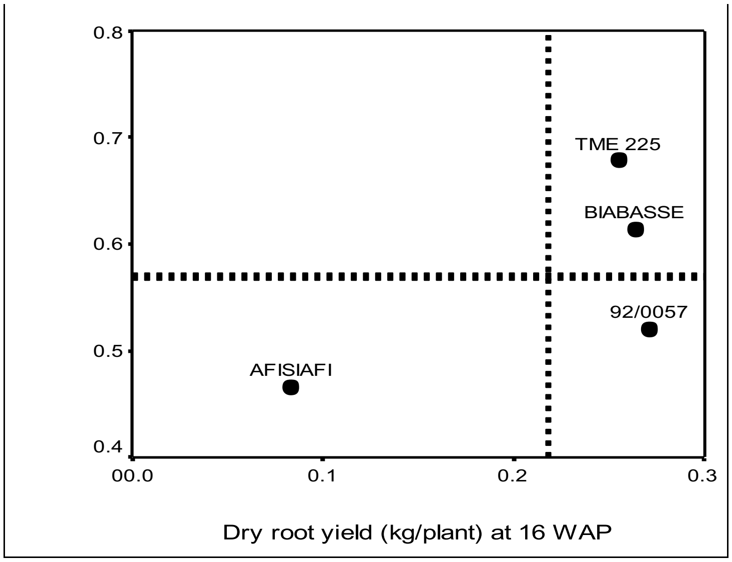

Figure 3. Scatter plot of dry root yield at 16 and 32 WAP of four cassava genotypes.

Discussion

Vegetative growth of the genotypes

The control genotypes (Biabasse and Afisiafi) were shorter and formed more leaves leading to broader canopy development than the introduced genotypes (92/0057 and TME 225) during the early part of growth. Genetic difference may account for the difference. The decrease in leaf number from the peak at 24 WAP for all four genotypes may be due to the onset of the dry periods in December leading to shedding of leaves. According to Indira *et al*. (1997), several factors especially combined effects of genotypes and environmental influenced branching and length of stem to apical branching. The length of stem to branch of Afisiafi was lower than the 75-100 cm reported (RTIP, 2002). The environment therefore might have contributed to the length to apical branching.

Adventitious root development

Adventitious roots were detected among genotypes from 6- 32 WAP with a progressive decrease in their number. The reduction of adventitious roots with time may be due to some of the adventitious roots being converted to tuberous roots and some becoming atrophied. Onwueme and Sinha (1991) have reported that in cassava, adventitious roots develop to make a fibrous root system and a few of these fibrous roots, between three and ten, start to bulk and become storage roots.

Earliness in root bulking

Wholey and Cock (1974) established that earliness in root yield is related to rapid bulking and that it varies from cultivar to cultivar. Early bulking genotypes have high source and sink capacities which translates into total biomass for the early bulking groups. Bulking base on dry weight of storage roots was observed in the genotypes at 12 WAP and it could be earlier in other varieties, eighth week after planting (CIAT, 1973). Bulking was relatively low in the much acclaimed variety Afisiafi even though it produced more leaves and canopy width than the other genotypes in the early growth period. Afisiafi was not able to utilise the photosythetic aparatus to produce photosynthetes which would have resulted in sink activity and early bulking. Examination of yield on dry weight basis shows that the introduced genotypes bulked earlier and higher than the improved variety, Afisiafi. The local variety, Bibiasse, used as check was comparable with the introduced genotypes and showed its adaptation to the envoronment.

Fresh and dry tuberous roots yield and factors correlating with them

Fresh tuberous root yield is determined by number and size (weight) of storage root. Variation was not detected among the genotypes in terms of number of storage roots formed at the final harvest. The number of storage roots formed according to Ntawuruhunga *et al*. (1998) is heritable even though it can be influenced by the environment. Fresh root yield of TME 225 at final harvest at 36 WAP was higher than the national average while that of Afisiafi was below the national average of 12 ton/ha (Adjei-Nsiah *et al*., 2007). Afisiafi, an improved variety noted for high yield and starch production (RTIP, 2002) was used as a control but performed below expectation. It produced many storage roots but were of smaller sizes contributing to its low storage root yield.The genotype, 92/0057, was planted in an inland valley system in the forest–savanna transition zone of Nigeria and 20.9 and 7.9 t/ha obtained in 6 months for fresh and dry root yield respectively was higher than the corresponding 11.7 and 4.81 t/ha obtained in this study (Okechukwu, and Dixon, 2009). The dry matter and root harvest index obtained in this study was comparable to that study

The correlation analysis shows that root size, shoot weight and harvest index showed significant relationship with both fresh and dry weights. Kawano (1987) treated yield as a function of biomass and harvest index. The introduced genotypes were taller than the control varieties and that might have contributed to shoot biomass that correlated with fresh and dry root yield. The smaller root size of Afisiafi might explain its inferior yield

Conclusion

The introduced genotypes bulked early and yield of TME 225was comparable with the locally established variety Bibiasse. Afisiafi, an improved variety used as control was outyielded by the test genotypes. Farmers in the nothern savanna ecology can cultivate the test genotype TME 225.

References

Adjei-Nsiah S, Kuyper TW, Leeuwis C, Abekoe MK and Giller KE (2007). Evaluating sustainable and profitable cropping sequences with cassava and four legume crops: Effect on soil fertility and maize yields in the forest/savannah transitional agro-ecological zone of Ghana. ***Field Crops Research***, **103**: 87-97.

CIAT (1973). ***Annual Report, 1972.*** Centro International de Agricultura Tropical Cali, Colombia, pp 192.

Dixon AGO, Bandyopadhyay R, Coyne D, Ferguson M, Ferris SB, Hanna R, Hughes Jd'A, Ingelbrecht I, Legg J, Mahungu N, Manyong V, Mowbray D, Neuenschwander P, Whyte J, Hartmann P and Ortiz R (2003). Cassava: From poor farmers' crop to pacesetter of African rural development. ***Chron. Hortic***. 43:8–15.

Dorosh P (1988) ***The economics of root and tuber crops in Africa***. RCMP Research Monograph no.1 RCMP, IITA, IBADAN, Nigeria, pp 65-92.

Indira JE, Osiru DSO and Porto CM (1997). ***Morphology of cassava***. IITA Research Guide 61. Ibadan, Nigeria, pp 6-27.

Hahn SK, Isoba JCG and Ikotun T (1989). Resistance breeding in root and storage root crops at the International Institute of Tropical Agriculture, Ibadan, Nigeria. ***Crop Prot.*** 8:147–168.

Kawano K (1987). Inherent environmental factors related to cassava varietal selection In: Harshey C. (ed) ***Casava breeding, a multidisciplinary review***.CIAT cali, Colombia, pp 207-226.

Lancaster PA, Ingram JS, Lim MY and Coursey DG (1982). Traditional Cassava based Foods. Survey of processing techniques. ***Economic Botany*** 36(1):12-45.

Ntawuruhunga P, Ojulong H and Dixon AGO (1998). Genetic variability among cassava genotypes and its growth performance over time. p. 242–248. *In* M.O. Akoroda, and I.J. Ekanayake (ed.) ***Root crops and poverty alleviation***. Proc. of 6th Symp. of ISTRC-AB. 22–28 Oct. 1995. Int. Soc. for Tropical Root Crops, Lilongwe, Malawi.

Nweke F (2004). ***New challenges in the cassava transformation in Nigeria and Ghana***. EPTD Discussion Paper No. 118. Available at http://www.ifpri.org/divs/eptd/dp/papers/eptdp118.pdf [accessed 10 March 2008; verified 29 July 2009]. Environment and Production Technology Div., Int.Food Policy Research Inst., Washington, DC.

Nweke FI and Lynam JK (1997). Cassava in Africa. African J. ***Root Storage Crops*** 2:10–13.

Nweke FI, Dixon AGO, Aseidu R, Folayan SA (1994). Cassava varietal needs of ***farmers and the potential for production growth in Africa***. COSCA working paper 10, pp 239.

Okechukwu RU and Dixon AGO (2009). Performance of improved cassava genotypes for early bulking, disease resistance, and culinary qualities in an inland valley ecosystem. ***Agronomy Journal***, 101: (5) 1258-1265

Onwueme IC and Sinha TD (1991). ***Field crop production in tropical Africa***. Technical centre for Agricultural and Rural Corporation (CTA), Ede, the Netherlands, pp 233-249.

Root and Tuber Improvement Programme (RTIP) (2002). Varietal characteristics of four improved cassava varieties, ***RTIP Fact sheet***, Published by Root and Tuber Improved Programme of Ministry of Food and Agriculture, p 1.

Wholey DW and Cock JH (1974). Onset and rate of root bulking in cassava. ***Experimental Agriculture*** 10:193-198