Original article

Fruit characteristics and ripening pattern of ten *Musa* genotypes in a sub-humid environment in Nigeria

K. Paul Baiyeri[1]*, Abdou Tenkouano[2]

[1] Departement of Crop Science, Univ. of Nigeria, Nsukka, Nigeria

Present address: Int. Inst. Trop. Agric. (IITA), Oyo Road, PMB 5320, Ibadan, Nigeria
p.baiyeri@cgiar.org

[2] IITA-Humid For. Eco-reg. Cent. BP 2008 Messa, Yaounde, Cameroon

* *Correspondence and reprints*

Received 14 March 2007
Accepted 24 July 2007

Fruits, 2008, vol. 63, p. 3–9

DOI: 10.1051/fruits:2007039
www.fruits-journal.org

***Resumen Español**, p. 9*

Fruit characteristics and ripening pattern of ten *Musa* genotypes in a sub-humid environment in Nigeria.

Abstract — Introduction. Conventional evaluation of *Musa* through multilocation trials has often been carried out to ascertain the yield stability and ecological range of new varieties but, for prospective growers, it is equally important to know the fruit characteristics and ripening pattern of the genotypes. Indeed, fruit characteristics determine consumers' attitudes towards the new varieties, and the associated market value of these varieties. **Materials and methods**. The metric traits and ripening pattern of fruits from nine *Musa* hybrids and one local variety of plantain were evaluated during two cropping seasons in a sub-humid environment in Nigeria. **Results**. All the traits measured varied with the genotype, but cropping cycle influenced only fruit weight and days to complete senescence of fruits. The interaction between genotype and cropping cycle was significant on fruit weight, fruit length and days to attain four different ripening stages. Most genotypes had better values in the ratoon harvest than in the plant crop. Fruit length and shape of PITA 21 were comparable with those of the local check, but the index of edible proportion was highest in PITA 22. PITA 21 and PITA 26 had the longest green life and total shelf life. **Conclusion**. The genotypes evaluated in our study revealed different utilization potentials. Also, the better postharvest life of some of the hybrids and comparable metric traits with the local check suggested the high adoption potential of the hybrids.

Nigeria / *Musa* / hybrids / variety trials / fruits / developmental stages / agronomic characters / storage

Caractéristiques et évolution de la maturation des fruits de dix génotypes de *Musa* dans un environnement subhumide au Nigéria.

Résumé — Introduction. L'évaluation conventionnelle de bananiers par essais multisites a souvent été effectuée pour étudier la stabilité du rendement et la gamme écologique de nouvelles variétés, mais, pour des cultivateurs éventuels, il est également important de connaître les caractéristiques et le comportement de maturation des fruits des différents génotypes. En effet, les caractéristiques des fruits déterminent l'attitude du consommateur vis-à-vis des nouvelles variétés et la valeur marchande qui leur est associée. **Matériel et méthodes**. Les caractéristiques biométriques et le comportement de maturation des fruits de neuf hybrides de *Musa* et d'une variété locale de plantain ont été évalués pendant deux cycles de culture dans un environnement subhumide au Nigéria. **Résultats**. Toutes les caractéristiques mesurées ont varié en fonction du génotype, mais le cycle de production n'a influencé que le poids des fruits et le nombre de jours nécessaires pour parvenir à leur sénescence. L'interaction entre le génotype et le cycle de production a été significative pour le poids et la longueur du fruit, ainsi que pour le nombre de jours requis pour atteindre quatre stades de maturation différents. La plupart des génotypes ont présenté de meilleures récoltes lors du cycle issu de rejets que lors du premier cycle de plantation. La longueur et la forme des fruits de PITA 21 ont été comparables à celles du témoin local, mais le taux de partie comestible a été le plus haut pour les fruits de PITA 22. PITA 21 et PITA 26 ont eu les plus longues vie verte et durée de conservation totale. **Conclusion**. Les génotypes évalués dans notre étude ont révélé différents potentiels d'utilisation. En outre, une meilleure conservation après récolte de certains hybrides par rapport au témoin local et des caractéristiques biométriques comparables à ce cultivar suggèreraient une forte probabilité d'adoption de ces hybrides.

Nigéria / *Musa* / hybride / essai de variété / fruits / stade de développement / caractère agronomique / stockage

1. Introduction

In response to the increasing number of biotic constraints to the production of banana and plantain (*Musa* spp.), several breeding programs have been launched around the world, resulting in the selection of genotypes that combine multiple resistance with good horticultural attributes [1]. Conventional evaluation through multilocation trials has often been carried out to ascertain the yield stability and ecological range of the new varieties, but it is equally important for prospective growers to know the fruit characteristics and ripening pattern of the genotypes. This is because fruit characteristics determine consumers' attitudes towards, and the associated market value of, the new varieties. Likewise, the ripening pattern of a variety determines its shelf life and utilization potential [2].

Plantain processing and consumption patterns vary with the cultural and socioeconomic settings of the consumers, particularly in Nigeria and other plantain-growing regions of West and Central Africa. It is a fact that there are specific uses associated with each ripening phase of the fruits, but the rate at which plantains ripen considerably determines how long the fruit remains useable for each specific method of cooking [3]. While pre-harvest and postharvest handling conditions may hasten or slow the ripening process, there are also reported differences between cultivars.

The objective of our study was to assess the morphological characteristics and ripening pattern of some banana and plantain hybrids, relative to the preferred landrace.

2. Materials and methods

The experiment was conducted at the research farm of the Faculty of Agriculture, University of Nigeria in Nsukka (lat. 06° 52' N, long. 07° 24' E, alt. 447 m above sea level) in south-eastern Nigeria. Nsukka is located in a sub-humid agro-ecology, with a bimodally distributed annual rainfall of about 1500 mm, and the soil is described as sandy loam oxisol of the Nkpologu series [4]. The postharvest study was conducted in the laboratory of the Department of Crop Science, University of Nigeria, Nsukka, Nigeria, with an average ambient temperature of (30 ± 1) °C and relative humidity ranging between 75% and 80%.

Ten genotypes comprising seven plantain hybrids (CRBP 39, PITA 14, PITA 21, PITA 22, PITA 23, PITA 25 and PITA 26), one cooking banana hybrid (BITA 7), one dessert banana hybrid (FHIA 17), and a Nigerian landrace plantain, 'Agbagba', as local check were evaluated. The name of the hybrid genotypes identifies the breeding institutes that obtained them. Thus, the PITA series correspond to *Plantain of the International Institute of Tropical Agriculture*, BITA to *Banana of the International Institute of Tropical Agriculture*, CRBP to the *Centre africain de recherche sur bananes et plantains* (Cameroon) and FHIA to the *Fundación Hondureña de Investigación Agrícola* (Honduras).

The experimental design was a randomized complete block design (RCBD) with three replications of five plants per replicate, per genotype. The plants were spaced at 3 m between the rows and 2 m within rows, giving a planting density of 1667 plants·ha^{-1}. The field was surrounded by a border row of landrace genotype that is susceptible to black Sigatoka disease. All other crop management practices were carried out following standard recommendations [5].

The plants were grown to maturity for two cropping cycles (plant crop and ratoon crop), and we studied fifteen bunches per genotype per cropping cycle. Bunches were harvested when the male bud had degenerated or when at least one fruit on the first nodal cluster had started ripening [5]. From each harvested bunch, fruits were sampled from the second proximal hand per bunch according to the recommendations of Dadzie and Orchard [6], and Baiyeri and Ortiz [7]. Five fruits per harvested bunch, thus 75 fruits per genotype and per cropping cycle, were used for the ripening test, while 30 fruits per genotype and per cropping cycle were utilized for dry matter analysis and other metric trait measurements.

Data were collected on initial fruit weight, length and circumference. The weights of the pulp and peel were also determined after peeling of the fruit, and the [pulp weight:fruit weight] ratio was calculated to estimate the edible proportion of the fruit. Both pulp and peel fractions were oven-dried at about 70 °C for (24 to 36) h to determine their dry matter content, which was calculated as the [dry weight:fresh weight] ratio.

The fruits were allowed to ripen under the ambient laboratory conditions, and ripening was monitored using a specific chart (*table I*). The number of days after harvest to ripening stage 3 (onset of ripening), stage 6 (complete ripeness), stage 7 (onset of senescence) and stage 10 (when fruit peel color was completely black) was recorded.

Data were analyzed with GENSTAT Discovery, Edition 1, Release 4.23 [8], as a split-plot in a randomized complete block design. The main-plot treatment was genotype, while the sub-plot was the cropping cycle. Split-plot analysis was performed to estimate the effect of cropping cycle with higher precision.

Table I.
Fruit peel color chart utilized for identification of ripening changes for banana fruits (adapted from Ferris [15] and Baiyeri [16]).

Ripening stage	Description of peel color	Ripening physiological phases
1	Green	Pre-climacteric
2	Pale green	Pre-climacteric
3	Pale green with yellow tips	Onset of climacteric
4	50% yellow, 50% green	Climacteric
5	More yellow than green	Climacteric
6	Pure yellow, complete ripeness	Climacteric
7	Yellow with black coalescing spots	Onset of senescence
8	50% yellow, 50% black	Senescence
9	More black than yellow	Senescence
10	Completely black	Senescence

3. Results

The analysis of variance of fruit characteristics and ripening pattern revealed a highly significant ($P < 0.01$) genotype effect on most of the traits (*table II*). The effect of cropping cycle was only significant on the fruit weight and the number of days for fruit to attain ripening stage 10. The interaction between genotypes and cropping cycles significantly influenced fruit weight, fruit length, pulp dry matter and days to all the ripening stages evaluated (*table II*).

The local check cultivar Agbagba had the heaviest mean fruit weight with a range of (140 to 206) g during the two crop cycles (*table III*); BITA 7 had the lowest weight in the two cycles. Fruit weight and fruit length increased in the ratoon crop for some genotypes but, for BITA 7, PITA 22 and PITA 26, there was a decrease for these traits (*table III*). The fruits of PITA 21 were the

Table II.
ANOVA showing sources of variation, degree of freedom, mean squares and significance test of the components of variance of fruit metric traits and shelf life for banana fruits.

Source of variation	Degree of freedom	Fruit weight	Fruit length	Fruit girth	Edible proportion	Pulp dry matter	Peel dry matter	Number of days up to			
								stage 3	stage 6	stage 7	stage 10
Replication	2	1084.1	2.999	4.62	21.93	2.948	1.765	0.546	0.253	1.001	0.169
Genotype (G)	9	3379.9**	17.386*	10.15 ns	101.70*	111.378***	8.529***	14.209***	36.113***	36.451***	47.947***
Main plot error	18	825.4	5.674	8.10	34.21	11.414	1.477	0.831	3.718	4.229	4.195
Cropping cycle (C)	1	3949.6**	13.901 ns	1.99 ns	125.57 ns	0.00 ns	3.902 ns	2.282 ns	10.004 ns	3.601 ns	33.750*
G × C	9	1553.4*	10.670*	9.46 ns	34.50 ns	13.840*	1.670 ns	3.063*	15.073**	16.789**	15.514*
Sub-plot error	20	451.4	3.603	11.02	36.97	5.355	0.993	1.276	3.495	3.932	5.820

ns: Non-significant, ***, **, * significant at the 0.1%, 1% and 5% probability level, respectively.

Table III.
Genotype by cropping cycle interaction effect on some banana fruit metric traits, and number of days to specific ripening stages.

Cropping cycle	Genotype	Fruit weight (g)	Fruit length (cm)	Edible proportion (%)	Pulp dry matter (%)	Number of days up to			
						stage 3	stage 6	stage 7	stage 10
Plant crop	Agbagba	140.3	19.8	57.2	37.0	2.7	6.4	7.8	14.0
	BITA 7	89.0	19.4	49.0	26.0	2.5	4.3	6.2	11.8
	CRBP 39	93.6	19.8	48.6	33.4	4.9	11.6	12.7	17.8
	FHIA 17	119.0	18.3	56.4	22.6	5.2	9.8	11.2	16.5
	PITA 14	101.9	20.8	55.2	32.6	5.8	10.7	14.0	18.9
	PITA 21	110.3	22.8	56.3	29.6	6.0	10.7	12.0	18.8
	PITA 22	144.3	20.8	63.7	27.0	4.8	8.4	10.3	15.4
	PITA 23	90.9	18.1	53.2	32.7	6.1	13.9	15.2	21.1
	PITA 25	99.4	20.5	55.1	30.1	3.2	6.8	8.1	15.2
	PITA 26	138.3	20.0	59.8	29.6	6.8	11.6	14.3	22.4
Ratoon crop	Agbagba	206.4	24.5	58.1	38.1	5.0	13.0	14.0	23.0
	BITA 7	70.2	17.3	63.8	29.0	2.5	5.3	6.7	14.6
	CRBP 39	130.1	21.3	50.4	28.0	3.6	7.9	9.1	16.5
	FHIA 17	150.0	19.4	60.4	19.7	6.2	12.2	13.5	18.3
	PITA 14	116.6	22.0	59.8	33.0	4.8	9.3	10.8	18.5
	PITA 21	127.9	23.7	54.8	29.1	8.9	14.3	16.0	20.6
	PITA 22	113.6	18.1	66.3	32.0	3.7	7.6	8.8	15.8
	PITA 23	136.2	21.6	56.5	34.7	6.2	10.7	12.2	18.0
	PITA 25	126.2	22.9	52.2	29.9	4.3	9.0	11.1	16.8
	PITA 26	112.0	17.7	61.1	27.3	6.7	13.3	14.6	24.9
Least significance difference (P = 0.05)		41.9	3.6	ns	4.8	1.7	3.1	3.3	3.7

longest but statistically similar to the local check cultivar. Longer and properly filled fruits command higher visual appeal and market price.

The edible proportion of the fruits varied significantly among genotypes but, across harvests, the variability was not statistically significant at the 5% probability level. For most genotypes, a higher proportion of the fruit weight was edible in the ratoon crop harvest. The mean over the two cycles showed that PITA 22 had the highest (65%) edible proportion; with 49.5%, CRBP 39 had the lowest. Most of the hybrids except PITA 22 had a statistically similar edible proportion to Agbagba, the local check cultivar. Dry matter content of fruit pulp was highest in Agbagba. Among the hybrids, PITA 14 and PITA 23 had relatively higher pulp dry matter, while FHIA 17 had the lowest value (*table III*).

The duration to ripening stage 3 of PITA 21 was the longest, ranging between (5.5 and 9.5) days. The local check cultivar, however, had a range between (2 and 5) days (*table III*). The number of days to stage 3 of some of the hybrids was longer than that of the check cultivar. Number of days to ripening stage 6 (when peel color completely turns yellow) and number of days to the onset and end of senescence were longest in PITA 21 and PITA 26 (*figure 1*). The number of days to all the ripening stages considered was shortest in BITA 7. The total shelf life (when peel color had completely turned black, *i.e.*, stage 10) was fairly long for some of the hybrids given that the fruits were laid out under ambient

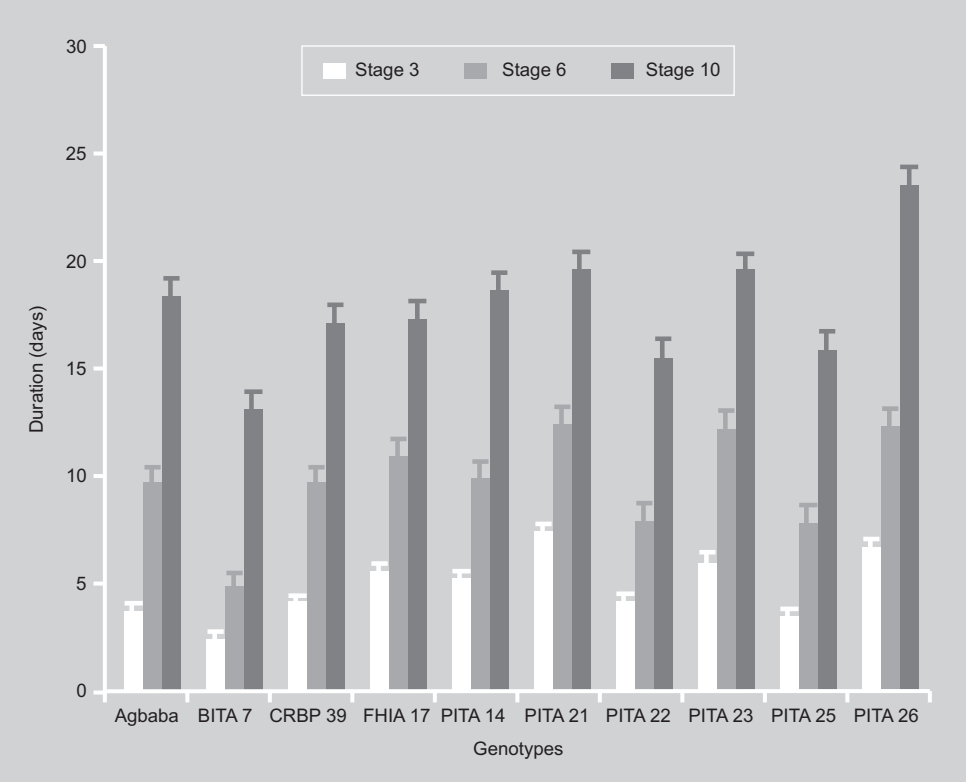

Figure 1.
The main effects of *Musa* genotype on number of days to ripening stages 3 (onset of ripening), 6 (complete ripeness) and 10 (fruit peel color completely black).

laboratory conditions. The number of days to ripening stage 3 of fruits harvested in the ratoon crop was generally longer than the plant crop harvest except for CRBP 39, PITA 14 and PITA 22 (*table III*). Days to complete ripeness (stage 6) was longest for PITA 23, PITA 26 and CRBP 39 during the plant crop but, for fruits harvested in the ratoon cycle, Agbagba, PITA 21 and PITA 26 had the longest duration to complete ripeness. Shelf life of ratoon crop fruits of Agbagba and PITA 26 was evidently longer. Generally, number of days to attain ripening stages 3, 6 and 10 was the longest in PITA 26 and PITA 21 (*figure 1*).

4. Discussion

Significant genotypic effects on the postharvest traits evaluated are in concordance with earlier reports [2, 9]. The plant crop and ratoon crop underwent different growing environments; therefore, significant changes in ripening patterns of fruits from the two crop cycles were probably due to the different pre-harvest conditions. Pre-harvest growing conditions influence ripening behaviors of banana and plantain fruits [6, 10].

Under the local conditions where these genotypes were evaluated, a number of the hybrids had better fruit traits than the local check, suggesting that, if cooking qualities of the hybrids are not a limiting factor, then those hybrids have high potential for adoption. The higher edible proportion of PITA 22 meant that the genotype had a higher fresh fruit processing value; however, the higher percent dry matter content of the local check suggested higher flour yield per unit weight of fresh fruit [11].

Ripening pattern and shelf life of climacteric fruits such as bananas and plantains are important components of delivery packages that will ensure that, after production, postharvest losses due to poor handling resulting from lack of knowledge are abated. Therefore, data on the ripening behavior of the ten genotypes is significant. Duration to ripening stage 3 was an indicator of the

green life and suggested the period for safe transportation with minimal mechanical injury, which could emanate from the softening of fruit peel. For most cases, in Nigeria, days to stage 6 (complete ripeness) and stage 7 (onset of senescence) are a marker for duration of commercial usefulness. Thus, PITA 21 and PITA 26 had the longest commercial value period. It also suggests that these genotypes have higher potential utility [2, 12]. At ripening stage 10, the peel color had turned black but the pulp of some genotypes still remains firm and edible; in western Nigeria, the pulp of such overripe or senesced fruit is ground with maize or guinea corn and boiled as pottage [13]. Utilization of overripe fruits for wine production has been investigated at the postharvest laboratory of the plantain and banana improvement program of the International Institute of Tropical Agriculture [14]. Thus, overripe fruits or fruits with senesced peel are still of economic importance in some socioeconomic settings. As such, the number of days to complete senescence indicates shelf life. Therefore, the genotypes evaluated in our study revealed different utilization potentials.

References

[1] Vuylsteke D., Ortiz R., Ferris R.S.B., Crouch J.H., Plantain improvement, Plant Breed. Rev. 14 (1997) 267–320.

[2] Baiyeri K.P., Tenkouano A., Mbah B.N., Mbagwu J.S.C., Genetic and cropping system effects on yield and postharvest characteristics of *Musa* spp. L. in southeastern Nigeria, Afr. Crop Sci. J. 7 (1999) 1–7.

[3] Burdon J.N, Moore K.G., Wainwright H., The post harvest ripening of three plantain cultivars (*Musa* spp. AAB group), Fruits 46 (1991) 646–648.

[4] Ndubizu T.O.C., Effect of split fertilizer application on growth and yield of falsehorn plantain (*Musa* spp.) in the rain forest belt of Nigeria, Der Tropenlandwirth, Z. Landwirtsch. Trop. Subtrop. 82 (1981) 153–161.

[5] Swennen R., Plantain cultivation under West African conditions - a reference manual, Int. Inst. Trop. Agric., Ibadan, Nigeria, 1990, 24 p.

[6] Dadzie B.K., Orchard J.E., Post-harvest criteria and methods for routine screening of banana/plantain hybrids, IPGRI/INIBAP, Montpellier, France, 1996, 47 p.

[7] Baiyeri K.P., Ortiz R., Agronomic evaluation of plantain and other triploid *Musa*, Acta Hortic. 540 (2000) 125–135.

[8] Anon., GENSTAT 5.0, Release 4.23DE, Discov. Ed. 1, Lawes Agricultural Trust, Rothamsted Exp. Stn., UK, 2003.

[9] Ferris R.S.B., Adeniji T.A., Chukwu U., Akalumbe Y.O., Vuylsteke D., Ortiz R., Postharvest quality of plantains and cooking bananas, in: Ortiz R., Akoroda M.O. (Eds.), Plantain and banana production and research in West and Central Africa, Int. Inst. Trop. Agric., Ibadan, Nigeria, 1996, pp. 15–22.

[10] Robinson J.C., Bananas and plantains, CAB Int., Crop Prod. Sci. Hortic, 5, Wallington, UK, 1996, 245 p.

[11] Adeniji T.A., Barimalaa I.S., Achinewhu S.C., Evaluation of bunch characteristics and flour yield potential in black Sigatoka resistant plantain and banana hybrids, Glob. J. Pure Appl. Sci. 12 (2006) 41–43.

[12] Baiyeri K.P., Effect of storage media on the green life span and culinary qualities of plantain (*Mus*a sp. AAB) fruits, AgroSci. 2 (2001) 19–25.

[13] Baiyeri K.P., Effect of nitrogen fertilization on mineral concentration in plantain (*Musa* sp. AAB) fruit peel and pulp at unripe and ripe stages, Plant Prod. Res. J. 5 (2000) 38–43.

[14] Adeniji T.A., Recipe for plantain/banana wine, *Mus*Afr. 8 (1995) 23–24.

[15] Ferris R.S.B., Effects of damage and storage environment on the ripening of cooking banana with implications for postharvest loss, Cranfield Inst. Technol., Thesis, Silsoe Campus, UK, 1991, 139 p.

[16] Baiyeri K.P., Variable light transmission through four polyethylene colours used for plantain (*Musa* sp. AAB) fruits storage as influencing its postharvest and culinary qualities, Int. Agrophys. 19 (2005) 19–25.

Características y evolución de la maduración de los frutos de diez genotipos de *Musa* en un entorno subhúmedo en Nigeria.

Resumen — Introducción. La evaluación convencional de bananos mediante estudios múltiples se llevó a cabo a menudo con el fin de estudiar la estabilidad del rendimiento así como la gama ecológica de nuevas variedades; pero, para cultivadores ocasionales, es importante también conocer las características y el comportamiento de maduración de los frutos de diferentes genotipos. Efectivamente, las características de los frutos determinan la actitud del consumidor respecto a nuevas variedades, y respecto al valor en el mercado que se les asocia. **Material y métodos**. Las características biométricas así como el comportamiento de maduración de los frutos de nueve híbridos de *Musa* y de una variedad local de plátano, se evaluaron durante dos ciclos de cultivo en un entorno subhúmedo en Nigeria. **Resultados**. Todas las características medidas variaron en función del genotipo, sin embargo el ciclo de producción sólo influyó el peso de los frutos y el número de días necesarios para alcanzar su senescencia. La interacción entre el genotipo y el ciclo de producción fue significativa para el peso y para la longitud del fruto, así como para el número de días necesarios para alcanzar cuatro estados de maduración diferentes. La mayoría de los genotipos presentaron mejores cosechas durante el ciclo resultados de los injertos que durante el primer ciclo de plantación. La longitud y la forma de los frutos de PITA 21 fueron compatibles con los del testigo local, sin embargo el porcentaje de parte comestible fue más alto para los frutos de PITA 22. PITA 21 y PITA 26 tuvieron ambos la vida verde y la duración de conservación total. **Conclusión**. Los genotipos evaluados en nuestro estudio mostraron diferentes potenciales de uso. Asimismo, una mejor conservación tras la cosecha de ciertos híbridos en relación con el testigo local por un lado, y por otro, con unas características biométricas comparables a este cultivar, sugirieron una fuerte probabilidad de adopción de estos híbridos.

Nigeria / *Musa* / híbridos / ensayos de variedades / frutas / etapas de desarrollo / características agronómicas / almacenamiento