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Characterization and grouping of plantain clones on the basis of their genomic constitution and morphological traits of economic importance[1,2]

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ABSTRACT

An experiment was established to characterize twenty-seven locally selected and introduced plantain clones. The clones were arranged in a randomized complete block design with three replications. Twenty morphological descriptors were used to obtain information of the plant, bunch and individual fruits at bunch-emergence and at harvest. The clones were first organized into two main groups on the basis of their genomic constitution: true plantain (*Musa* AAB) and cooking banana (*Musa* ABB, AAAB). Within the second group, we included three *Musa* AAB clones that are considered distinctive cooking bananas because the *M. acuminata* species responsible for the donation of the A genome had its origin in the Pacific and not in Asia. In each main group the clones were subdivided into true-horn, false-horn and French on the basis of bunch phenotype. Clones in these three subgroups were further subdivided into tall and dwarf, depending on the height of the pseudostem. After the clones were organized into this classification, statistical comparisons were made between or among those corresponding to the same subdivision, utilizing the data obtained from the plant, bunch and individual fruit traits. This scheme is easy to implement in the field, provides for

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the clustering and separation of clones regardless of their geographical origin and common names, and offers the opportunity for agronomists and horticulturists to learn about the economic potential of the clones from the outset. The application of this scheme will allow the number of plantain accessions in the TARS collection to be reduced from 27 to 20 clones.

Key words: plantain, clones, description, grouping

RESUMEN

Caracterización y agrupación de clones de plátano a base del genotipo y rasgos morfológicos de importancia económica

Veintisiete clones de plátano, seleccionados localmente e introducidos, se sembraron con el propósito de caracterizarlos. En el experimento se utilizó un diseño de bloques completos al azar con tres repeticiones. Se recopiló información de 20 rasgos morfológicos de la planta, racimo y frutas individuales al momento de la floración y la cosecha. Los clones se organizaron en dos grandes grupos a base de su constitución genómica: plátanos verdaderos (*Musa* AAB) y guineos de cocinar (*Musa* ABB, AAAB). Dentro del segundo grupo se incluyeron tres clones de *Musa* AAB que son considerados guineos de cocinar distintivos porque la especie de *M. acuminata* donante del genoma A es oriunda del Pacífico y no de Asia. En cada grupo los clones se subdividieron en tipo cuerno, cuerno-falso y francés, a base del fenotipo del racimo. Una vez los clones se organizaron mediante el fenotipo del racimo, éstos se volvieron a sub-dividir en altos y enanos, dependiendo de la altura del pseudotallo. Después de organizar los clones en este esquema de clasificación, éstos se compararon entre sí utilizando los datos obtenidos de la planta, racimo y frutas individuales. Este esquema es fácil de implementar en el campo, y provee para la agrupación y separación de clones independientemente del origen geográfico y nombres comunes. Además, ofrece la oportunidad a los agrónomos y horticultores de conocer inmediatamente sobre el potencial económico de los clones. La aplicación de este esquema permitirá que se pueda reducir el número de accesiones en la colección de TARS de 27 a 20 clones.

INTRODUCTION

The traditional scheme for classifying domesticated plantain and banana is based on the contribution in terms of numerical values of the two wild species *Musa acuminata* and *M. balbisiana* to 15 plant and inflorescence structural features (Simmonds and Shepherd, 1955; Haddad and Borges, 1974). In plantain, the scheme assumes that this perennial herbaceous plant originated from a natural interspecific cross between these wild species in which *M. acuminata* contributed the A genome and *M. balbisiana* the B genome.

More recently, the International Plant Genetic Resources Institute (IPGRI) proposed the use of five categories of descriptors (passport, management, environmental site, characterization and evaluation) for the identification and conservation of *Musa* germplasm in collections (IPGRI-INIBAP/CIRAD, 1996). Among these categories, characterization provides for an easy and rapid distinction of phenotypes, and usually involves highly heritable traits that can easily be recognized visually and are not sensitive to environmental conditions. Evaluation allows for a more detailed description of economic traits, and includes the use of replicated plots and if possible multi-site experiments.

Except for the recommended use of some highly discriminating descriptors in each category, IPGRI does not expect that *Musa* curators utilize all the proposed descriptors. It suggests focusing on the use of only those that fulfill the needs of a particular program.

Although some progress has been made, most of the germplasm in field collections continues to be maintained without proper characterization and documentation and the clones are recognized mainly by a descriptive common name.

In this study, we attempted to describe and compare the various plantains growing in the Tropical Agriculture Research Station (TARS) germplasm collection with the objective of grouping clones having similar traits and identifying those with agronomic potential. The developed scheme utilized all five proposed categories of descriptors but emphasized the use of those that relate to characterization and evaluation.

MATERIALS AND METHODS

A replicated collection of plantain clones was established at the Isabela farm of the USDA-ARS-TARS from August 1998 through November 1999. The farm is located in the northwestern region of Puerto Rico (18.7°N, 67°W at an elevation of about 138 m). The soil is a Coto clay (very-fine, kaolinitic isohyperthermic Typic Hapludox). In the top 20-cm layer, the soil pH was 6.5 and contained 34 mg/kg of P (Bray method 2). The exchangeable cation capacity was 7.9 cmol(+)/kg of soil.

During the experiment the mean monthly minimum and maximum temperatures were 21.2 and 29.7°C, respectively. Mean monthly rainfall was 159.1 mm and Class A pan evaporation was 130.6 mm. Soil moisture was monitored by tensiometers strategically located in the field and buried 30 cm into the ground. Plants were drip irrigated when the soil water tension exceeded 20 kPa.

Twenty-seven clones of different origin (Tables 1 and 2) were arranged in a randomized complete block design with three replications. Each treatment contained four experimental plants per replication. To prevent plant competition for sunlight, tall and dwarf clones were separately grouped (sub-blocked) within a block (i.e., the arrangement was not completely randomized). The plants were spaced 3.05 m between rows and 1.52 m apart in the row, about 2,150 plants per hectare. The clones in each sub-block were surrounded by guard rows of plantain with either tall or dwarf pseudostem.

Medium-size corms, weighing about 2 kg each, were used as propagating material. At planting, 50 g of triple superphosphate was placed under each corm. Two months after planting the plants were fertilized with a 10-5-20-5 (N, P_2O_5, K_2O, MgO) fertilizer supplemented with 22.7 kg/t of a minor element mixture at the rate of 488 kg/ha. The complete fertilizer applications were repeated when the plants were five, eight and 10 months old, at the rate of 732 kg/ha.

Soil-borne pathogens and weeds were controlled by following recommended cultural practices (Agric. Exp. Sta., 1995). Plants were not sprayed because yellow Sigatoka was not a problem during the experimental period.

At the bunch-emergence stage, the plant pseudostem height and diameter, and number of functional leaves were recorded. Measurements were taken from the base of the plant to the point of bunch-emergence and about one meter above ground level.

The number of days required from bunch-shooting to fruit filling was determined when the fruit reached the mature-green stage. At that stage, the bunch was harvested, weighed, hands and fruits were counted, and the bunch mean fruit weight was determined. The first, third and last hands of the harvested bunch were cut off and the individual fruit mean weight was determined. Four fruits from the middle of the third and last hands were further sampled to obtain fruit outer length and widest diameter. Length was measured from the fruit pedicel to the apex; diameter, in the middle of the fruit. Number of leaves and suckers per plant was also recorded at harvest.

With the objective of grouping according to similar traits, these clones were first arranged into true plantain and cooking banana on the basis of their proposed genomic composition (Simmonds and Shepherd, 1955; Simmonds, 1966; 1987) as well as on the basis of the geographical origin of the species that donated the A genome (Lebot et al. 1993; 1994). True plantains were considered the triploid (*Musa* AAB) clones that originated from the natural interspecific cross between *Musa acuminata* (AA) × *M. balbisiana* (BB) and possess *M. acuminata* dominance (Simmonds and Shepherd, 1955) or those later developed from these hybrids through spontaneous mutations. Somatic mutation has played a major role as the main source of genetic variability in plantains (De Langhe, 1964; Simmonds, 1966). The cooking banana group included both triploid (*Musa* ABB) and tetraploid (*Musa* AAAB) clones. The former originated from the natural interspecific cross between the two proposed species or through spontaneous mutation, and possess *M. balbisiana* dominance. The latter originated from man-made crosses between triploid fertile true plantain (*Musa* AAB) and diploid wild banana *Musa acuminata*, AA (Rowe, 1987; Swennen and Vuylsteke, 1990). In the true plantain group (*Musa* AAB), there are clones of Pacific origin that are considered to be distinct cooking bananas because the A genome has been found to be more closely related to Papuan *M. acuminata* spp. *banksii* than to Asian *M. acuminata* (Lebot et al., 1993; 1994). For the purpose of this study, these clones were included in the cooking banana group.

Within each of the two main groups, the clones were separated into three easily distinguishable subgroups on the basis of their bunch phenotype: true-horn, false-horn and French (Tezenas du Montcel and Devos, 1978; Tezenas du Montcel et al., 1983). The true-horn plantain bears a bunch with fewer hands and fruits, but individual fruits are very large. At maturity, the inflorescence is incomplete due to the absence of hermaphrodite flowers and the male floral bud. The inflorescence axis terminates in a deformed glomerule. In the false-horn plantain, the bunch contains an increased number of hands and fruits, but the individual fruits are smaller than those of the true-horn type. At maturity, the inflorescence is incomplete with the presence of only a few hermaphrodite flowers and the remains of the male floral bud. The French-type plantain bears a bunch containing many hands with an increased number of fruits per hand, but the fruits are small. At maturity, the inflorescence is complete with the presence of both hermaphrodite flowers and a persistent male floral bud. In summary, bunch phenotype determines yield and fruit quality in plantains, and is considered the most striking morphological trait for differentiation of clones (Swennen and Vuylsteke, 1987).

Plant height and pseudostem color are also traits that have been used to differentiate plantain clones (De Langhe, 1964). The author used three plant height subdivisions (tall, medium and small) to separate clones, but cautioned that under field conditions the expression of plant height and pseudostem color is highly influenced by environmental factors, thus resulting in an overlapping effect. In an attempt to reduce overlapping, we proceeded to classify the clones into tall and dwarf. Tall clones were considered those whose pseudostems developed 2.8 m or more in height, and dwarf those whose pseudostems measured 2.7 m or less at the time of bunch-emergence. The use of pseudostem height in combination with some bunch traits is considered to be sufficient to assemble clones belonging to the true plantain (*Musa* AAB) group (Swennen et al., 1995). After the clones were organized under the above described scheme, the data obtained from 20 plant, bunch and individual fruit traits at the bunch-emergence and harvest stages were statistically analyzed by using the GLM procedure (SAS, 1987). Mean comparisons among three or more clones within a given group, subgroup and plant height subdivision were determined with the Waller-

Duncan test by using $P \leq 0.05$. In those cases where the comparison was limited to two clones, a "t" test of significance was applied to the data and significant differences accepted at the $P \leq 0.05$.

RESULTS AND DISCUSSION

True plantain having in common a false-horn bunch type and a tall pseudostem

We identified seven clones in the collection that fulfill this description (Table 1). These are known by the common names of African Rhino (Cuerno de Arce), Dominico-Hartón, Common Hartón, Corozal Selection 25, False-horn Dominican Red, Hartón Selection Chago and Maricongo. The donor country of the clone African Rhino is unknown, Dominico-Hartón was introduced from Colombia, and the False-horn Dominican-Red from the Dominican Republic. Maricongo is the most widely grown commercial clone in Puerto Rico. Clones Corozal Selection 25, Common Hartón and Hartón Selection Chago are local selections originated from Maricongo (Irizarry et al., 1985). Some unique traits of Corozal Selection 25 are the consistent production of a high number of fruits and hands per bunch, and adaptability to different agroenvironments. Both Hartón selections are distinguished by the production of a bunch with fewer fruits and hands, but with larger individual fruits.

Among the designated clones representing this subgroup, some differ in plant height, bunch yield and individual fruit traits (Table 1). Clone African Rhino developed the tallest (3.8 m) and thickest (20.6 cm) pseudostem. Likewise, Maricongo developed the smallest (3.4 m) and thinnest (16.5 cm) pseudostem. In this subgroup, all clones had a green pseudostem except for the red False-horn Dominican. There were no significant differences among clones for number of functional leaves at bunch-emergence or at harvest, number of suckers at harvest, or days needed for fruit filling (Table 1).

On the basis of bunch size and yield, the False-horn Dominican-Red was the most promising clone, averaging 59.5 marketable fruits and 7.8 hands per bunch with a weight of 25.5 kg (Table 1). This clone significantly outyielded all other clones for number of fruits per bunch, but was not significantly different from Dominico-Hartón and Corozal Selection 25 for number of hands or bunch weight. There was no significant difference between Dominico-Hartón and Corozal Selection 25 for number of fruits and hands or bunch weight. Clones African Rhino, Common Hartón and Hartón Selection Chago produced the smallest bunches with significantly fewer fruits and hands. However, these clones had a significantly higher bunch mean fruit weight and

TABLE 1.— *Grouping of true plantain (Musa AAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plant, bunch and individual fruit traits of economic importance.*

			Plant pseudostem		Functional leaves at			
Clone common name	Accession number	Donor country of origin	Height (m)	Diameter (cm)	Bunch-emergence (no.)	Harvest (no.)	Propagating suckers at harvest (no.)	Days needed for fruit filling (no.)
Clones having in common a false-horn bunch phenotype and a tall pseudostem								
African Rhino	TARS-17181	Unknown	3.8 a[1]	20.6 a	12.6 a	11.3 a	5.0 a	95.4 a
Dominico-Hartón	TARS-17180	Colombia	3.7 ab	17.3 bc	14.5 a	11.4 a	4.8 a	104.7 a
Common Hartón	TARS-16510	Puerto Rico selection	3.6 abc	17.6 b	13.9 a	13.0 a	5.9 a	97.5 a
Corozal Selection 25	TARS-17179	Puerto Rico selection	3.6 abc	17.1 bc	14.1 a	12.6 a	4.8 a	102.8 a
False-horn Dominican Red	TARS-17813	Dominican Republic	3.5 bc	17.4 b	13.3 a	11.9 a	6.1 a	102.3 a
Hartón—Selection Chago	TARS-17814	Puerto Rico selection	3.5 bc	17.0 bc	13.4 a	11.5 a	5.5 a	96.9 a
Maricongo	TARS-16509	Puerto Rico selection	3.4 c	16.5 c	13.5 a	11.6 a	4.6 a	99.9 a
Clones having in common a true-horn bunch phenotype and a tall pseudostem								
Plantain without a male floral bud	TARS-16514	SIATSA, Honduras	3.5	16.0	13.8	12.4	1.9	87.4

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.

TABLE 1.—*(Continued) Grouping of true plantain (Musa AAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plant, bunch and individual fruit traits of economic importance.*

Clone common name	Accession number	Donor country of origin	Plant pseudostem: Height (m)	Plant pseudostem: Diameter (cm)	Functional leaves at: Bunch-emergence (no.)	Functional leaves at: Harvest (no.)	Propagating suckers at harvest (no.)	Days needed for fruit filling (no.)
Clones having in common a false-horn bunch phenotype and a dwarf pseudostem								
Dominican—Dwarf	TARS-16508	Dominican Republic	2.7 a[1]	17.6 a	14.3 a	12.8 a	4.8 a	100.1 a
Common—Dwarf	TARS-16505	Puerto Rico selection	2.5 a	18.2 a	14.2 a	12.6 a	5.9 a	98.0 a
Colombian—Dwarf	TARS 16506	Colombia	2.5 a	16.7 a	14.9 a	12.7 a	5.2 a	90.9 a
Clones having in common a French-bunch phenotype and a dwarf pseudostem								
Dwarf Superplantain	TARS-16507	Puerto Rico selection	2.5	17.7	13.9	12.0	4.3	100.7
Clones having in common a French-bunch phenotype and a tall pseudostem								
Congo-300	TARS-16513	Unknown	4.5 a[1]	25.2 a	14.6 a	12.9 a	6.8 a	88.0 b
Chinga	TARS-16512	Unknown	3.6 b	16.7 b	14.8 a	13.5 a	5.0 a	100.2 a
Tall Superplantain	TARS-17815	Puerto Rico selection	3.5 bc	17.4 b	12.4 b	10.9 a	3.8 a	102.9 a
French-type—Dominican Red	TARS-17816	Dominican Republic	3.5 bc	17.7 b	12.8 b	11.5 a	4.7 a	107.1 a
Maiden plantain	TARS-16511	SIATSA, Honduras	3.3 c	17.9 b	13.2 ab	11.6 a	3.9 a	112.3 a

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.

TABLE 1.—*(Continued) Grouping of true plantain (Musa AAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plant, bunch and individual fruit traits of economic importance.*

Clone common name	Fruits/ bunch and range (no.)	Hands/ bunch and range (no.)	Bunch wt (kg)	Bunch mean fruit wt (g)	Fruits in first hand		Fruits in third hand				Fruits in last hand			
					No.	Mean wt	No.	Length (cm)	Diam. (mm)	Mean wt (g)	No.	Length (cm)	Diam. (mm)	Mean wt (g)
Clones having in common a false-horn bunch phenotype and a tall pseudostem														
African Rhino	24.0 d 11-33	1.6 d 1-2	19.5 cd	810.7 a	15.5 a	796.7 a	0.0	0.0	0.0	0.0	8.5 a	41.3 a	58.0 a	626.0 a
Dominico-Hartón	53.6 b 49-60	7.6 a 7-8	24.2 ab	450.7 e	11.0 b	476.7 de	8.0 a	30.2 ab	54.6 bc	441.7 c	2.7 b	28.7 bc	51.6 bcd	291.7 c
Common Hartón	28.4 d 25-32	5.7 c 5-7	18.0 cd	635.0 b	7.4 d	647.0 b	5.3 c	33.3 a	57.4 ab	625.3 a	3.3 b	31.9 b	54.9 ab	475.0 b
Corozal Selection 25	54.3 b 43-63	7.4 ab 6-8	21.8 abc	400.7 f	10.7 b	437.7 e	8.5 a	28.8 b	51.9 c	393.7 c	4.1 b	27.6 c	50.0 d	289.7 c
False-horn Dominican Red	59.5 a 51-72	7.8 a 7-9	25.5 a	425.7 ef	10.9 b	478.3 de	8.4 a	30.7 ab	52.3 c	441.0 c	4.2 b	29.0 bc	50.3 d	280.0 c
Hartón—Selection Chago	28.2 d 22-38	5.5 c 4-7	15.9 d	563.3 c	8.3 cd	566.7 c	5.4 bc	33.6 a	58.0 a	532.3 b	3.3 b	30.3 bc	56.0 a	472.7 b
Maricongo	42.3 c 26-54	6.8 b 5-8	21.4 bc	508.3 d	9.1 c	543.3 cd	6.5 b	30.4 ab	55.9 ab	513.7 b	3.7 b	28.7 bc	54.1 abc	378.7 bc

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.

TABLE 1.—*(Continued) Grouping of true plantain (Musa AAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plant, bunch and individual fruit traits of economic importance.*

Clone common name	Fruits/ bunch and range (no.)	Hands/ bunch and range (no.)	Bunch wt (kg)	Bunch mean fruit wt (g)	Fruits in first hand		Fruits in third hand				Fruits in last hand			
					No.	Mean wt	No.	Length (cm)	Diam. (mm)	Mean wt (g)	No.	Length (cm)	Diam. (mm)	Mean wt (g)
Clones having in common a true-horn bunch phenotype and a tall pseudostem														
Plantain without a male floral bud	30.9 24-35	3 3-3	19.6	634.5	11.0	660.0	9.8	30.6	60.6	565.0	0	0.0	0.0	0.0
Clones having in common a false-horn bunch phenotype and a dwarf pseudostem														
Dominican - Dwarf	50.8 a 37-59	8.2 a 8-9	19.6 a	386.7 a	11.0 a	407.7 a	8.1 a	28.4 a	50.0 a	376.0 a	3.1 a	27.2 a	48.3 a	298.3 a
Common - Dwarf	50.1 a 47-59	8.1 a 6-9	20.4 a	410.3 a	10.8 a	340.7 a	7.8 a	26.2 a	46.9 a	322.3 a	2.3 a	24.6 a	44.4 a	216.7 a
Colombian - Dwarf	46.7 a 32-58	7.6 a 6-9	16.4 a	345.3 a	9.8 a	361.0 a	7.3 a	27.2 a	48.7 a	333.3 a	2.4 a	25.3 a	45.3 a	247.7 a
Clones having in common a French-bunch phenotype and a dwarf pseudostem														
Dwarf—Superplantain	102.3 68-135	7.9 6-9	22.6	219.0	12.7	275.0	13.8	26.7	45.2	224.0	10.6	25.2	42.4	121.7

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.

TABLE 1.—*(Continued) Grouping of true plantain (Musa AAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plant, bunch and individual fruit traits of economic importance.*

Clone common name	Fruits/ bunch and range (no.)	Hands/[1] bunch and range (no.)	Bunch wt (kg)	Bunch mean fruit wt (g)	Fruits in first hand		Fruits in third hand				Fruits in last hand			
					No.	Mean wt	No.	Length (cm)	Diam. (mm)	Mean wt (g)	No.	Length (cm)	Diam. (mm)	Mean wt (g)
Clones having in common a French-bunch phenotype and a tall pseudostem														
Congo-300	152.3 a 89-193	10.2 a 7-12	26.8 a	177.7 c	15.3 a	214.3 b	16.3 a	24.0 b	39.0 b	172.7 b	10.7 a	21.1 b	33.7 b	92.7 b
Chinga	81.0 b 65-103	6.9 b 6-8	24.2 a	298.5 ab	13.5 a	325.0 a	12.4 b	27.7 a	46.6 a	270.0 a	11.2 a	25.2 a	42.1 a	175.0 ab
Tall Superplantain	91.8 b 65-107	7.4 b 6-8	25.7 a	279.7 b	15.0 a	315.7 a	12.9 b	26.6 a	43.7 a	267.7 a	9.2 a	25.2 a	40.0 ab	135.0 b
French-type Dominican Red	87.9 b 71-99	7.2 b 7-8	28.8 a	327.3 ab	13.6 a	379.7 a	12.6 b	28.1 a	46.9 a	316.3 a	9.5 a	27.3 a	45.1 a	192.7 ab
Maiden plantain	84.1 b 67-98	7.1 b 7-8	29.6 a	354.7 a	14.2 a	390.0 a	13.3 b	27.0 a	47.9 a	324.3 a	8.7 a	25.2 a	44.5 a	240.3 a

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.

heavier individual fruits in the first, third and last hands (Table 1). Among these, regardless of the hand position, clone African Rhino always produced the heaviest, largest and thickest individual fruits. Except for bunch mean fruit weight and individual fruit weight in the first and third hands, there was no significant difference between Common Hartón and Hartón Selection Chago for other plant, bunch and individual fruit traits.

The results of the statistical comparisons among the seven designated clones in this subgroup suggest that those could be reduced to five unique clones. Those that will maintain their clonal identity are African Rhino, False-horn Dominican-Red and Maricongo. Among these, the red pigmentation of the pseudostem is a unique trait of the False-horn Dominican-Red. Although the clone Dominico-Hartón was introduced from a different geographical area, bunch mean fruit weight was the only trait that separated this clone from Corozal Selection 25. The local selections Common Hartón and Hartón-Chago also appeared to be duplicates of a single clone. Bunch mean fruit weight and individual fruit weight in the first and third hands were the only traits that differentiated these clones.

True plantain having in common a true-horn bunch type and a tall pseudostem

The plantain "Without a Male Floral Bud" is the only clone in the collection representing this subgroup. This plantain was introduced from the Tropical Agriculture Research Services (SIATSA), La Lima, Honduras. It is highly distinguishable by the absence from the bunch of hermaphrodite flowers and the male floral bud, and by the production of three uniform hands containing between 24 to 34 extra-large marketable fruits (Table 1). Bunch mean fruit weight was 635 g and individual fruit weight in the first and third hands was 660 and 565 g, respectively. The pseudostem is green and the production of suckers is scanty.

True plantain having in common a false-horn bunch type and a dwarf pseudostem

There are three clones in the collection showing these phenotypic forms: the Common-Dwarf, Dominican-Dwarf and Colombian-Dwarf. The former is a dwarf mutant presumably selected from the local tall Maricongo clone. The other two plantains were introduced from the Dominican Republic and Colombia, respectively. Their pseudostem pigmentation is green. However, in local commercial plantations of the

Common-Dwarf, the senior author has observed the presence of plants with red pseudostem. Although these clones have a dissimilar geographical origin, there were no significant differences among them for the plant, bunch and individual fruit traits studied (Table 1). These findings indicate the existence in the collection of only one false-horn type and dwarf plantain clone with a bunch yield potential of between six to nine hands, 32 to 59 marketable fruits, which weighed between 16.4 to 20.4 kg. Bunch mean fruit weight ranged from 387 to 410 g. All individual fruits from the three uppermost hands of the bunch were of superior grade, surpassing the fruit weight and length standards established for marketable fruits (Soto-Santiago, 1994).

The three previously reported subgroups comprise most of the economically important clones that are used for the production of fruits for export markets and processing, particularly in countries where the fruits are sold by units.

True plantain having in common a French bunch type and a dwarf pseudostem

The Dwarf-Superplantain is the only clone in the collection representing this subgroup. This clone originated as a reverted bunch mutation from the local false-horn Common-Dwarf plantain. The pseudostem was reddish, and measured 2.5 m in height and 17.7 cm in thickness (Table 1). The bunch contained between six to nine hands and 68 to 135 fruits. Bunch weight averaged 22.6 kg, and bunch mean fruit weight was 219 g. On the basis of established marketing standards, only fruits from the first hand attained the required minimum fruit marketing weight of about 270 g.

True plantain having in common a French bunch type and a tall pseudostem

There are five designated clones in the collection representing this subgroup: Congo-300, Chinga, Tall-Superplantain, French-type Dominican-Red and the Maiden plantain. The donor countries of clones Congo-300 and Chinga are unknown. Tall-Superplantain is a local selection obtained from a reverted bunch mutation that occurred in the unstable false-horn Maricongo plantain (Irizarry et al., 1991). The French-type Dominican-Red and the Maiden plantains were introduced from the Dominican Republic and SIATSA, Honduras, respectively.

Clone Congo-300 developed the tallest and thickest pseudostem, which measured 4.5 m in height and 25.2 cm in diameter (Table 1). These means were significantly different from the means of the other clones. The clone with the smallest pseudostem was the Maiden plantain, which averaged 3.3 m in height. Chinga possessed the thinnest pseudostem, which measured 16.7 cm in diameter. Except for the green pigmentation on the pseudostem of the Maiden plantain, all the clones developed a reddish pseudostem. Congo-300 and Chinga had significantly more functional leaves, which averaged 14.7 at bunch-emergence (Table 1). However, all clones in this subgroup maintained more than the minimum 10 functional leaves required for fruit filling in bananas at the bunch-emergence stage (González, 1987). There were no significant differences among clones for number of functional leaves and number of sprouted suckers at harvest.

Clone Congo-300 appeared to require significantly fewer days for fruit filling (Table 1). However, this was not the case. Because this clone developed the tallest pseudostem of all clones in the collection (4.5 m) and produced significantly larger bunches, which averaged 10.2 hands and 152 fruits, the plants were uprooted by the force of the wind before the fruits reached the mature-green stage. Bunch weight was similar to that of other clones in the subgroup, but bunch mean fruit weight and individual fruits in the first, third and last hands were significantly reduced in weight and size (Table 1). Comparisons among Chinga, Tall Superplantain, French-type Dominican Red and Maiden plantain for fruit traits demonstrated that, except for the Maiden plantain, which had a significantly higher bunch mean fruit weight when compared to the Tall Superplantain, these clones performed similarly for other economically important fruit traits. Most of the fruits produced by French-type clones are undersized and do not fulfill the grading standards established for marketable fruits. Those in the uppermost hands of the bunch can be upgraded to marketing standards by pruning the lower hands and the male floral bud of the immature bunch (Irizarry et al., 1991; 1998). Ideal candidates for applying the pruning technique are those French-type clones that produce a bunch with a wide spacing between hands and contain a narrow range of fruits and hands. Except for Congo-300, all the clones in this subgroup are potential candidates for applying bunch pruning.

The analysis of the data obtained in this subgroup suggested that, on the basis of plant phenotype and bunch size, the Congo-300 and the Maiden plantain tended to maintain a separate clonal identity. The former developed the taller and thicker pseudostem, with reddish pigmentation, and produced significantly larger bunches. Maiden developed a significantly shorter and thinner green pseudostem, and produced bunches with a substantially reduced number of hands and fruits. Since Chinga, Tall Superplantain and the French-type Dominican-Red showed similar plant, bunch and individual fruit traits, there may be no justification to maintain these plantains as distinct clones.

Cooking banana having in common a French-bunch type and a tall pseudostem

The most important attribute of clones assembled in this subgroup is the possession of natural or acquired resistance to pests and diseases (Stover and Richardson, 1968; Haddad et al., 1979). The double-B genome from *M. balbisiana* confers hardiness and disease resistance to the plant, along with starchiness and acidity to the fruit (Simmonds, 1987). However, in newly developed man-made black sigatoka (*Mycosphaerella fijiensis* Morelet) resistant tetraploids (AAAB), the source of resistance is wild male-fertile *M. acuminata* (AA) diploids (Rowe, 1987; Swennen and Vuylsteke, 1990). Cooking bananas, locally known as "Chamaluco" or "Mafofo" type (Barret, 1925), are in less demand than true plantains. As compared to the true plantain, the fruit of the cooking banana has a softer texture, low pulp dry matter content or a higher moisture content, low pulp to peel ratio and high titratable acidity (Dadzie, 1998). In some clones, the green fruit is difficult to peel by hand. During cooking, the softer texture precludes a high absorption of oil or water, which offsets the natural fruit flavor. In addition, the preclimacteric life or post-harvest green life of the fruit is short. These undesirable attributes lessen consumer acceptability and diminish economic potential for the export market. However, those clones that demonstrate field resistance to pests and diseases may be potential candidates for organic farming.

Clones in this subgroup with the prefix TMPx were introduced from the International Institute of Tropical Agriculture (IITA), Nigeria (Table 2). The donor countries of Pelipita clones were Costa Rica and Colombia. Clones FHIA-21 and Cárdaba were introduced from Honduras. FHIA-21, from the 'Fundación Hondureña para la Investigación Agrícola' (FHIA) and Cárdaba, from SIATSA. Among these clones, TMPx1621-1, Pelipita-Costa Rica, Pelipita-Colombia and FHIA-21 developed significantly taller and thicker pseudostems, which averaged 3.5 m and 18.9 cm, respectively. Clones Cárdaba-Honduras and TMPx7152-2 developed the smallest and thinnest pseudostems (Table 2). All clones in this subgroup showed green pseudostems varying in degree of pigmentation. The Pelipita clones contained a significantly greater number of functional leaves at bunch-emergence, averaging 19.1 leaves. However, all clones contained well over the minimum number of functional leaves required for fruit filling in banana (González, 1987). As compared to the other clones, both Pelipita plantains and Cárdaba maintained significantly more functional leaves at harvest. All clones produced a similar number of suckers at harvest, an average of five.

TABLE 2.—*Grouping of cooking banana (Musa ABB and AAAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plants, bunch and individual fruit traits of economic importance.*

			Plant pseudostem		Functional leaves at			
Clone common name	Accession number	Donor country or origin	Height (m)	Diameter (cm)	Bunch-emergence (no.)	Harvest (no.)	Propagating suckers at harvest (no.)	Days needed for fruit filling (no.)
Clones having in common a French-bunch phenotype and a tall pseudostem								
TMPx1621-1	TARS-17817	IITA, Nigeria	3.5 a[1]	19.2 a	12.9 c	10.9 b	4.1 a	98.1 d
Pelipita—Costa Rica	TARS-17818	Costa Rica	3.5 a	18.5 ab	18.1 ab	16.1 a	5.6 a	126.8 b
Pelipita—Colombia	TARS-17819	Colombia	3.5 a	18.4 ab	20.1 a	18.0 a	4.7 a	133.3 ab
FHIA-21	TARS-17820	FHIA, Honduras	3.5 a	19.3 a	12.2 c	10.9 b	4.6 a	104.4 cd
TMPx4479-1	TARS-17821	IITA, Nigeria	3.2 ab	17.4 bc	11.8 c	9.5 b	5.3 a	141.5 a
Cardaba—Honduras	TARS-17822	SIATSA, Honduras	3.0 b	16.5 cd	16.9 b	15.6 a	5.9 a	129.4 ab
TMPx7152-2	TARS-17823	IITA, Nigeria	2.9 b	15.4 d	11.6 c	9.7 b	5.2 a	113.4 c
Distinctive cooking banana (Musa AAB) clones having in common a French-bunch phenotype and a tall pseudostem								
Lacknau—P.I. 23472	TARS-16516	SIATSA, Honduras	3.2 ns[2]	18.4*	14.0 ns	12.3 ns	5.0 ns	112.0*
Lacknau—P.I. 23479	TARS-16515	SIATSA, Honduras	3.0	16.2	12.9	11.1	6.1	95.3
Distinctive cooking banana (Musa AAB) clones having in common a false-horn bunch phenotype and a tall pseudostem								
Huamoa	TARS-17824	Hawaii	2.8	16.0	14.7	12.4	5.5	63.3

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.
[2]ns = Non significant, * = Significant at 0.05 probability level, ** = Significant at 0.01 probability level.

TABLE 2.—*(Continued) Grouping of cooking banana (Musa ABB and AAAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plants, bunch and individual fruit traits of economic importance.*

Clone common name	Fruits/ bunch and range (no.)	Hands/ bunch and range (no.)	Bunch wt (kg)	Bunch mean fruit wt (g)	Fruits in first hand		Fruits in third hand				Fruits in last hand			
					No.	Mean wt	No.	Length (cm)	Diam. (mm)	Mean wt (g)	No.	Length (cm)	Diam. (mm)	Mean wt (g)
Clones having in common a French-bunch phenotype and a tall pseudostem														
TMPx1621-1	91.4 bcd 75-138	6.9 a 6-10	15.8 cd	174.3 de	15.3 a	199.3 cd	13.3 a	20.7 b	42.2 b	174.3 b	11.0 a	18.8 b	39.9 c	112.3 de
Pelipita—Costa Rica	104.4 ab 83-117	8.1 a 7-8	20.4 bc	197.3 cde	13.5 a	223.3 bc	13.1 a	17.0 c	44.5 b	194.3 b	9.5 a	14.7 d	40.7 c	117.0 de
Pelipita—Colombia	115.7 a 93-131	8.4 a 7-9	27.0 a	234.5 bc	13.2 a	256.5 ab	14.9 a	17.2 c	43.6 b	218.5 ab	12.9 a	16.3 cd	42.0 bc	135.0 cde
FHIA-21	102.1 ab 71-131	7.5 a 6-10	26.5 a	259.7 ab	16.8 a	274.7 a	13.3 a	24.5 a	42.4 b	263.0 a	7.9 a	22.5 a	40.1 c	141.7 c
TMPx4479-1	93.3 bc 89-121	7.3 a 6-7	19.7 bc	210.0 bcd	15.9 a	250.0 ab	13.9 a	20.9 b	41.0 b	218.0 ab	6.3 a	18.7 b	38.2 c	176.0 abc
Cardaba—Honduras	74.9 d 52-92	6.3 a 5-7	21.9 ab	292.7 a	13.7 a	292.7 a	13.1 a	18.5 c	48.8 a	267.0 a	7.4 a	16.8 bc	47.2 a	218.7 a
TMPx7152-2	88.5 bcd 67-112	7.1 a 6-8	13.4 d	151.0 e	15.2 a	172.0 d	13.3 a	20.5 b	33.8 c	137.7 c	10.1 a	18.2 bc	30.6 c	93.7 e

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.

[2]ns = Non significant, * = Significant at 0.05 probability level, ** = Significant at 0.01 probability level.

TABLE 2.—*(Continued) Grouping of cooking banana (Musa ABB and AAAB) clones on the basis of the bunch phenotype and plant height, and comparisons within subgroups for twenty plants, bunch and individual fruit traits of economic importance.*

Clone common name	Fruits/ bunch and range (no.)	Hands/ bunch and range (no.)	Bunch wt (kg)	Bunch mean fruit wt (g)	Fruits in first hand		Fruits in third hand				Fruits in last hand			
					No.	Mean wt	No.	Length (cm)	Diam. (mm)	Mean wt (g)	No.	Length (cm)	Diam. (mm)	Mean wt (g)
Distinctive cooking banana (Musa AAB) clones having in common a French-bunch phenotype and a tall pseudostem														
Lacknau—P.I. 23472	81.4 65-93	7.6 ns 5-7	27.8 ns	341.0**	14.0 ns	436.3**	13.4 ns	27.2 ns	50.7 ns	333.7**	10.4 ns	25.5 ns	47.3 ns	203.7 ns
Lacknau—P.I. 23479	87.6 ns 63-107	7.6 5-7	24.9	284.3	13.5	373.3	13.7	26.7	48.2	256.7	8.7	25.0	45.2	166.7
Distinctive cooking banana (Musa AAB) clones having in common a false-horn bunch phenotype and a tall pseudostem														
Huamoa	28.2 12-44	6.6 4-8	10.3	368.5	5.2	465.5	4.7	0.0	0.0	0.0	2.0	17.0	57.5	225.1

[1]Means within a subgroup and a column followed by the same letter do not differ significantly at 0.05 probability level.
[2]ns = Non significant, * = Significant at 0.05 probability level, ** = Significant at 0.01 probability level.

These clones differed widely in the number of days needed for fruit filling. Clones TMPx4479-1, Pelipita-Colombia and Cárdaba-Honduras, on the average, needed 135 days for fruit filling (Table 2), whereas TMPx1621-1 filled their fruits in a significantly shorter time, requiring only 98 days. All clones produced a similar number of hands per bunch, but both Pelipita plantains and FHIA-21 produced bunches with significantly more fruits, averaging 107 fruits. The heaviest bunches were obtained from clones Pelipita-Colombia and FHIA-21, with a mean weight of 26.8 kg. This bunch weight was significantly heavier than that of the other clones, except for Cárdaba-Honduras. Clone Cárdaba-Honduras contained the highest bunch mean fruit weight, which averaged 293 g. Except for clone FHIA-21, this mean was significantly higher than that of the other clones.

There were no meaningful differences among clones for number of fruits in the first, third and last hands of the bunch (Table 2). Clones FHIA-21 and Cárdaba-Honduras produced the heaviest individual fruits in the first and third hands, which averaged 284 and 265 g, respectively. These means were significantly different when compared to those of clones TMPx1621-1, Pelipita-Costa Rica and TMPx7152-2, but not different from those of Pelipita-Colombia and TMPx4479-1. Clone FHIA-21 also produced the largest individual fruits in the third and last hands; however, the fruits produced in the same numerical hands of the Cárbaba-Honduras bunch attained the thickest diameter. Mean differences were significant when compared to those of other clones.

Comparisons among the TMPx clones demonstrated that except for TMPx1621-1, which developed a significantly taller and thicker pseudostem, and TMPx4479-1, which produced significantly heavier fruits in the first hand at the expense of a longer fruit filling period, there were no significant differences among these clones for the other plant, bunch and individual fruit traits studied. However, since these clones originated from control-pollinated seed the integrity of these clones should be maintained.

Except for bunch weight, there was no trait that justifies the separation of Pelipita clones. Since the bunch weight trait is influenced by environmental and management factors, the results suggest that the Pelipita clone introduced from Costa Rica is similar to the clone that was obtained from Colombia. The clonal integrity of FHIA-21 and Cárbaba-Honduras is well established. In addition to the detected morphological differences, FHIA-21 is a man-made tetraploid and Cárdaba is a natural triploid. A major concern, related to the general performance of the man-made newly released tetraploids, was the high incidence of virus infection. About 50% of the plant populations in these clones showed virus-like symptoms under field conditions.

Distinctive cooking banana having in common a French-bunch type and a tall pseudostem

The most relevant feature of this subdivision of the cooking banana subgroup is that during their natural hybridization process the A genome was transferred from the Papuan *M. acuminata* spp. *banksii* rather than from the Asian *M. acuminata* (Lebot et al., 1993). Clones under this subdivision produce fruits with organoleptic qualities similar to those of the genuine cooking bananas. There are two Lacknau clones in the collection, PI 23472 and PI 23479, that were originally classified in the AAB or true plantain group (Valmayor et al., 1981), but were later reclassified as distinctive cooking bananas (Lebot et al., 1993; 1994). These were introduced from SIATSA, Honduras. Their pseudostem is green. The comparison between clones demonstrated that introduction PI 23472 developed a significantly thicker pseudostem, required substantially more days for fruit filling, and produced significantly heavier fruits (Table 2). There was no significant difference between the two clones for the other plant, bunch and individual fruit traits studied. The information obtained was not enough to maintain a separate clonal identity. However, PI 23472 and other Lacknau clones have been reported to possess field resistance to the corm weevil (*Cosmopolites sordidus* Germar) (Irizarry et al., 1988). Clone PI 23479 has not been evaluated for this attribute. Until this evaluation is performed, these clones should be maintained as separate entities.

Distinctive cooking bananas having in common a false-horn bunch type and a tall pseudostem

This subdivision of the cooking banana subgroup is represented in the collection by only one clone, Huamoa, also known as Hawaiian Hybrid and locally as "Panaplátano." The clone was introduced from Hawaii. Although the subdivision description indicates that clones under this array would develop a tall pseudostem, the 2.8-m pseudostem height developed by Huamoa clearly classified this clone as intermediate between tall and dwarf (Table 2). The pseudostem is green. Another unique attribute of this clone is that it is an early yielder. It completed the planting to bunch-emergence cycle in 242 days (Irizarry and Goenaga, 2001), and required only 63 days for fruit filling (Table 2). Most plantain clones in the collection required 100 days or more for fruit filling. Fruits are short and thick (stout), and heavy, particularly those in the first hand, which averaged 466 g. The pulp is soft, but contrary to most cooking types, the fruit stays green for a longer period of time. The peel strongly adheres to the pulp, thus making the hand peeling process somewhat difficult.

The proposed scheme is easy to visualize and implement under field conditions. It provides for the recognition and elimination of duplicated clones regardless of their geographical origin and common names, and instantly reveals the economic potential of the clones. The application of this scheme will permit the reduction of plantain accessions in the TARS collection from 27 to 20 clones. Molecular markers are being used to confirm separation among *Musa* genomic groups and to identify duplicated clones within the subgroups. This technique has been successfully used to detect genetic diversity in plantain and banana (Labot et al., 1993; Howell and Newbury, 1994; Damasco et al., 1998).

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