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A Study on the Morphological and Physicochemical Characteristics of Five Cooking Bananas

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Abstract: The objective of the present study conducted during July 2006 to July 2008 seasons was to evaluate 5 varieties of cooking bananas under calcareous soil and irrigation conditions. The number of suckers per mat, height at flowering, cycling time, bunch number and weight, productivity index (PIX), brix and color were determined. Mean total fruits were highly significantly different for Bom, Pelipita and Blue Torres with 107, 63 and 51 total fruits, respectively. Mean total number of hands per bunch was highly significant for Bom (8.30) followed by Pelipita (6.0). Gypungusi and Cacambou demonstrated the lowest number of hands with 4.5 and 4.2, respectively. Pelipita, Cacambou and Blue Torres had the highest brix levels with 14.65, 12.72 and 12.57, respectively. Results obtained demonstrate that the color of skin can be objectively measured by the use of a colorimeter. The susceptibility of the varieties to yellow or black Sigatoka, caused by *Mycosphaerella* sp., was also evaluated. External (visual) evaluation of disease graveness was made three times during the experiment. A skewed scale of 1-5 where, 1 = vigorous and 5 = dead was used. Results showed that all the varieties have resistance/tolerance to Sigatoka and should be considered for production in areas affected by this disease. All cultivars but Blue Torres Island, produced reasonable to high yields of good to exceptional fruit, hence are recommended for use in tropical/subtropical areas with a dry season and limestone soils.

Key words: *Musa*, colorimeter, bunch weight, brix, variety

INTRODUCTION

Cultivated bananas and plantain originate from two wild diploid species, *Musa acuminata* and *M. balbisiana*, with many cultivars being hybrids of the two (Stover and Simmonds, 1987). *Musa* sp. cultivars vary greatly in plant height, fruit size, plant morphology, fruit quality and disease and insect resistance. Most bananas have a sweet flavor when ripe; exceptions to this are cooking bananas and plantains. Edible bananas originated in the Indo-Malaysian region with its center of origin reaching Northern Australia. They were known only by rumor in the Mediterranean region in the 3rd Century B.C. and are believed to have been first introduced to Europe in the 10th Century A.D. (Morton, 1987).

Bananas are grown in all tropical regions and play a key role in the economies of many developing countries. In terms of gross value of production, bananas are the world's 4th most important food crop after (*Oryza sativa* L.), wheat (*Triticum* sp.) and maize (*Zea mays* L.). They are both a food staple and an export commodity (Janick and Paull, 2008). As a staple, bananas (including plantains and other types of cooking bananas) contribute to the food security of millions of people in much of the developing world and when traded in local markets they provide income and employment to rural populations (Arias *et al*., 2003). Bananas and plantains are perennial crops that grow quickly and can be harvested all year round. Nine million hectares were planted in year 2000 and world production averaged 92 million tonnes per year from 1998-2000, with an estimated 97 million tonnes in 2001 (Janick and Paull, 2008). These values are an approximation because the bulk of world banana production (almost 85%) comes from relatively small plots and kitchen or backyard gardens for which statistics are lacking (Arias *et al*., 2003).

World production in 2006 was estimated to be 70, 756, 347 metric tonnes; 65% from Latin America, 27% from Southeast Asia and 7% from Africa (FAOSTAT, 2006). One-fifth of the crop is exported to Europe, Canada, the United States and Japan as fresh fruit. Production statistics in 2004 show that banana is an important crop in three major regions: Asia, Latin America and Africa. Most of the export bananas produced come from Latin America. In contrast, bananas produced in Africa are consumed locally, underscoring the importance of banana as a major component of the African daily diet (Molina *et al*., 2005).

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Bananas and plantains are casually grown in some home gardens in Southern Florida. A few small commercial plantations exist in South Florida that supply local markets (Degner *et al*., 1997). Banana, cooking banana and plantain cultivars most often grown in Florida are, Dwarf Cavendish, Apple and Orinoco and the Macho plantain. The Red and Lady finger bananas are only occasionally grown in sheltered locations (Crane *et al*., 2006). Worldwide, the cooking bananas are especially important. For example in some places, people eat close to 1 kg of cooking bananas every day. They can eat in 2 weeks what the average North American and European consume in a year (INIBAP, 2005). Despite the history and importance of banana in South Florida, the crop is poorly adapted to calcareous soil conditions.

Nearly all soil types in Miami-Dade County are shallow with hard calcareous bedrock several inches below the soil surface. The marl and rocky calcareous soils in Miami-Dade County usually contain from 30 to 94% $CaCO_3$. Their pH values are greater than 7.0, usually in the range of 7.4-8.4 (Noble *et al*., 1996). Texture can be sandy, loamy or gravelly and soil depth ranges from less than 5 inches to several feet. These soils are important for production of vegetable, fruit and ornamental plants. Over 85% of Florida's tropical fruits are grown on calcareous soils in the Southern part of the state because of favorable temperature, rather than favorable soil characteristics (Li, 2001).

Due to the low interest in conventional banana growing and disappearance of fertile soils; urban sprawl and an increase of people with interest in cooking bananas in south Florida, it was of interest to test the yielding potential of cooking banana cultivars under the climatic and limestone soil conditions found in South Florida. This research was in support of CRIS Project No. 6631-21000-013-00D management and genetic improvement of subtropical-tropical fruit, sugarcane and tripsacum genetic resources.

MATERIALS AND METHODS

The experiment was conducted at the National Germplasm Repository, Subtropical Horticulture Research Station (SHRS) in Miami, Florida. The soil is a Krome (Loamy-skeletal, carbonatic, hyperthermic Lithic Udorthents). It consists of 3-10' of a well drained, gravely soil over porous limestone bedrock with a pH ~7.0-7.5. Average annual precipitation is approximately 1360 mm with a bimodal distribution. The wet season generally lasts from June to October and the dry season lasts from November to May. About 70% of the annual rainfall occurs during the wet season.

The land was cleared of secondary grasses and large stumps as well as larger rocks. All other biomass was retained. Natural fallow vegetation was mowed and controlled with herbicides. The slashed material was retained, not burned. The soil chemical properties of the site, determined at crop establishment, are described by Crane *et al.* (2006). Potassium, phosphorus, magnesium and calcium were applied at the rate of 75, 26, 9 and 75 g plant^{-1}, respectively, while other fertilization and cultural practices were done as recommended for banana production under South Florida conditions (Crane *et al*., 2006).

Suckers of five cooking banana cultivars (Blue Torres Strait Island; Bom; Cacambou; Gipungusi and Pelipita, of at least 1.5 kg in weight, were harvested from our current *Musa* sp. collection (Daniells *et al*., 2001). All suckers were cleaned of soil and were cut-off as described by Colbran (1967), then, the suckers were treated with fungicides and nematicides.

Suckers were planted at a within-row distance of ~2 m and an inter-row distance of 3.63 m. Each replication contained four plants. Planting holes of 20×20×20 cm were dug. A layer of about 5 cm of topsoil was place into the planting hole. The suckers were placed on top of this layer and the hole refilled with soil. The plots were weeded by slashing the growth at soil surface level with trimmers, mowers and application of herbicides as needed. Weekly micro irrigation (MaxiJet®) and standard fertilization practices for banana were used for the duration of the experiment.

Four months after planting, the number of pseudostems was recorded weekly. Banana bunches were tagged at the time of flower emergence (shooting). Plant height and the date of flower emergence of each plant were recorded so as to calculate the physiological age of the bunch at the time of harvest. At flowering, plant height was recorded as measured from the pseudostem base to the overlap of the last two emerged leaves. Yield measurements and assessments of bunches were made on all plants. Bunches were harvested when the fingers had reached maximum width and before they began to turn yellow. At harvest, the number of hands were counted and then cut from the rachis. Number of hands, fruits/hand, thickness (mm), length (mm) and total bunch weight were recorded.

Currently, the method for evaluation of color in banana is visual matching the Royal Horticultural Society Color Charts (RHSCC). First developed in 1966, the RHS system uses a set of paint chips each with a small hole in the center. The color strip is placed over the leaf or object and is matched by peering through the hole. In all there are 884 different colors arranged in four fans. Growers,

Table 1: Variety, origin, genome/ploidy level and accession numbers, synonyms and usage for cooking bananas at USDA ARS SHRS

Variety[y]	Accession No.[Z]	Origin	Genome*	Synonyms	Usage
Blue Torres Strait Island	ITC-0338	Australia	ABB	N/A	Cooking
	MIA 34918				
Bom	ITC-0053	Papua	ABB	Pisang awak	Cooking
	MIA34907	New Guinea			
Cacambou	ITC-0058				
	MIA 34914	Australia/India	ABB	(Blugoe of the British)	Cooking
Gipungusi	ITC-0173				
	MIA 34910	Malaysia	ABB	N/A	Cooking
Pelipita	ITC-0472				
	MIA 34923	Philippines	ABB	Pelipita Pisang Kuri	Cooking

[y]Variety names are those assigned by the original donor the International Plant Genetic Resources Institute (IPGRI) and International Network for the Improvement of Banana and Plantain (INIBAP), *Genome (A and B refer to the haploid contributions of *Musa acuminata* and *Musa balbisiana* to the ploidy of the cultivars), [Z]Accession numbers are for the International Transit Center (ITC) in Belgium and the Miami Repository collection (MIA) in Miami, FL, USA

registration authorities and specialist organizations use these colors to precisely describe plants. The purpose of RHSCC is to describe plant colors and not to thoroughly sample all colors. These measurements depend on subjective interpretation of the observer and they do not facilitate the visual separation of varieties. The use of a colorimeter could offer a more objective notation of color and a greater reduction in human error in color evaluation (Voss and Hale, 1998). Variety, origin, genome/ploidy level and accession numbers, synonyms and usage for cooking bananas at USDA ARS SHRS are shown in Table 1.

Banana color was measured with a Minolta Chroma Meter CR-400 portable tristimulous colorimeter (Minolta Chroma Meter CR 400, Osaka, Japan) and SpectraMatch software, set to L*, a*, b* mode. Fruit chromaticity was recorded in Commission Internationale d'Eclairage L*, a* and b* color space coordinates. In this system of color representation the values L*, a* and b* describe a uniform three-dimensional color space, where the L* value corresponds to a dark-bright scale, a* is negative for green and positive for red and b* is negative for blue and positive for yellow.

Yields were based on fresh bunch weights and reported yields were cumulative for the replicates. Harvested plants were cut at ground level and the largest sucker was retained to grow the ratoon crop and seed. Accessions were completely randomized and replicated four times; replications were single plants. The susceptibility of the varieties to yellow or black Sigatoka, caused by *Mycosphaerella* sp., was also assessed. An external (visual) evaluation of disease severity was made three times (each season) during the experiment. A skewed scale of 1-5 where, 1 = vigorous and 5 = dead was used throughout the experiment.

All analyses were performed using SAS® analytic software of The SAS® Institute, Cary, NC, USA. The data were tested for any serious deviations from normality using Proc Univariate. The traits, plant height and plant diameter were found to be slightly bimodal. There were slight deviations in the raw data from normality, however, when the final model was run, there were no serious deviations in the residuals when plotted versus the predicted values, indicating no serious deviations from the standard assumption of mixed model analysis of variance. Therefore a mixed model was used for analysis as described below, using the Proc Mixed procedure of SAS®. The following dependant variable (traits) were analyzed: plant height, plant diameter, number of hands, total fruits, fruit length, fruit weight, fruit diameter, color and brix. The effect of the accession was considered to be a fixed effect, while replications (reps), years and the interactions of reps X years and cultivar X years were considered to be random. All models converged with little trouble; it was found that between-within denominator degrees of freedom were more compatible than Kenward-Roger denominator degrees of freedom, the most appropriate type of degrees of freedom for Proc Mixed for many situations, or containment denominator degrees of freedom, the default for Proc Mixed. Least Square Means (LSMeans) were calculated for the fixed effect in each model (accession). The use of LSMeans produced statistical estimates not only with the error for the residual term removed from the standard error of the LSMean, but also all error due to random effects. Multiple comparisons of LSMeans were then performed using the Bonferroni adjustment. The Bonferroni adjustment was chosen due to the relatively small number of accessions (five) being compared. Several different variations on the model and its components were compared, until the model used was finally considered to be the most appropriate.

RESULTS AND DISCUSSION

The model converged successfully for all traits. Differences among accessions were highly significant ($\alpha<0.0001$) for all traits measured in the F-test of sums of squares for differences among accessions. All of the random effects produced small variance components. Proc

Mixed produces an asymptotic standard error for each variance component and tests the significance of variance components with a Wald Z-test. This test should be used with care when variance components are small and if a test of a given variance component is of interest to the particular experiment, there are preferred methods of testing their effect discussed in the documentation of Proc Mixed, as well as in most reference books on mixed models (Littell *et al*., 1996; Verbeke and Molenberghs, 1997). The small size of the variance components of the random effects (reps, years and interactions) shows that the largest source of variance was due to the differences among accessions. Even though they were small, removing the error due to random effects allows a more precise comparison among accessions. The LSMeans of all accessions were compared and most accessions were statistically significantly different from one another for most of the traits measured.

Mean suckering rate per mat ranged from 4.62 to 7.0 during the initial harvesting cycle (Table 2). Height at fruiting and cycling time varied significantly among varieties. Pelipita was over 2 m taller than Blue Torres Strait Island and Cacambou but slightly taller than Bom and Gipungusi. Cycling time varied from 343 days for Gipungusi to 500 for Pelipita (Table 2). Bunch weight was highly correlated with accession, ranging from 3.2 kg for Blue Torres to 6.8 for Bom (Table 3). Productivity indexes ranged from 0.56 Blue Torres Strait Island to 2.02 for Gipungusi (Table 3). Stem diameter was also significant among cultivars. Pelipita and Bom demonstrated the largest diameter with 57.0 and 51.0 cm in diameter. Mean total fruits were highly significantly different for Bom, Pelipita and Blue Torres with 107, 63 and 51 total fruits, respectively. Mean total number of hands per bunch was highly significant for Bom (8.03) followed by Pelipita (6.0). Cacambou and Gypungusi demonstrated the lowest number of hands with 4.2 and 4.5, respectively (Table 3). Pelipita, Cacambou and Blue Torres demonstrated the highest brix levels (Table 4) with 14.65, 12.72 and 12.57, respectively.

Interpreting the changes in color indicates that, as the skin ripens or the severity of the yellow color increases, the b* variable increases, causing a decrease in L* variable. In addition, the a* variable which represents the red-green color also increases, but at a lower value, these values indicate that neither red nor green are present (Table 4). The measurements from the colorimeter could allow the identification of a cultivar by any single attribute (L*a*b* value, chroma or hue) so that color differences may be noted more specifically.

All cultivars performed well under limestone soil conditions with minimal irrigation. There were no significant differences (i.e., yield, height, diameter) from plants planted in raised beds or with supplementary water available (data not shown, field observation from collection site). However, it was observed that accessions planted without a bed remained standing during the entire year (no lodging due to high winds) as has been the case with raised beds (personal observation). This could have been the result of good drainage, no periods with standing water and thus lower humidity than bananas planted in beds. The bananas on raised beds were on poorly drained soil with a hard pan about 12 to 24' below the surface. Banana roots deteriorate under these conditions (Gauggel *et al*., 2005).

All the cultivars tested had an ABB genome. Only Pelipita had been grown in south Florida before. All varieties but Blue Torres Strait Island and Bom had ABB characteristics (plantain like appearance). These two varieties demonstrated more characteristics of a dessert banana than a cooking banana. Even though these

Table 2: Mean growth characteristics of five varieties of cooking bananas

Variety^y	Height at fruiting (m)^Z	Stem diameter (cm)	Pseudostems/ mat	Cycling time (days)*
Blue Torres Strait Island	1.73de^w	40.00dc^w	5.62b^w	370c^w
Bom	2.64b	50.58b	4.62d	475b
Cacambou	1.97d	38.48e	7.00a	368c
Gipungusi	3.52bc	43.38c	5.81b	343d
Pelipita	3.61a	56.64a	5.00bc	500a

*Days from planting to first fruit collected, ^{Z}Height in meters from base of plant to top of peduncle, ^{y}Variety source, genome are shown in Table 1. ^{w}Mean separation within columns, means in a column followed by the same letter(s) are not significantly different at p = 0.001

Table 3: Yield characteristics of five varieties of cooking bananas

Variety^y	No. hands per bunch	Bunch weight (kg)	Total fruits	Productivity index^Z
Blue Torres Strait Island	5.37c^x	3.20cd^x	51.0c^x	0.86e^x
Bom	8.30a	6.80a	107.0a	1.43a
Cacambou	4.30cd	4.4bc	36.0de	1.20d
Gipungusi	4.50cde	4.55b	38.0d	1.33b
Pelipita	6.00b	6.50a	63.0b	1.30c

^{Z}Productivity index = 100 x bunch weight/cycling time, ^{y}Cultivar source, genome are shown in Table 1, ^{x}Mean separation within columns, means in a column followed by the same letter(s) are not significantly different at p = 0.001

Table 4: Brix (sugar content) and color readings of five varieties of cooking bananas

	Color			
Cultivar^u	Brix$^{(o)}$	L^x	a^y	b^z
Blue Torres Strait Island	12.59b^w	68.00a^w	2.33a^w	36.78c^w
Bom	11.96c	61.30c	-8.34d	34.17d
Cacambou	12.72b	67.65a	4.34a	34.30de
Gipungusi	11.60cd	65.73bc	4.05a	42.66a
Pelipita	14.65a	65.04bc	1.59c	39.85b

^{u}Cultivar source, genome are shown in Table 1, ^{w}Means in a column followed by the same letter(s) are not significantly different at p = 0.001. ^{x}Luminosity, ^{y}Red and green color, ^{z}Blue and yellow color varieties are not new (received in 1993-1994) to the United States very little is known about their particular characteristics. All cultivars showed good resistance to high winds (personal observation), performed well under limestone soil conditions.

The susceptibility of the varieties to yellow or black Sigatoka, caused by *Mycosphaerella* sp., was also evaluated. A skewed scale of 1-5 where, 1 = vigorous and 5 = dead was used. All varieties demonstrated tolerance/ resistance to yellow and black Sigatoka (data not shown). Results showed that all the varieties have resistance/ tolerance to Sigatoka and should be considered for production in areas with this disease (data to be reported in a separate paper) and specifically South Florida. The majority of banana varieties are sensitive to cold weather (Stover and Simmonds, 1987); however, all of these varieties demonstrated tolerance/resistance to cold weather. During the winter season cold temperatures are not unusual in Miami-Dade, Florida. In the winter of 2006 and 2008, the minimal temperatures registered in present research station weather station ranged from 2 and 4°C for several days (January and February). Surprisingly no damage to the plants or pseudostem was observed.

Based on these results, these varieties should be considered for cultivation in South Florida and perhaps areas within USDA hardiness zones 7b to 11 and similar environments worldwide.

CONCLUSION

These cultivars could be used as a source of cooking bananas, wine, beer, wind break or ornamental use. In Florida and the Caribbean, bananas are highly prized for their use as food source and ornamental appeal in the landscape. This information should be useful for farmers, nurseries, garden aficionados desiring to expand the use of cooking bananas in the aforementioned regions.

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