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Field Evaluation of Tissue Cultured Banana (*Musa* spp.) Using a Narrow Pit System under Atoll Environment Conditions

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ABSTRACT

Bananas are widely grown in the Marshall Islands and are an important food crop for domestic consumption. This study reports on the field evaluation of new varieties of tissue cultured banana in the local soil and climatic conditions of the Marshall Islands using a narrow pit system. The study was conducted during Yr. 2002-2004 at the College of the Marshall Islands experimental station in Arrak village, Majuro atoll. A dozen local varieties of banana were documented with their usage as either dessert or cooking type. Plant height, bunch weight, number of hands/bunch, stem diameter, color, and maturity of 11 new varieties were determined. Var. Robusta and FHIA-17 were recorded as being dwarf (180 cm) while Saba was the tallest variety (390 cm). Longest cycling time (15 months) was observed in Saba compared to Pesang Ceylan (12.2 months). The weight of the fruit bunch varied considerably with accession, ranging from 6.3 kg for Pesang Ceylan to 23.2 kg for Robusta. Girth or stem diameter of the pseudostem was also significant among varieties. Saba demonstrated the largest diameter (85.0 cm) and produced a high number of fruits (fingers), 122/bunch. The reaction of varieties to yellow or black Sigatoka and panama (Fusarium wilt) diseases was assessed. Introduced cooking or dessert varieties produced fruits and performed well under the soil and climatic conditions of the Marshall Islands in a narrow pit system.

Keywords: Central Pacific, composting, *In-vitro*, organic bulking, sustainable, variety trials

INTRODUCTION

Banana and plantain are popular fruits throughout the tropics and are a good source of potassium low in sodium (Ramcharan and George 1999; Robinson and de Villiers 2007). The Republic of the Marshall Islands (RMI) consists of 29 low-lying Coral Atolls covering a total land area of approximately 171.5 km^2. Atoll agriculture has become more important in terms of production and food security in the village communities of RMI (Deenik and Yost 2006). Banana is grown for subsistence by small-scale farmers and backyard gardeners in the RMI and provides an important contribution to the food security and dietary needs of the population. Vulnerability of the atolls, the country's dependency on imported food, the shortage of quality planting material, a declining economy, limited land area, poor and nutrient deficient soil are the major constraints for banana production in the Marshall Islands (Nandwani 2000; Nandwani *et al*. 2003).

The narrow pit system of banana production used in the current study was introduced from the South Pacific Islands. The advantage of the narrow pit system is the organic matter bulking within the pit while the banana shoots are planted on the side of the 1 to 1.5 m depth of the narrow (1-1.5 m wide) pit. On atoll soils, the growth of crops is limited due to many factors such as low water holding and cation exchange capacity, high pH and insufficient micro-nutrients. Sustainable atoll agriculture is based on soil management systems built on the addition of organic matter. Studies have shown that the use of compost, fresh organic matter and animal manure can increase crop production on atolls (Deenik 2000).

This paper catalogues the banana varieties and describes a field evaluation of FHIA varieties using a narrow pit system in the Marshall Islands.

MATERIALS AND METHODS

Catalogue of local banana varieties

The Crop Production team periodically visited a field on Majuro atoll to survey local banana varieties. Samples of fruits, suckers and flowers (male buds) were collected and identified with the assistance from the community, extension agents and in consultation with regional experts for internationally recognized names.

Introduction of new varieties

Tissue cultured plants of new varieties and FHIA hybrid lines were obtained from the Center for Pacific Crops and Trees (CePaCT), Secretariat of the Pacific Community (SPC), Fiji. Upon receipt, tissue cultured plants were washed with distilled water to remove the agar that adhered to roots and transferred to planter bags (1L, 1 plant/bag) containing potting mix (vermiculite, ACE hardware, Majuro). Plants were kept in a nursery for 4 weeks for hardening and acclimatization.

Land preparation and planting

A randomized plot selected at the College of the Marshall Islands-Marshall Islands Science Station (CMI-MISS) in Arrak village, Majuro atoll, was used for the experiments. The land was cleared of trees, shrubs, grasses and rocks. The plots were weeded with lawn mowers, and 1.0 m wide, 1.0 m deep and 10.0 m long pits were dug with a backhoe (**Fig. 1A**). RMI soil is coral in nature with limestone and calcareous deposits. The average annual precipitation is approximately 140 cm with the wet season generally lasting from June to November and the dry season lasting from December to May. On the floor of the pit, 1-2 layers of coconut husks was spread and then covered with coconut leaves (**Fig. 1B**). Planting was done in the wet season to ensure that the plantlets or

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Fig. 1 (**A**) Preparation of narrow pits (1.0 m wide × 1.0 m deep × 10.0 m long). (**B**) Narrow pits filled with organic matter at the CMI-MISS, Arrak. (**C**) Planting bananas along the wall in narrow pits. (**D**) Compost bin filled with coconut husks at the bottom, organic matter and animal manure. (**E**) Fruit bunch of most favorable local banana variety 'Jilibugi' (Mysore). (**F**) Mature banana plants in narrow pits.

roots close to the water-table could survive. Well-hardened plants were transferred to one side of the pit into a 3.0 m × 1.5 m space (**Fig. 1C**). Doses of fertilizer were hand-spread around the pseudostem, or (after flowering) around the daughter plants. Locally prepared compost (see next section) was applied and then organic matter such as leaves, grasses, banana stems (chopped) and animal manure (chicken and pig manure) were added to the pits to elevate the depth 0.5 m from 1.0 m. Pits were continuously filling with the same organic matter throughout the trial period.

Compost preparation

Bulking up organic matter for nutrient supplements and sustainability is the main activity in soil management and for maintaining favorable production on atolls. Compost for the narrow pits was prepared at the CMI-MISS as follows:

Raw materials for compost such as leaves and green branches of *Leucaena leucocephala*, grasses, banana stems, food waste, copra cake, fishmeal, poultry and pig manure were collected locally. Materials were collected a day prior to shredding. All plant materials were shredded to smaller portions by chipper to ease decomposition. The household decomposable waste was applied directly to the compost heap. Coconut husks (1-2 layers) were arranged horizontally at the bottom of the compost heap. A few layers (4-6) of timber walls (made from local trees such as coconut or *Leucaena*) were placed initially to create the bin and a layer approx. 60 cm thick of shredded organic material was placed inside the compost bin (**Fig. 1D**); the layers of shredded material were tossed up and down for a few minutes to compact the layer. Soft material (30-60 cm) were placed on the top of the *Leucaena* leaves and again tossed for a few minutes above the heap. Banana stems were cut to small pieces with a bush knife and added to the top of the layer of soft material creating a 15-20 cm layer. Next, animal manure (2 kg) was mixed and diluted in tap water (11.4 l) and applied to the heap. The same pattern (except for coconut husks on the floor) of layers was repeated until the heap reached 150 cm in height. Other locally available materials such as fishmeal and copra-cake produced locally from fish and copra processing plants were added to the pile at approx. 3 Kg each. These were added as a thin layer on to each of the banana stem layers before the diluted manure was poured on top. After 3 days, the heap was tested for its readiness by inserting a bush knife through the mid-section of the heap; the blade was very hot. The height of the heap dropped notably (120 cm) after 3 days. After a week, the heap was turned with a digging fork and turned every 3 days until 3 weeks, when compost was ready to use in the pits. A further drop in the height noticed (80-90 cm).

Field trials

Field trials were conducted at the CMI-MISS, Arrak village, Majuro atoll from 2002-2004. An experimental field was irrigated on a weekly basis and standard fertilization practices were used for the duration of the field evaluations. Plants were labeled and tagged. Data on plant height, pseudostem diameter (thickness), the color of the pseudostem and petiole was recorded. Yield measurements and assessment of bunches were made for all plants. Fruit bunches were harvested when the fingers were green and starting to yellow and reached maturity (width). The number of hands, number of fingers/hand, and bunch weight were recorded at the time of harvest. Yield was based on fresh bunch weight and reported yields were cumulative for the replicates, i.e. data was pooled. The field plot was scouted for disease and insect pest infestation and data was recorded. The susceptibility of the varieties to yellow or black Sigatoka and Panama (Fusarium wilt) diseases was assessed based on visual evaluation of disease severity (based on visual observation only). Harvested plants were cut at the ground level and the largest sucker was retained to grow the ratoon crop (i.e., the second and subsequent crop from the suckers) and for the second cycle of fruiting in each variety. Infected leaves were pruned to reduce the amount of inocula of leaf diseases. Dried and diseased leaves were cut once a month and leaves with < 50% affected were trimmed. Fruit bunches appeared at the top of the plant in about 9-10 months; at that time, male buds were cut off at the end of the bunch after bunches began to mature. Fruit bunches were bagged to protect from pest damage and injuries. This was done when the last hand in the bunch had fully emerged. Bunches were covered with perforated plastic cover to keep out diseases from infecting fingers. Plants bearing fruit bunches were supported with a forked pole (propping) and mulched around the plant with mowed grass, leaves, etc.

Table 1 Catalogue of local banana varieties (introduced and local) in the Marshall Islands.

Variety	Genome /Ploidy	Common name/Subgroup	Usage/Type
Introduced			
Saba	BBB	Saba	Cooking
Robusta	AAA	Cavendish	Dessert
FHIA 01	AAAB	Gold finger, SH-3481	Dessert
FHIA 02	AAAA	SH-3486, Mona Lisa	Dessert
FHIA 03	AABB	SH-3565	Cooking
FHIA 17	AABB	SH-3649	Cooking
FHIA 18	AAAB	SH-3480, *Pome hybrid*	Dessert
Pisang Ceylan	AAB	Mysore	Dessert
Local			
Jok	ABB	Bluggoe	Cooking
Ailing Kein (Jorukwor)	ABB	Monthan	Cooking
McKanzie	BBB	Saba	Cooking
Manila	AAB	Silk	Dessert/Eating
Jilibugi	AAB	Mysore, Misiluki	Dessert/Eating
Macau	AAA	Lakatan	Dessert/Eating
China	AAA	Williams	Dessert/Eating
Dwarf	AAA	Dwarf Cavendish	Dessert/Eating
Ice cream	ABB	Blue Java	Dessert/Eating
Brown banana	AAA	Cuban Red	Dessert/Eating
Biro (Pacific Plantain)	AAB	Maoli-Pōpōʻulu and Iholena	Cooking
Wild banana (Mokar)	-	-	Dessert/Eating

Table 2 Growth characteristics of introduced varieties in the RMI.

Variety	Accession No. (SPC-CePCT)	Plant height (cm)	Girth (stem diameter) (cm)	Maturity* (months)	Pseudostem color and No. of leaves	Color of petiole channel	Disease reaction**
Saba	Saba	390.0	85.0	15.0	Green w/brown spot, 8	Light brown	MR
Robusta	MS 28	180.0	58.2	14.7	Light green and brown spots, 9	Light red	S
FHIA 01	Gold finger, SH-3481	230.0	64.5	13.5	Light green, 9	Light red	R
FHIA 02	F02	235.0	60.0	14.2	Green-brown with spots (light red when young), 10	Light red at the edge	R
FHIA 03	F03	267.0	68.2	13.5	Green, 9	Light red	R
Pacific Plantain	MS 19	183.0	69.8	13.9	Red stem, 8	Red	S
FHIA 17	Fa 17	165.0	38.7	14.0	Light green/brown, 7	Dark red	S
FHIA 18	Fa 18	234.0	48.7	13.5	Light green, 8	Light red	MR
Pesang Ceylan	MS01c	276.0	48.6	12.2	Gold brown with spots (red when young), 9	Light red at the edge	R
FHIA 21	MS17	273.3	49.8	13.5	Light green-brown, 8	Dark red stripes	R
Williams	MS04C	234.0	50.1	14.2	Light brown with dark brown spots, 9	Light red	S

*Maturity period (months) is when fruit bunch harvested (0.2, 0.5 and 0.7 values represents 1, 2, and 3 weeks after full month). **Flowering to harvesting is about 3 months
** R; Resistant, MR; Moderately Resistant, S; Susceptible

RESULTS AND DISCUSSION

A dozen local varieties were identified and documented. They varied greatly in plant and fruit size, morphology, fruit quality, disease and insect resistance. Data was recorded on the fruit, and usage such as dessert or cooking (**Table 1**). Mysore banana, known locally as 'Jilibugi', is rated number one in the Marshall Islands (**Fig. 1E**), and is resistant to Black leaf streak disease (*Mycosphaerella fijiensis*). Demand for this dessert banana is extensive in local markets; however, production has not met the demand and quality standards. Cavendish and plantain are the local varieties of banana grown for domestic consumption. The tropical climate of the Marshall Islands is ideally suited for the production of banana, although the crop is affected by a host of factors and production constraints.

All new varieties, cooking and dessert (eating) completed the crop cycles successfully. Differences were highly significant for all traits measured in introduced varieties. Height at fruiting and cycling time varied significantly among varieties (**Table 2**). Robusta and FHIA-17 are dwarf varieties (180 cm tall). Among moderate varieties, FHIA-2, Pesang Ceylan and Williams were observed to have medium height (210-270 cm tall). Saba was the tallest variety and grew up to 390 cm in height. Cycling time varied from 15 months for Saba to 12.2 months for Pesang Ceylan. Bunch weight was varied considerably with accession, ranging from 6.3 kg for Pesang Ceylan to 23.2 kg for Robusta (**Table 3**). Girth or stem diameter of the pseudostem was also significant among varieties. Saba had the largest diameter (85.0 cm) while FHIA-17 had the narrowest diameter (38.7 cm). Mean total number of fruits (fingers) was significantly different. Saba produced highest while Pacific Plantain produced lowest number of fruits/bunch (122 vs 30/bunch, respectively). The mean total number of hands/bunch was lowest (6) in Pacific Plantain and Robusta was highest (11). Morphological characters, namely pseudostem color and the color of the petiole channel, were recorded for all 11 varieties. Most of the varieties showed a green-brown pseudostem and a red-brown petiole. Pacific Plantain had a distinguished dark red pseudostem with an all-red petiole channel. The number of leaves produced at flowering varied from 7 in FHIA-17 to 10 in FHIA-2.

Composting is an essential part of planting food crops in atolls. The process is probably as old as planting of food crop itself in atoll soils. Techniques that were developed and evolved over hundreds of years have sustained agriculture for many generations. However, there are demands for increased local food production, and calls for more efficient methods of composting to improve productivity. Nutrient recycling through traditional composting is unreliable and rather slow. A scientific approach to this traditional technique would speed up the composting process thus availing nutrients for better crop growth.

Table 3 Yield characteristics of introduced varieties in the RMI.

Variety*	No. of hands/ bunch (mean)	Bunch weight (Kg) (mean)	No. of fingers/ bunch (mean)
Saba	7	15	122
Robusta	11	23.2	101
FHIA-01	10	25	118
FHIA 02	8	21.8	76
FHIA 03	6	19.0	90
FHIA 18	8	20.45	84
Pacific Plantain	6	18.2	30
FHIA 17	10	18.7	83
Pesang Ceylan	7	7.3	63
FHIA 21	9	8.2	81
Williams	8	6.8	61

*Variety source and genome are shown in **Table 1**.

Reports on micropropagation of banana cultivars from Micronesia (Josekutty *et. al* 2005), constraints in banana production in the Northern Mariana Islands (Nandwani 2010) and evaluation of FHIA banana (Jean-Simon 2005) are available in the literature. Five varieties of cooking bananas were evaluated under calcareous soil and irrigation conditions in Florida (Ayala-Silva *et. al*. 2008). Wairegi and van Asten (2010) conducted a study aimed to explore the possibility of increasing yields through the use of fertilizer and mulch, and to evaluate the benefits of these inputs across the major banana-producing regions in Uganda. Gaidashovaa *et al*. (2010) reported on the effect of toposequence-related variations in soil on banana yields, foliar nutrient status, and nematode impact.

Bananas and plantains are cultivated in over 100 countries throughout the tropical and sub-tropical regions of the world and grown over 10 million ha, with an annual production of around 88 million metric tones, of which approximately one third is produced in each of the African, Asia-Pacific and Latin America and Caribbean regions (Sharrock and Frison 1999; latest available statistic). *Musa* sp. cultivars vary greatly in plant height, fruit size, plant morphology, fruit quality and disease and insect resistance (Ayala-Silva *et al*. 2008). In this study, all 11 varieties (cooking or dessert) fruited and performed well under the soil and climatic conditions of the RMI with minimal irrigation in a narrow pit system (**Fig. 1F**). The names, usage and type (cooking or dessert) of local varieties have been catalogued and documented. Dwarf varieties mainly showed good resistance to high winds (data not available). The susceptibility to diseases such as black or yellow Sigatoka and Fusarium wilt or Panama disease (*Fusarium oxysporum* f.sp.

cubense. (Foc)) recorded, based on visual observations. No serious insect pest damage was observed in the varieties. The new varieties could be used as a source of cooking bananas, value-added products such as banana chips, gems, cookies or for ornamental use. Several hundred plants of new varieties of banana were propagated *in-vitro* and distributed to the farming community for their commercial production throughout the RMI.

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