The International Journal on Banana and Plantain

infoMusa

Parthenocarpy in hybrids

Impact of intercropping

Are deeper planting holes better?

The taste of improved hybrids

Peruvian organic bananas

Georges Wilson

Vol. 13 No.1
June 2004

INFO*MUSA*
Vol. 13, No. 1

Publisher:
International Network for the Improvement of Banana and Plantain

Managing editor: Claudine Picq

Editorial Committee:
Anne Vézina, Jean-Vincent Escalant, Richard Markham, Nicolas Roux

With the scientific support of:
Frédéric Bakry, Sylvio Belalcázar, Guy Blomme, Xavier Draye, Charles Staver, Jean Tchango Tchango

Layout:
Crayon & Cie
Printed in France
ISSN 1023-0076

Editorial Office:
INFO*MUSA,* INIBAP, Parc Scientifique Agropolis II, 34397 Montpellier Cedex 5, France. Telephone + 33-(0)4 67 61 13 02; Telefax: + 33-(0)4 67 61 03 34; E-mail: inibap@cgiar.org
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The mission of the International Network for the Improvement of Banana and Plantain is to sustainably increase the productivity of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.
INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI), a Future Harvest centre.

Info*Musa*

Vol. 13 No.1

Cover photo:
Ugandan small vendor.
(Regis Domergue, CIRAD)

Contents

Upping scientific standards

From time to time, we are asked to consider making INFO*MUSA* a peer reviewed journal. Recently, the demand has been cropping up more often as career advancement is increasingly tied to the number of articles published in recognized peer reviewed journals. Our position has always been to resist such a change. We feel that the role of INFO*MUSA* is to inform members of the research and development community of what is going on in the world of bananas, even if the research reported is not necessarily at the 'cutting edge' scientifically or did not yield the expected results. Without a publication like INFO*MUSA*, we believe that banana researchers would lose out on a lot of valuable information that would remain buried in the so-called grey literature. Bananas are grown in a variety of environments and a sense of déjà vu is inevitable as many variations on the same theme, such as screening germplasm for resistance to familiar pests and diseases, are played out by different researchers in their own situation. Negative results are an even more neglected species and rarely find their way into respected peer reviewed journals. Yet negative results are extremely useful in weeding out erroneous hypotheses. Reporting them also prevents the duplication of unnecessary effort and the waste of resources, which in developing countries, where most of the research on *Musa* is conducted, are particularly scarce.

Although we want to keep INFO*MUSA* author-friendly, we also feel that bringing information to our readers should not be at the expense of scientific integrity. A piece of information is of little use if readers do not understand how it was derived or if no statistical analysis has been performed on the data. Yet the rules of scientific investigation and reporting on which we depend for our confidence in using published results are not intuitively obvious. Most authors, even native speakers of one of the three languages we publish in, need help in presenting their work, especially with regards to data analysis. We try to ensure that the articles we publish meet the basic requirements of scientific reporting, by passing manuscripts out to members of our editorial committee for an informal review, on the basis of which the texts are often returned to authors for improvement. The question we now face is how much further we can go in raising the quality of INFO*MUSA* without sacrificing what you, our readers, appreciate about it. We argued against a formally peer reviewed INFO*MUSA* but maybe you feel differently?

Please let us know what you think by answering the enclosed questionnaire, which has been designed to find out your opinion about the changes we have recently made to INFO*MUSA* and what we can do to produce a journal that better meets your needs. You can also write to us. In this issue, we are inaugurating a Forum section, which is open to all our readers. We hope that you will use it to comment on past articles or spark debates on relevant topics.

INIBAP's web site is also undergoing changes. It has been expanded to include a section on banana uses and products, general information on the banana aimed at the general public and a genomics website to report on the progress made in decoding the banana and *Mycosphaerella* genomes.

The editors

Growth of cell suspensions of cv. 'Cau man'

Bui Trang Viet and Tran Thanh Huong

The i*n vitro* multiplication of bananas is mostly performed through the proliferation of vegetative meristems. The recent development of embryogenic cell suspensions opens up the possibility of mass producing banana plants at low cost (Haicour *et al.* 1998). A number of studies on cellular suspensions have been done at the Vietnam National University in Ho Chi Minh City (Bui Trang Viet *et al.* 2000, Tran Thanh Huong and Bui Trang Viet 2000, Cung Hoang Phi Phuong and Bui Trang Viet 2000, Tran Thanh Huong and Bui Trang Viet 2003). In this paper, we report the growth of a cell suspension from immature male flowers of a widely cultivated cultivar in Vietnam, 'Cau man'.

Materials and methods

Immature male flowers were taken and placed on MA1 medium (Escalant *et al.* 1994, Shii *et al.* 1992). The cell suspension was initiated by placing the 4-month-old callus in liquid MA2 medium (Escalant *et al.* 1994, Shii *et al.* 1992) supplemented with 35 g/L of sucrose, 1 mg/L of 2,4-D, and 15 mg/L of ascorbic acid. The cultures were kept in 100 ml Erlenmeyer flasks that were placed on a gyratory shaker at 80 rpm and cultured at 28˚C under 1000 lux (12 h photoperiod). The old culture medium was replaced with fresh medium every two weeks. After 2 months, the suspension contained a mixture of cell clusters and single cells. After 2 weeks of subculture, the cell suspension was filtered through 0.8 mm metal filters. Cell growth was evaluated by measuring the settled cell volume (SCV) after 5 minutes of sedimentation (Gomez *et al.* 2000, Schoofs 1997).

The respiration rate was measured during the growth of the cell suspensions. The changes in pH and the concentrations of oxygen and total salts in the growth medium were also measured every week. The growth medium was separated from the cell suspension by rotating at 1000 rpm for 5 minutes.

The presence of indoleacetic acid (IAA), an auxin, and abscisic acid (ABA) was detected by using silica gel thin-layer chromatography (60 F254, 105554, Merk). The chromatograms were developed in chloroform:methanol:acetic acid (80:15:5 v/v). Plant growth substances were visualized under UV light according to Yokota *et al.* 1980. Identification was made by comparing with known IAA and zeatin reference standards. The *Oryza* coleoptile elongation test was used to measure the level of IAA. This test is based on the ability of the auxin to stimulate the elongation of coleoptile sections floating in the liquid medium. The level of zeatin was detected by using a test based on the cytokinin-dependent expansion of cucumber cotyledons (Meidner 1984).

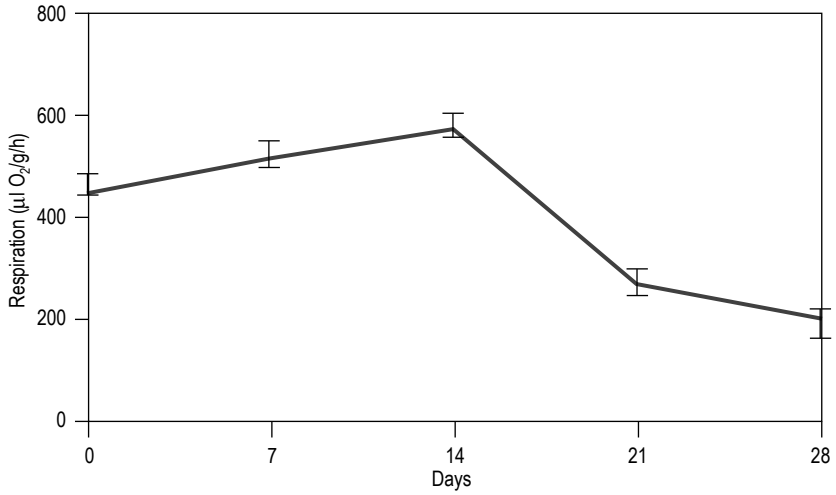
Five ml aliquots of cell suspensions filtered through a 800 µm sieve were inoculated on 5 ml of solid MA3 medium supplemented with 0.2 mg/L of naphthaleneacetic acid (NAA), 0.1 mg/L of kinetin and 0.05 mg/L of zeatin (Escalant *et al.* 1994, Shii *et al.* 1992).

Results and discussion

The growth of the cell suspension over time followed a sigmoid curve. A period of slow growth, up to the 7th day, was followed by a period of rapid growth between the 7th and 21st day. This rapid growth was followed by a stationary phase. Respiration increased during the period of rapid growth and decreased before the stationary phase (Figure 1).

The influence of the initial inoculation density on the growth of the cell suspension was studied by testing three settled cell volumes: 50, 75 and 100 µl/ml of medium. The highest percentage of embryogenic cells

Figure 1. Respiration rate during the growth of the cell suspension.



with dense cytoplasm and large nucleus (Figure 2) was observed at 75 µl/ml.

After replacing the old culture medium with fresh medium, the suspension was heterogeneous and contained a mixture of cell clusters and single cells. The cell clusters were divided into three groups on the basis of their diameter: small (under 200 µm), medium (200-800 µm) and large (over 800 µm). The growth of the cell suspension was assessed by measuring the number of these cells and clusters. The maximum number of small and medium clusters (48 000±147 and 1820±120, respectively) was observed on the 14th day, while the maximum number of single cells (77 280±2219) and large cell clusters (338±18) was observed on the 21st day.

During the rapid growth phase, a large number of small clusters were formed from large clusters. The total SCV was very low when the culture was established from small clusters (Table 1).

The pH and concentrations of oxygen and total salts in the growth medium decreased during the growth of the cell suspension (Figure 3).

Using one-dimensional thin-layer chromatography, auxin activity corresponding to IAA was identified at Rf 0.84-0.89, and cytokinin activity corresponding to zeatin was observed at Rf 0.67-0.74. The levels of these growth hormones during growth of the cell suspension are shown in Figure 4. The results show that the growth of the cell suspension increased with an increased concentration of zeatin but that high levels of IAA inhibited this growth.

With 0.2 mg/L of NAA, 0.1 mg/L of kinetin and 0.05 mg/L of zeatin, somatic embryos developed normally up to the globular stage (after 8 days of culture, at the earliest) but their subsequent development was suppressed. The absence of embryo bipolarity was caused by poor individualization of the shoots and root meristems. An epidermis was present but there was no clear internal organization. The results provide evidence for the embryogenic capacity of 'Cau man' cells but the current culture conditions need to be improved in order to obtain well formed somatic embryos.

Acknowledgements

This study was supported by a grant from the Vietnam national council on fundamental problems in life sciences.

Figure 2. Cell clusters after two weeks of culturing.

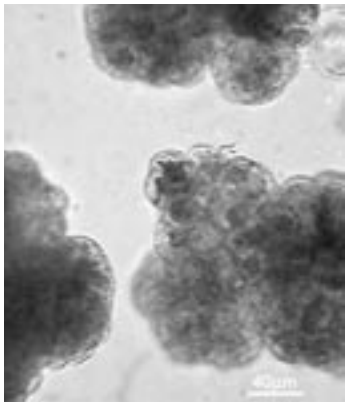


Figure 3. Changes in pH and the concentrations of total salts and oxygen in the culture medium.

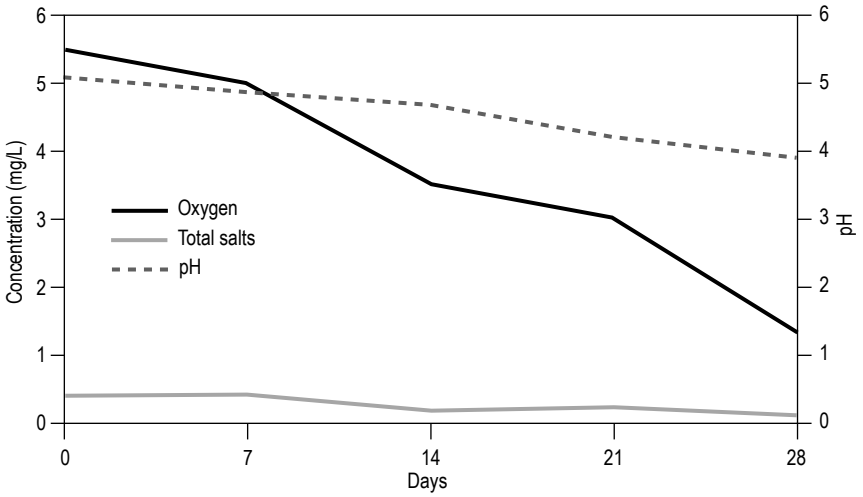
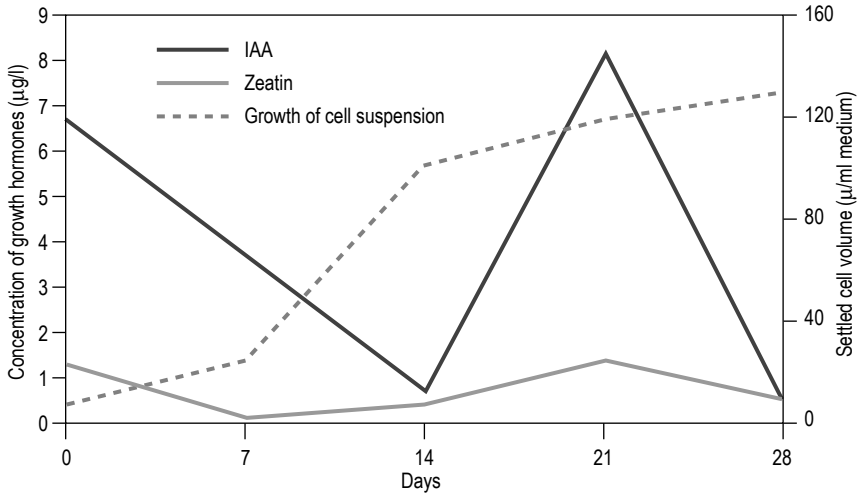


Table 1. Settled cell volume (µl/ml of medium) of the cell suspensions after 14 days of culture

Initial size of cell clusters	Final size of cell clusters			
	Under 200 µm	200-800 µm	Over 800 µm	Total
Under 200 µm	22.7 ±1.4	27.4 ±2.4	3.9 ±3.2	54.0 ± 5.1
200–800 µm	19.6 ±2.0	20.2 ±2.0	58.1 ± 5.9	97.9 ± 8.6
Under 800 µm	7.5 ± 0.6	42.9 ± 1.7	50.4 ±1.2	100.8 ±10.0
Over 800 µm	57.4 ± 4.3	25.4 ±2.8	67.2 ± 5.0	150.1 ±12.0

Figure 4. Changes in the concentrations of growth hormones during the growth of the cell suspension.



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Bui Trang Viet *works at the Department of Plant Physiology, University of Natural Sciences, Vietnam, e-mail: btviet@hcmuns.edu.vn and* ***Tran Thanh Huong*** *at the National University, 227 Nguyen Van Cu street, district 5, HoChiMinh City, Vietnam, e-mail: trthuong@hcmuns.edu.vn.*

Tissue culture

Use of biobras-6 in micropropagation of FHIA-21

F.A. Jiménez Terry, D. Ramírez Aguilar and D. Agramonte Peñalver

Reduced shoot proliferation, high oxidation of explants and slow growth are some of the problems encountered during the micropropagation of plantains, in particular the hybrid FHIA-21 (AAAB). Biobras-6, an analogous brassinosteroid, is a possible substitute for some of the growth regulators used in tissue culture (Gómez *et al.* 2000). The present study was carried out to evaluate the effect of biobras-6 on the *in vitro* micropropagation of FHIA-21.

Materials and methods

Trials were carried out at the *Instituto de Biotecnología de las Plantas* with *in vitro* plants derived from a third subculture of the plantain hybrid FHIA-21. The instruments were sterilized in a dry heat oven at 180ºC and the culture media in autoclaves at a temperature of 121ºC and 1.2 kg/cm² pressure for 20 minutes. The vegetative materials were transferred to light chambers in which the natural light was on average 4500 lux and the temperature 28±2ºC.

Multiplication phase

The multiplication phase basal medium contained Murashige and Skoog salts (MS salts), 1.0 mg/L of thiamine, 3% saccharose and 8% agar. Each flask contained 30 ml of culture medium and 10 explants. There were 10 replicates per treatment. In a variation using liquid culture media, the MS salts were reduced to 70% and 15 ml of medium was added to each 250 ml flask. Three subcultures were performed every 21 days. The axillary buds were separated, the phenolized tissues extracted and the corms of the completely formed plants cut transversally.

Two experiments, on semisolid and liquid media, were carried out during the multiplication phase. Various combinations of two concentrations of the cytokinin 6-BAP (2.0 and 4.0 mg/L) and of biobras-6 (0.01 and 0.05 mg/L) were evaluated (Table 1). The multiplication rate, the numbers of buds and roots per explant and the length of the plantlets were recorded after 21 days.

Rooting phase

In the rooting phase, the concentration of saccharose in the culture medium was increased to 4%. The concentrations of biobras-6 tested during the rooting phase are given in Table 2. The multiplication rate, the numbers of buds and roots per explant and the length of the plantlets were recorded after 28 days.

Acclimatization phase

In the acclimatization phase, the roots of the *in vitro* plants were immersed in different solutions of biobras-6 and naphthyl acetic acid (NAA) for 10 minutes before planting (Table 3). The vitroplants were transferred to 69 cm x 45 cm polystyrene boxes containing 70 wells. The data recorded 45 days after planting were the number of leaves and roots per explant, and the plant's fresh and dry weights.

The data for all the experiments were processed by using the statistical package Statistical Program Scientific System (SPSS) version 9.0 for Windows. The data were first tested for homogeneity of variance and normality, then subjected to a multifactorial analysis of variance followed by Duncan's multiple range test.

Table 1. Concentrations of biobras-6, 6-BAP and indoleacetic acid (IAA) during the multiplication phase

Treatment (mg/L)	6-BAP (mg/L)	Biobras-6 (mg/L)	IAA
1	0	0.01	-
2	0	0.05	-
3	2	0.01	-
4	2	0.05	-
5	4	0.01	-
6	4	0.05	-
Control	4	-	0.65

Table 2. Concentrations of biobras-6 and indoleacetic acid (IAA) during the rooting phase

Treatment	Biobras-6 (mg/L)	IAA (mg/L)
1	0.01	-
2	0.05	-
3	0.01	0.65
4	0.05	0.65
5	0.01	1.3
6	0.05	1.3
Control	-	1.3

Table 3. Concentrations of biobras-6 and naphthyl acetic acid (NAA) during the acclimatization phase

Treatment	Biobras-6 (mg/L)	NAA (mg/L)
1	0.01	
2	0.01	10
3	0.05	
4	0.05	10
Control		10

Results and discussion

Multiplication phase

As can be seen in Table 4, the numbers of shoots per explant and the multiplication rate in the semisolid medium were significantly higher in treatments 5 and 6, which both contained 4 mg/L of 6-BAP and 0.01 mg/L and 0.05 mg/L of biobras-6, respectively. However, the number of shoots per explant in the control, which contained 4 mg/L of 6-BAP but no biobras-6, was not significantly different from the value obtained in treatments 5 and 6.

The longer plantlets were observed in treatments 1 and 2 that contained biobras-6 but not the cytokinin 6-BAP (treatments 1 and 2), suggesting an auxin effect. The explants in these treatments also had the lowest multiplication rate and the highest number of roots. The results suggest that biobras-6 could be used as a substitute for IAA in the multiplication culture medium of FHIA-21. The results with the liquid culture medium follow the same pattern (Table 5) as those with the semisolid medium.

Brassinosteroids have been observed to have an effect on elongation, cellular division, vascular development and reproduction (Núñez 2000). The use of biobras-6 during *in vitro* cultivation of FHIA-18 had an effect

Table 4. Effect on FHIA-21 plantlets of various concentrations of growth regulators in a semisolid multiplication medium (see table 1 for details on treatments)

Treatment	Number of buds/explant	Multiplication rate	Number of roots/explant	Length of plantlets (cm)
1	1.3 c	1.1 d	6.1 c	2.9 ab
2	1.7 c	1.1 d	7.9 c	3.2 a
3	2.6 b	2.2 c	0.6 a	2.5 bc
4	2.9 b	2.5 c	1.3 b	2.7 b
5	3.4 a	3.1 a	0 a	2.3 c
6	3.8 a	3.5 a	0 a	2.6 b
Control	3.1 a	2.8 b	0.2 a	2.5 bc

Values followed by different letters are significantly different at probability 0.05

on the germination of somatic embryos (Gómez *et al.* 2000).

A culture medium containing both biobras-6 and 6-BAP favoured cellular division and the growth of buds that give rise to an increase in the multiplication rate, without the negative aspect of root formation observed when biobras-6 was used alone.

Rooting phase

The best values for the number of roots per explant, plantlet length, and fresh and dry weights were observed in the treatments containing both biobras-6 and IAA, and in the case of plantlet length and fresh weight, were not significantly different from the values obtained with IAA alone (Table 6). Previous results on large-scale micropropagation of plantain and banana had demonstrated that biobras-6 has the capacity to substitute for 6-BAP in the establishment phase (Barranco 2001) and for IAA in the rooting phase (Nuñez 2000).

Acclimatization phase

The longest plantlets and the ones with the highest fresh weight were observed in treatment 4, which contained 0.05 mg/L of biobras-6 and 10 mg/L of NAA (Table 7).

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Table 5. Effect on FHIA-21 plantlets of various concentrations of growth regulators in a liquid multiplication medium (see table 1 for details on treatments)

Treatment	Number of buds/explant	Multiplication rate	Number of roots/explant	Length of plantlets (cm)
1	1.1 c	1.0 d	5.3 c	3.1 a
2	1.1 c	1.0 d	5.5 c	3.2 a
3	2.2 b	1.8 c	0.3 a	2.6 b
4	2.4 b	2.1 c	1.3 b	2.7 b
5	2.7 a	2.5 a	0 a	2.4 b
6	3.0 a	2.8 a	0 a	2.7 b
Control	2.7 a	2.5 a	0.2 a	2.5 b

Values followed by different letters are significantly different at probability 0.05

Table 6. Effect on FHIA-21 plantlets of various concentrations of growth regulators in a rooting medium (see table 2 for details on treatments)

Treatment	Number of leaves/explant	Number of roots/explant	Length of plantlet (cm)	Dry weight (g)	Fresh weight (g)
1	3.5	4.9 c	3.8 b	1.8 b	0.30 d
2	3.7	5.1 c	4.0 b	2.0 b	0.36 c
3	3.5	5.6 b	4.2 b	2.4 a	0.39 bc
4	3.8	5.8 ab	4.7 a	2.6 a	0.41 ab
5	3.7	6.3 a	4.9 a	2.6 a	0.43 a
6	3.9	6.2 a	4.8 a	2.4 a	0.46 a
Control	3.8	5.6 b	4.8 a	2.5 a	0.39 bc

Values followed by different letters are significantly different at probability 0.05

Table 7. Effect on FHIA-21 plantlets of various concentrations of growth regulators in the acclimatization phase (see table 3 for details on treatments)

Treatment	Length of plantlet (cm)	Fresh weight (g)
1	12.3 d	109.9 d
2	12.8 b	117.6 b
3	12.5 c	112.4 c
4	13.2 a	119.0 a
Control	12.6 c	111.2 cd

Values followed by different letters are significantly different at probability 0.05

The authors *work at the* Instituto de Biotecnología de las Plantas, Universidad Central de Las Villas, *Carretera a Camajuani km 5 ½, Santa Clara, Villa Clara, CP 54830, Cuba.*

Influence of male and female parent on parthenocarpy

V. Krishnamoorthy, N. Kumar and K. Sooriyanathasundaram

The fact that triploid cultivars are seedless makes them edible but it is also a constraint when it comes to improving their yield and resistance to biotic stresses. Breeders always aim to get parthenocarpic hybrids with enhanced resistance. Simmonds (1952, 1953 and 1959) reported that parthenocarpy is controlled by three complementary dominant genes. The present study was carried out to investigate seed germination and parthenocarpy in the progeny resulting from crosses between diploids, triploids and diploids with triploids.

Materials and methods

The work was carried out at Horticultural College and Research Institute, Tamil Nadu Agricultural University in Coimbatore. The triploids and diploids used in the study are shown in Table 1, and the synthetic diploid hybrids in Table 2.

Except for 'Rasthali', 'Nendran' and 'Ney poovan', which are male sterile, all cultivars were utilized as female and male parent. 'Robusta' was used as male parent. A total of 7830 crosses were made, representing 71 combinations.

Table 1. Cultivars used in the crosses.

	Group	Subgroup
Triploid cultivars		
Nendran	AAA	French plantain
Red banana	AAA	Red
Robusta	AAA	Giant Cavendish
Rasthali	AAB	Silk
Bareli chinia	ABB	
Karpooravalli	ABB	Pisang awak
Diploid cultivars		
Ambalakadali	AA	
Anaikomban	AA	
Eraichivazhai	AA	
Matti	AA	
Namarai	AA	
Nivediyakadali	AA	
Pisang lilin	AA	
Sannachengadali	AA	
Tongat	AA	
Ney poovan	AB	

Table 2. Parentage of the synthetic diploid hybrids used in the crosses.

	Group	Parents
H-110	AA	Matti × Tongat
H-201	AB	(Bareli chinia × Pisang lilin) × Robusta

The crosses were performed between 7:30 AM and 10:30 AM. The unopened anthers of male parents were collected from opened flowers on the day of the crossing. The anthers were twisted and forced to dehisce. Pollen was collected and smeared over the stigma of the female flowers by using a No. 2 brush. A receptive stigma was sticky to the touch, while one that had lost its receptivity was bluish or brown. The flowers were covered with a perforated paper bag and tagged with information about the date of the cross, the parental combination and the number of fingers crossed. The bags were removed five days later. Bunches were harvested after one or two fingers had ripened *in situ*.

The seeds were extracted manually from the pulp and classified as 'good' or 'bad' following immersion in water. Floating seeds were considered bad and discarded. Seeds were soaked in water for eight days and sown in a sterilized soil mixture (Rowe and Richardson 1975). They were kept in a mist chamber and watched closely for germination. Only 312 hybrid seedlings were obtained from 18 out of the 71 combinations attempted. The hybrids were planted in the field and at the time of flowering the female flowers were covered with a paper bag to prevent natural pollination. One month after flowering, pulp development was observed on a cross section of the female flowers.

The ploidy of the hybrids was assessed at two different times. Stomatal density and the size and number of chloroplasts per pair of guard cells were measured at the seedling stage. The hybrids having from 62.6 to 109.6, 50.4 to 56.9 and 19.7 to 35.1 stomata per square millimeter were respectively rated as diploid, triploid and tetraploid (Sathiamoorthy 1973). The chloroplast number in the guard cell pair was counted using the method suggested by Tenkouano *et al.* (1998). Plants with a chloroplast density between 10.1 and 10.3, 13.1 and 13.3 and between 15.5 and 15.8 were respectively classified as diploid, triploid and tetraploid.

Later, the number of chromosomes in root tips were counted. The number of

Fruits of the tetraploid hybrid resulting from a cross between 'Karporaralli' and 'Red banana'.

chromosomes was determined by using a slightly modified version of the method described in Dolezel *et al.* (1997).

The genomic composition of the new hybrids was evaluated by using a morphological scoring method (Simmonds and Shepherd 1955).

Results and discussion

Of the 71 combinations attempted, only 23 produced seeds for a total of 1096 (Table 3). Out of these, 1003 were viable, or sinkers, and the remaining 93 were floating seeds and considered as bad seeds. The mean number of seeds per fruit was 1.23. The highest germination rates were observed with the open pollinated H-201 and the crosses H-201 × H-110 and 'Karpooravalli' × 'Red banana'. None of the seeds obtained from crossing 'Anaikomban' with 'Pisang lilin', 'Anaikomban' with 'Eraichivazhai', 'Ambalakadali' with 'H-110', 'Karpooravalli' with 'Anaikomban' and 'Red banana' with 'Pisang lilin' germinated. Out of the 1003 viable seeds, 312 seeds, representing 18 combinations, germinated. The time taken for germination varied from 15 days (open pollinated H-201) to 54 days ('Anaikomban' × H-110).

A poor seed set and a high occurrence of partly filled or empty seeds were observed. Simmonds (1952, 1959) suggested that the occurrence of partly filled seeds, failed germination and early seedling mortality might be attributed to genetic and cytological events immediately after fertilization in banana. The relatively good germination rate might be due to the fact that it took place in February and March, during which time sunny days and cool nights prevailed. The experience of this department is that the cooler months (November to January) and warmer months (May and June) should be avoided. Sathiamoorthy (1987) reported that germination was very low and erratic in winter.

Ploidy was estimated by phenotypic appearance and confirmed either by stomatal density or the number of chloroplasts per pair of guard cells and root-tip chromosome counting. In the present study, stomatal density did not concur with ploidy levels in earlier reports (Sathiamoorthy 1987) so the ranges of stomatal densities of the parents

Table 3. Number and characterization of hybrids obtained from the 23 successful combinations

Combination	Number of fingers crossed	Seeds		Days to germination		Number of hybrids obtained	Ploidy				P*	NP**
		Sinkers	Floaters				2x	3x	4x	5x		
AA × *AA*												
Anaikomban × Pisang lilin	31	2										
Anaikomban × Eraichivazahi	30	1										
Anaikomban × H-110	33	7		54	1			1				1
Ambalakadali × Anaikomban	15	1		51	1	1					1	
Ambalakadali × H-110	30	2										
Matti × Pisang lilin	30	30	1	26	4	4					4	
AB × *AA*												
H-201 × Eraichivazhai	64	142	31	29	49	38		5	6		1	48
H-201 × Anaikomban	102	105	7	18	15	12		3			2	13
H-201 × Ambalakadali	30	5	1	18	1	1						1
H-201 × Pisang lilin	79	340	11	18	115	90		25			1	114
H-201 × Nivediyakadali	36	2	2	26	1	1						1
H-201 × H-110	53	73	4	18	33	17		16			4	29
H-201 (open pollinated)	64	50	5	15	37							
Triploid × *Diploid*												
Karpooravalli × Pisang lilin	1105	25	3	32	7		1	6			3	4
Karpooravalli × H-110	630	9		34	1			1				1
Karpooravalli × Nivediyakadali	135	10	2	37	3			3				3
Karpooravalli × Eraichivazhai	107	16	3	35	1			1			1	
Karpooravalli × Ambalakadali	155	54	2	34	1			1				
Karpooravalli × Anaikomban	80	1										
Red Banana × Pisang lilin	137	0	4									
Triploid × *Triploid*												
Karpooravalli × Red banana	233	87	6	26	33	1		29	4		16	17
Karpooravalli × Robusta	150	80	13	28	8			5	3		1	7
Karpooravalli (open pollinated)	195	33	11	26								

* Number of parthenocarpic hybrids
** Number of non-parthenocarpic hybrids

were used for ploidy assessment. Based on this criterion, 299 hybrids (197 diploids, one triploid and 101 tetraploids) fell within the range of the parental cultivars, whereas 15 fell outside that range. The 15 hybrids did not fall under either diploid, triploid or tetraploid when using the number of chloroplasts.

Root-tip chromosome counts were carried out on 48 hybrids and the 15 hybrids that could not be classified as diploid, triploid or tetraploid. The ploidy level of 33 hybrids agreed with the results from stomatal density and 13 out of the 15 hybrids had 55 chromosomes.

Of the 312 hybrids obtained, 36 were parthenocarpic. Out of the 6 hybrids obtained from AA × AA crosses, 5 were parthenocarpic (Table 3). The hybridization of an AB with an AA yielded 8 parthenocarpic hybrids out of 214 hybrids. The triploid × diploid crosses gave 13 hybrids, of which only 4 were parthenocarpic, whereas the triploid × triploid crosses produced 41 hybrids, out of which 17 were parthenocarpic.

In the case of crosses between H-201 with AA diploids, many hybrids proved to be non-parthenocarpic, suggesting the influence of the highly fertile female parent. Looking at the pedigree of hybrid H-201, it seems that 'Bareli chinia', which was utilized as the female parent, could explain the non-pathernocarpy observed in this study. The parthenocarpic hybrids obtained in crosses involving H-201 and a diploid parent, or diploid parents, might be due to the conditioning of parthenocarpy by complementary dominant genes derived from edible natural diploids, which are variously heterozygous in their genetic composition for these genes. From the breeding point of view, it is an important consideration as parthenocarpic plants can be readily sorted out in crosses involving these diploid parents.

In the AA × AA crosses, 5 parthenocarpic diploid hybrids were obtained but no parthenocarpic triploid or tetraploid. It cannot be claimed as a rule, however, as in an earlier study triploid hybrids were obtained with the same parents (Sathiamoorthy 1987), although the proportion was low. The parthenocarpic hybrids obtained from AB × AA crosses deserve evaluation for use as potential parents in future breeding programmes.

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Fruits of the hybrid H-201

***The authors** work at the Department of Fruit Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India. The current address of V. Krishnamoorthy is Krishi Vigyan Kendra, Vriddhachalam - 606 001, Cuddalore, Tamil Nadu, India, e-mail: krishort@hotmail.com*

Cultural practices

Effect of dehanding and planting distance on production characteristics of plantain FHIA-20

Manuel Aristizábal L.

In Colombia, plantains are traded as bunches but lately they are also sold as hands and fingers in specialized markets (Arcila *et al.* 2000a) where size determines sale price (Giraldo 1998). Bunches have a longer shelf-life but they are more difficult to manage and losses are important compared to fingers or hands (Arcila *et al.* 2000a). In general, the last hands are smaller and are discarded or sold at lower prices because they fail to meet the standards of the specialized markets.

Dehanding consists in removing some of the last hands (Rodríguez *et al.* 1988) and is intended to distribute the dry matter with no commercial value to the remaining hands, thereby increasing their size. It is not known if planting distance affects this response.

Fruit size being an important criteria in these markets, the objective of the study was to determine the effect of planting distance on the production and quality of FHIA-20 plants subjected to various intensities of dehanding.

Materials and methods

The study was conducted at the Montelindo farm (property of Caldas University) located in the Santágueda region, municipality of Palestina (Caldas), 5º05' N and 75º40' W, and 1050 metres above sea level. The average temperature was 22.5ºC, relative humidity 76%, annual rainfall 2100 mm and number of hours of sunshine in a year 2010.

Sword suckers of FHIA-20 coming from the farm and trimmed to about 500 g were planted in holes of 40 cm x 40 cm. The distance between plants within a row was fixed at 3 m but two between-row distances were tested, 3 and 4 m. Cultivation practices were conducted as needed and included fertilization, desuckering, removal of dried leaf sheaths, deleafing, bagging and weeding.

Dehanding was carried out 15 days after bud emergence. The intensity of dehanding is expressed as the number of hands left on the bunch: 6, 7 or 8 hands. No hand was removed in the control plants but the bud was.

Bunch weight, mean finger weight, mean hand weight, weight of individual hands, mean weight of fingers in each hand and yield were recorded at harvest. The experimental field was laid out as 4 replications of a 2x4 factorial arrangement on a randomized complete block design, with seven usable plants per replication. The data were subjected to an ANOVA and the means compared by using Tukey's test. The SAS (*Statistical Analysis System*) programme was used for all analyses.

Results

Dehanding had a significant effect on all the evaluated parameters (Table 1). Planting distance had a significant effect on yield only, whereas the interaction between planting distance and dehanding was always significant.

For both planting distances, the control plants had the highest bunch weight, but the lowest mean finger weight and mean hand weight because, on average, there were 11 hands per bunch. The higher the number of hands remaining on the bunch, the higher the bunch weight, due to the higher numbers of fingers, whereas the mean finger weight and mean hand weight decreased as the number of hands remaining increased (Table 2). Bunches with six hands had the lowest bunch weight, but the highest finger weight and hand weight (Table 2). Mean hand weight was 48.7%, 29.3% and 14.6% higher in bunches with six, seven and eight hands respectively, in comparison with the control, at the 3 m x 3 m planting distance; the corresponding values for the 4 m x 3 m planting distance were 44.7%, 42.1% and 28.9%, suggesting that the effect of dehanding was stronger at the wider planting distance.

Yield was significantly higher at the closer planting distance, due to differences

Table 1. Mean squares and significance levels of the effect of dehanding and planting distance on agronomic parameters of FHIA-20

Source of variation	DF	Bunch weight	Mean hand weight	Mean finger weight	Yield
Dehanding	3	100.7**	4.2**	25501**	93.3**
Planting distance	1	8.3	0.16	5832	1100**
Interaction	3	11.6**	0.24*	6104 *	13.5 *
Residual	24	3.7	0.06	2011	4.2
R2		0.821	0.926	0.722	0.941
CV		5.12	5.04	12.14	5.15

*, ** Significant (5%) or highly significant (1%) effects according to Fisher's test

Table 2. Effect of dehanding and planting distance on agronomic parameters of FHIA-20

Planting distance	Number of hands left on the bunch	Bunch weight (kg)	Mean hand weight (kg)	Mean finger weigth (g)	Yield (T/ha)
3 m x 3 m					
	6 hands	36.6 cd	6.1 a	497 a	40.6 bc
	7 hands	37.3 cd	5.3 bc	375 b	41.4 b
	8 hands	37.5 bcd	4.7 d	342 b	41.6 b
	Control	44.6 a	4.1 e	308 b	49.5 a
4 m x 3 m					
	6 hands	33.1 d	5.5 ab	393 b	27.5 f
	7 hands	37.7 bcd	5.4 bc	387 b	31.4 ef
	8 hands	39.1 bc	4.9 cd	357 b	32.6 ed
	Control	42.0 ab	3.8 e	297 b	41.6 b
Least significant difference (5%)		4.67	0.593	106.4	4.87

Means within a column followed by different letters were significantly different according to Tukey's test.

in the densities, 1111 and 833 plants/ha at 3 m x 3 m and 4 m x 3 m, respectively. Nevertheless, at the closer planting distance, differences between dehanding intensities were not significant (Table 2).

The means for the dehanding treatments across planting distances indicate that bunch weight declined significantly by 19.4%, 13.4% and 11.5% in bunches with six, seven and eight hands respectively, in comparison with the control. Similar results were also observed with yield, with reductions of 19.2%, 14.0% and 12.3% respectively. Thus, in terms of production volume, dehanding would be a disadvantage to the producer, particularly with respect to bunches with six hands. The lower bunch weights can be attributed to the number of fingers per hand (78, 97 and 111, when bunches were left with six, seven and eight hands, respectively), rather than finger size, as the mean finger weight was higher in bunches with the fewer hands. Indeed, the mean finger weight was significantly higher by 42.9%, 22.1% and 11.9%, and the mean hand weight increased by 48.7%, 35.9% and 23.1% in comparison with the control. Thus, the best quality was obtained in bunches with six hands.

For both planting distances, the mean finger weight in each hand was lowest in the controls. At 3 m x 3 m, the mean finger weight of the first hand in bunches with eight, seven and six hands, exceeded the value obtained in the control plants by 21.9%, 48.3% and 52.0%, respectively and by 14.8%, 42.6% and 29.5%, respectively, at the 4 m x 3 m planting distance (Table 3). At the 3 m x 3 m planting distance, the mean finger weight in each hand increased as the numbers of hands left on the bunch decreased, but at 4 m x 3 m the trend was more erratic.

In general, plantain bunches tend to be triangular in form because the proximal hands are larger than the distal ones (Aristizábal 1995). In this study, the weight of the last hand was 28.3% the weight of the first hand in the control plants at the 3 m x 3 m planting distance, and 21.3% at the 4 m x 4 m planting distance. In the dehanding treatments, the percentages were 43.5%, 43.0% and 58.8% for bunches with eight, seven and six hands, respectively, at 3 m x 3 m, and 38.5%, 42.7% and 49.4%, respectively, at 4 m x 3 m. Dehanding resulted in bunches that were less triangular.

Discussion

In this study, dehanding reduced the bunch weight of FHIA-20 but increased fruit quality, namely the weight of the hands and fingers, particularly with bunches with six hands.

Increases in hand and fruit weight following dehanding have been reported by Arcila *et al.* (2000b) in FHIA-21, Rodríguez *et al.* (1988) in 'Superplátano', 'Laknau' and 'Maricongo', and by Quintero and Aristizábal (2003) in 'Dominico hartón'. That the effect did not compensate for the decline in bunch weight is in agreement with Irizarry *et al.* (1994).

Dehanding is supposed to redistribute the dry matter that would have ended in the removed hands, to the hands remaining on the bunch. This is theoretically valid if there is no change in the functional leaf area. According to the theory on the relationship between source and sink, dehanding translates into a smaller sink and reduced activity of the source, that is in photosynthetic activity (Shibles 1984). This explains why in plants with a similar number of functional leaves at flowering (mean of 12 in the present study), the weight of bunches

Table 3. Mean finger weight per hand (g) in bunches of FHIA-20 as a function of the planting distance and the number of hands left on the bunch

Hand number	Planting distance 3 m x 3 m				Planting distance 4 m x 3 m			
	Control	Eight	Seven	Six	Control	Eight	Seven	Six
1	333	406	494	506	359	412	512	465
2	347	381	412	473	341	406	412	412
3	347	386	446	478	306	367	373	400
4	343	343	357	467	329	350	371	350
5	314	331	353	454	315	338	336	367
6	315	292	317	427	285	333	373	325
7	285	283	309		283	275	350	
8	293	250			264	245		
9	267				280			
10	270				256			
11	189				186			

from which hands had been removed was less than in intact bunches.

The beneficial effect of dehanding is to improve the commercial size of the fruits, particularly when production is traded as hands or fingers, or is intended for sale in specialized markets, which is the tendency today (CCI 2000). In these situations, hand weight or finger weight is a determinant factor that stabilizes the sale price of production and hence the returns for the producer.

Belalcázar and Cayón (1998) observed that with 'Dominico hartón' an increase in planting distance increased bunch weight. In this study, the best responses were obtained at 3 m x 3 m, suggesting that the prevailing microclimate conditions occurring at this distance, particularly solar radiation, does not limit plant growth and productivity.

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The author *works at the* Departamento de Fitotecnia, Universidad de Caldas, *PO Box 275, Manizales, Colombia*.

Cultural practice

Effect of planting depth on crop cycle duration and yield

S. B. Bakhiet and G. A. A. Elbadri

There are two main methods for planting banana plants, namely holes and furrows (Simmonds 1966). The depth of planting varies with the type of soil and type of planting material (Robinson 1995). Since the growth of suckers usually takes place from the middle and upper parts of the corm, there is a tendency for successive shoots to be borne near the soil surface and even above the soil surface (Simmonds 1966). In plants established from suckers, the root system is adventitious and unfavourable conditions increase the sensitivity of the plant to water stress. Reducing the extent of the root system tends to result in plants being less securely anchored. Such plants are prone to topple under the weight of an early maturing bunch, especially during the windy or wet seasons. The entire mat may be uprooted, leaving the area unproductive for the life of the plantation.

In the Kassala region, Sudan, banana plants are usually planted at a depth of 30 to 40 cm. A high proportion of the banana plantations become uneconomic after the third ratoon crop. The reduction in yield might be due to the relatively shallow planting depths. Several workers investigated the

decline in banana production after a few ratoon crops. Turner (1970) postulated that ratoon crops are potentially more productive because they benefit from the residues of previous crops and that yield decline is associated with infection with pests and diseases, particularly nematodes. Robinson (1995) reported that shallow planting depth could cause the plant to dry out and induce a superficial root system in the motherplant and suckers. This study was initiated to examine the effect of planting depth on crop cycle duration and yield of bananas.

Materials and methods

The planting materials used in this investigation were sword suckers. They were planted in 30 cm x 30 cm holes of varying depths: 30, 40, 50 and 60 cm. The holes were then filled with the extracted soil. The soil in this region is a deep silt deposit of the Gash River area. This type of soil, with a silt loam to silty clay loam texture, has the highest available moisture capacity of the Gash Delta soil (Dijkshoorn 1994). It is neither loose nor compact and a typical profile covers from 40 cm to over 2 meters.

A randomized complete block design was used, with four replicates and four plants per plot. Plant spacing was 3 meters within and between rows. Planting was done on 31 March 1997 at the Kassala Experimental Research Station. Cultural practices, except fertilization, were done as required throughout the experimental period.

The number of days the corms took to germinate was recorded. The number of newly formed suckers per mat was counted four months after planting. The number of days from planting to shooting (flowering), from shooting to harvesting and from harvest to harvest over four crop cycles was recorded. Bunch maturation was determined by measuring the diameter of the outer central fruit of the second hand at harvest. The harvested bunches were weighed using a spring balance. The number of hands per bunch and of fingers per hand were counted. The means were compared using Duncan's Multiple Range Test at probability 0.05.

Results and discussion

As shown in Table 1, the time to corm germination and the number of suckers per mat did not statistically differ with planting depth. These results might be the result of using uniform sword sucker planting materials. Bakhiet *et al.* (2003) had observed differences in the time to corm germination when the type of planting material differed. Days from planting to shooting and from planting to the harvest of the motherplant crop significantly decreased with increased planting depth, but the time from shooting to harvest did not statistically differ. The results show that a planting depth of 60 cm significantly reduced the number of days from planting to shooting and to harvest, but not from shooting to harvest. The interval between harvests over the four crop cycles significantly differed with planting depth. A planting depth of 60 cm resulted in a significantly shorter interval between harvests. The only exception was the 3rd ratoon crop at a depth of 50 cm, which was not significantly different from the 3rd ratoon crop at 60 cm (Table 1).

Digging deep holes seems to hasten flowering, whereas maturation seems controlled by temperature during bunch development, as observed by Robinson (1981), whereas Fraser and Eckstein (1998) reported a tendency for a longer cycle as a result of deep planting using tissue culture derived banana plantlets. This discrepancy might be a consequence of using different planting materials.

The results also show that bunch weight increased with planting depth, with the largest bunch observed at 60 cm, except in the first ratoon crop for which bunch weight at 50 and 60 cm were not significantly different (Table 2). These findings are in agreement with those reported by Manica (1976), Obiefuna (1983) and Fraser and Eckstein (1998) who observed that shallow planting was associated with smaller bunches.

Table 1. The effect of planting depth on agronomic performance

Planting depth (cm)	Time to corm germination (days)	Number of suckers 4 MAP**	Time from planting to shooting (days)	Time from shooting to harvest (days)	Time from planting to harvest (days)	Time from harvest to harvest (days)		
						R1	R2	R3
30	29 a*	2.7 a	314 a	98 a	412 a	147 a	127 a	147 a
40	32 a	3.0 a	312 a	95 a	407 a	136 a	128 a	125 ab
50	32 a	2.5 a	305 ab	100 a	405 a	144 a	124 a	73 bc
60	32 a	2.3 a	285 b	100 a	385 b	44 b	50 b	54 c

* Means followed by the same letter are not significantly different at p= 0.05 according to Duncan's Multiple Range Test.

** MAP: Months after planting

R1 = First ratoon crop. R2 = Second ratoon crop. R3 = Third ratoon crop

Table 2. Effect of planting depth on yield parameters

Planting depth (cm)	Bunch weight (kg)				Number of hands/bunch				Number of fingers/hand			
	MP	R1	R2	R3	MP	R1	R2	R3	MP	R1	R2	R3
30	14.5 b*	16.9 b	16.0 b	15.4 b	8.0 c	8.9 b	8.5 b	8.0 c	17.2 a	18.0 a	18.2 a	17.2 a
40	14.5 b	16.7 b	16.0 b	16.2 b	8.8 b	8.7 b	8.4 b	8.3 bc	17.1 a	17.5 a	17.9 a	18.4 a
50	15.3 b	19.3 ab	18.6 b	20.0 b	8.4 b	9.2 ab	9.1 b	9.6 ab	17.6 a	18.9 a	17.7 a	18.3 a
60	18.2 a	22.3 a	25.5 a	25.1 a	9.5 a	9.9 a	10.8 a	10.9 a	18.0 a	19.7 a	18.4 a	18.9 a

* Means within the same column having the same letter are not significantly different at p= 0.05 according to Duncan's Multiple Range Test.
MP=Motherplant crop, R1 = First ratoon crop, R2 = Second ratoon crop, R3 = Third ratoon crop

The results also show that at a planting depth of 60 cm, bunch weight increased until the second ratoon crop before levelling off (Table 2). This was not observed with the other treatments, in which bunch weight decreased after the first ratoon crop. Usually, bunch weight increases up to the third ratoon crop and then levels off, except when there are root growth problems due to poor drainage or nematodes (Stover and Simmonds 1987).

The results also show a significant effect of planting depth on the number of hands per bunch over the 4 crop cycles (Table 2). The number of hands per bunch of plants planted in 60 cm holes was significantly different from the number of hands in all the other treatments, except for the first and third ratoon crops of those planted in 50 cm holes. The trend was similar to the one observed with bunch weight, given the relationship between bunch weight and the number of hands per bunch. The number of fingers per hand, however, did not vary with planting depth (Table 2).

Although a 60 cm planting depth seems to reduce crop cycle duration and increase bunch weight, more research is needed to determine the relationship between planting depth, soil moisture contents, nutrients uptake and nematode infection.

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S. B. Bakhiet *works at the Kassala Research Station and* ***G. A. A. Elbadri*** *at the Gezira Research Station, Agricultural Research and Technology Corporation, Wad Medani, P.O. 126, Sudan.*

Root system

Relationship between electrical capacitance and root traits

G. Blomme, I. Blanckaert, A. Tenkouano and R. Swennen

Given the importance of roots in nutrient and water uptake, and plant stability, many efforts have been made in recent years to investigate the *Musa* root system. But excavating whole plants is not only labour intensive, time consuming and destructive, the estimated root system traits are valid for a specific time only.

Taking representative root samples is an option (Blomme 2000). Alternately, multiple regression equations can take advantage of the strong relationships between shoot traits and root system traits (Blomme 2000, Blomme *et al.* 2001). This method, however, can only be used on plants that are in the vegetative stage.

A fast and non-destructive root assessment method that has been tried with other plant species (e.g. carrot, maize, oats, onion, sunflower and tomato) is the use of electrical capacitance (Chloupek 1972, Chloupek 1977, Dalton 1995, Van Beem *et al.* 1998).

A capacitor consists of two flat parallel plates separated by a vacuum or any other insulator. One plate is connected to a battery and the other one grounded. When voltage is applied to the first plate, a simultaneous charge is induced on the second one. Any difference in potential between the two plates is a measure of capacitance, C. Capacitance is dependent on the dielectric constant ε_r of the non-conductive material in between the two plates: $C=[\varepsilon_r \times A]/d$ (A=surface area and d=distance between the plates).

With plants, it is assumed that an electrical current applied to the plant will pass through the vascular tissues that transport nutrients and water, and through the soil and soil-root interface, without major resistance. In a banana plant, the soil and the root vascular tissue are separated by a zone of significantly higher resistance, i.e. the root cortex. Each root segment can be schematically represented as a symmetric cylindrical capacitor consisting of vascular tissue surrounded by the root cortex (Figure 1). The outer border of the cortex is in contact with the electrolytic soil solution. The central and outer layers are separated by the less conductive cortex tissue.

Capacitance has never been used before with bananas and plantains, which is surprising given that banana tissues contain a lot of water. The objective of this study was to evaluate the possibility of using capacitance measurements to provide information on the banana root system.

Materials and methods

The experiments were carried out between August and the end of September 1999 at the International Institute of Tropical Agriculture (IITA) High Rainfall station in Onne, Nigeria. The experimental field was established using plants derived from suckers.

Before planting, the soil was superficially tilled. The experimental design was a split plot design within a randomized complete block design with two replications of two sucker derived plants per genotype. The main plot treatment was the time of the observation (24, 29 and 33 weeks after planting). The subplot treatment was the genotype: 'Mbi egome' (AAB) and 'Fougamou' (ABB). Plant spacing was 3.5 m x 3.5 m to prevent an overlap of adjacent root systems.

All capacitance measurements were carried out with a portable capacitance meter, type ISO-TECH 9023 RS 205-7496. Based on preliminary testing, the scale was fixed on 2µF (10^{-6} F) at a frequency of 800 Hz. Both poles were attached to copper needle electrodes by using crocodile clips.

A 45 cm long positive electrode was inserted in the soil. The current passed through the root cortex tissue, reached the central cylinder, i.e. the root's vascular tissue, continued through the corm's vascular tissue and arrived at the 15 cm long negative electrode inserted in the pseudostem. The circuit was closed by the capacitance meter (Figure 2).

The negative electrode was placed at two heights on the pseudostem (0 and 10 cm) and depths in the pseudostem (1, 5 and 8 cm), and the positive electrode was positioned at various distances from the pseudostem (40, 80 and 120 cm) and depths in the soil (10, 20, 30 and 40 cm). Measurements were carried out in each of the four quadrants around the mother plant. The 0° line ran from the motherplant to the tallest sucker. Quadrants were assessed clockwise, with the first quadrant being the 90° area left of the 0° line. The capacitance value, which varies with time, was noted 60 seconds after the meter was switched on. All

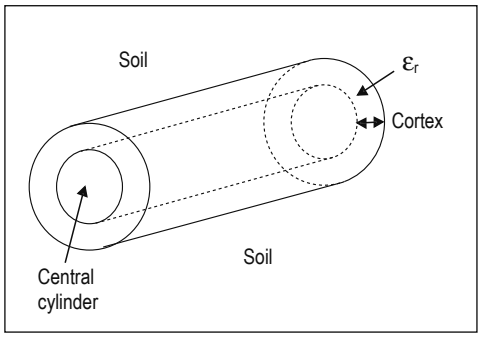

Figure 1. A root segment visualized as a cylindrical capacitor. The central cylinder and the soil are separated by the less conductive root cortex whose dielectric constant is ε_r

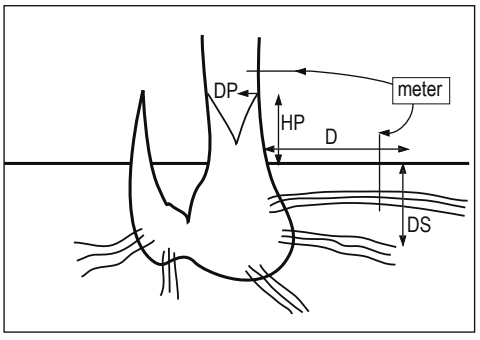

Figure 2. Traits defining the position of both electrodes (HP: Height on the pseudostem, DP: Depth in the pseudostem, D: Distance from the pseudostem, DS: Depth in the soil)

capacitance measurements were carried out two hours after rainfall or irrigation.

Based on an experiment by Chloupek (1977), an alternative method of capacitance measurement was tested. Four electrodes were positioned in a square around the motherplant and interconnected by a thin copper wire. The crocodile clip was attached to the electrode at the 0º position, i.e. the position of the tallest sucker. Measurements were conducted at a distance of 40 and 80 cm from the motherplant. Soil depth remained constant at 40 cm. Positions for the negative electrode were the same as with the standard method. Measurements were carried out on all plants.

Because of the presence of an underground corm, an additional experiment was conducted to determine the effect of corm size on capacitance measurements. Ten corms of three genotypes (FHIA-03, TMPx548-9 and TMPx1658-4) were excavated. Corms with different dimensions were selected. All roots and the pseudostem were cut off. The capacitance of each corm was measured while the corm was partially submerged in a water tank. One electrode was inserted at a depth of 1 cm in the corm, without making contact with the water. The other electrode was held in the water, at a constant distance of 20 cm from the floating corm. After measuring the capacitance, each corm was cut in half and both corm height and corm widest width were assessed.

As soon as capacitance measurements were completed on field-established plants, each plant was carefully excavated and the following shoot and root characteristics were assessed: plant height, plant circumference, number of suckers, height of the tallest sucker, leaf area of the mother plant, corm weight of the mother plant, corm weight of the suckers, number of cord roots of the mat, root dry weight of the mat, cord root length of the mat and average diameter of 40 randomly chosen cord roots. Leaf area was calculated as: leaf length x leaf widest width x 0.8 (Obiefuna and Ndubizu 1979). Cord root length was measured using the line intersect method (Tennant 1975). The line intersect method consists of scattering cord roots on a grid and counting the number of intersection points, which was then multiplied by the conversion factor, 2.3571, appropriate for a 3 cm x 3 cm grid. Basal cord root diameter was measured using a Vernier calliper.

An analysis of variance, using the SAS statistical package, was performed. Scatter plots and linear correlation analyses (Proc CORR in SAS) was carried out on the complete dataset, but also according to the age of the plants.

Results

Few significant correlations were found between capacitance values and root system traits for all combinations of electrode positions and stages of plant development (data not shown). Only 12.5%, 8% and 5.7% of the correlations between capacitance and the number of cord roots, dry root weight and cord root length, respectively, were significant. No needle position gave more significant correlations and the few significant correlations between root system traits and capacitance values were not consistently positive. Finally, none of the four quadrants assessed gave a higher number of positive correlations.

Although capacitance was not significantly correlated with any root system trait, the position of the electrode affected capacitance readings. The distance of the electrode from the pseudostem had no significant effect on capacitance values, a result that agrees with observations made on corn by Van Beem *et al.* (1998), but its height and depth on the pseudostem and its depth in the soil did (Table 1). Increasing the height at which the electrode was inserted caused a drop in capacitance as the greater quantity of plant tissue in the electrical circuit increased resistance in this circuit. On the other hand, increasing the depth at which the electrode was inserted in the pseudostem increased capacitance. The highest values of capacitance were obtained when the electrode was inserted at the greatest depths in the soil. The quadrant also had a significant effect on capacitance values (Table 2).

The significant effect of the quadrant may indicate an influence of the uneven distribution of roots and corm tissue around the mother plant. Since the side on which the sucker develops would have a greater root density, it was expected that the capacitance value on that side would be higher than on the side where there is no sucker, or only a small one. The results show, however, that sucker size was negatively correlated with capacitance. The corm of the sucker and, more importantly, the physiological changes over time in the organic connection between the sucker and the motherplant, may play

an important role in influencing capacitance values.

The capacitance values obtained through the method of four interconnected soil electrodes were highly correlated with the values obtained using the standard method (R^2= 0.87, p<0.0001), in accordance with observations made by Chloupek (1977) on *Helianthus annuus* L. cv. 'Maják'.

No significant correlations were found between the height and width of the corm and capacitance values (Table 3). Contrary to the crops assessed in previous research on capacitance, banana plants form numerous corms at soil level. These corms may prevent the electrical circuit from giving an accurate picture of the root system.

Table 1. Mean square and significance tests for the capacitance value of 'Fougamou' and 'Mbi Egome' (4 plants per cultivar, 24 weeks after planting)

Source of variation	Df	Fougamou	Mbi egome
Height on the pseudostem	1	0.32515392***	0.43843809***
Depth in the pseudostem	2	0.78452294****	0.57899544***
Distance from the pseudostem	2	0.00573300	0.01609219
Depth in the soil	3	0.59036384***	0.88199040***

Table 2. Mean square and significance tests for the capacitance value (two cultivars, Fougamou' and 'Mbi Egome', 4 plants per cultivar, 24 weeks after planting)

Source of variation	Df	
Quadrant	3	0.17668901***
Height on the pseudostem	1	1.07109907***
Depth in the pseudostem	1	0.13158450*
Distance from the pseudostem	1	0.04201376

Table 3. Correlation coefficients between capacitance values and corm traits

	Corm height	Corm width
Capacitance value	0.29	0.38
Corm height		0.91***

Discussion

Our results show that measuring capacitance cannot be used to estimate root traits of juvenile and adult *Musa* plants in the field. The lack of correlation between capacitance values and root traits may be related to the morphology of the banana plant. For example, the position of vascular bundles in banana tissues may be significant. The electrode was not connected with the real stem of the plant (which is the corm) but instead was inserted in the pseudostem, which consists of leaf sheaths. This tissue contains air cavities, which may affect conductivity, but the extent to which these factors affect the results is not known. Another characteristic of the banana plant is the presence of an underground corm and the formation of suckers. The presence, position and dimensions of the suckers, in particular, seem to be significant.

Although the field assessments were carried out under irrigated conditions and the leaf canopy attenuated extreme soil temperature fluctuations, changes in soil temperature may have occurred and influenced capacitance measurements. In addition, although the soil was ploughed prior to planting, abrupt textural changes and cavities may still have been present in the soil, which could have influenced the electrical circuit.

Previous research (Van Beem *et al.* 1998, Dalton 1995, Kendall *et al.* 1982, Chloupek 1977) identified soil humidity and soil temperature as key factors influencing the capacitance of the root system. Soil humidity is important not only for the conductivity of the soil but also for the contact between the roots and the soil. Capacitance is only a reflection of root system traits when there is a good electrical contact between the root surface and the soil. A shortage of soil water will thus lead to a lower value of capacitance. This value could be falsely interpreted as an indication for a lower root mass, while in reality it could be a reflection of the lower soil humidity. The strong effect of soil temperature on capacitance plays a significant role in interpreting the results and can therefore be considered as an important disturbance to measuring capacitance in the field. It is assumed that an increase in soil temperature increases soil resistance, resulting in a lower capacitance value.

Finally, the concentration of electrolytes in the soil also affects conductivity. As a plant grows, nutrients are taken from the soil, resulting in spatial changes in the nutrient condition of the soil that could also affect capacitance measurements.

Acknowledgements

Financial support by the Flemish Association for Development Co-operation and Technical Assistance (VVOB) and the Belgian Directorate General for Development and Cooperation (DGCD) is gratefully acknowledged.

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G. Blomme *works at INIBAP-ESA, P.O.Box 24384, Kampala, Uganda, e-mail: g.blomme@cgiar.org, but the present work was conducted while at the International Institute of Tropical Agriculture, High Rainfall Station, PMB 008 Nchia-Eleme, Rivers State, Nigeria.*
I. Blanckaert and R. Swennen *are at the Laboratory of Tropical Crop Improvement, Katholieke Universiteit Leuven, Kasteelpark Arenberg 13, 3001 Heverlee, Belgium, e-mail: rony.swennen@agr.kuleuven.ac.be, and*
A. Tenkouano *at the Humid Forest Ecoregional Center, International Institute of Tropical Agriculture, BP 2008 Messa, Yaoundé, Cameroon, e-mail: a.tenkouano@cgiar.org.*

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Intercropping

Productivity of a False horn plantain intercropped with cowpea and maize in southeastern Nigeria

J.O. Shiyam, B.F. D. Oko and W. B. Binang

Intercropping of plantain has been reported in the Andes region of South America (Stover and Simmonds 1987), the West Indies (Rao and Edmund 1984) and the Philippines (Alviar and Cuevas 1976). In the rainforests of West Africa, Devos and Wilson (1979), Ikeorgu *et al.* (1989) and Oko *et al.* (2000) have noted that intercropping is usually practiced by low income families to maximize the use of land and to provide extra food and cash. In the humid tropics, especially in southeastern Nigeria, plantains are frequently intercropped with food crops such as maize, cocoyam and vegetables (Francis *et al.* 1976). Intercropping plantain by resource-poor farmers has also been reported by Karikari (1972) and Obiefuna (1984). But plantain cultivation is usually profitable for one or two years after which soil fertility declines, resulting in annual yields as low as 4 to 8 tonnes/ha (Nweke *et al.* 1988) compared with the 30 to 50 tonnes/ha observed in backyard gardens in which the soils can sustain high yields over many years (Wilson 1987).

Despite the popularity of plantain intercropping, few experimental studies of this cropping system have been conducted in Nigeria. Consequently, little is known about the interactions between the plants, the yield and the overall productivity of the intercropping systems in which plantain is a major component, probably because of the difficulty of evaluating the yields of traditional farming systems. This trial was designed to determine the effect on productivity of intercropping plantain with cowpea and/or maize.

Materials and methods

The experiment was conducted during the 1998 and 1999 cropping seasons at the University of Calabar teaching and research farm situated in the rainforest belt of southeastern Nigeria. The climate of the area is humid and supports a lowland tropical rainforest vegetation. The annual rainfall is about 2000 to 3000 mm, most of it falling between March and November. The rainfall shows a characteristic bimodal distribution, with maxima in July and September. Maximum and minimum temperatures are 33°C and 23°C, respectively, while mean relative humidity is 80%. The experimental site is on a sandy loam soil (Cobbina *et al.* 1990) with a pH of 5.8, an organic carbon content of 2%, a total N content of 0.17%, a phosphorus index (Bray P1) of 55.7 ppm, an exchangeable acidity of 1.28, a cation exchange capacity (CEC) of 4.14 meq/100g and a magnesium content of 0.6 meq/100g.

A False horn plantain, commonly known in West Africa as 'Agbagba' was intercropped with a cowpea (*Vigna unguiculata Walp.)* variety (1T82D-719), recommended for the rainforest agroecological zone of Nigeria (Enwezor *et al.* 1989), and a medium maturity local maize *(Zea mays, L.)* variety popularly known as 'Jkom white'. The experiment was laid out in a randomized complete block design with four replications. The treatments were: sole plantain; sole cowpea; sole

maize; plantain and cowpea; plantain and maize; plantain, cowpea and maize.

The suckers were obtained from old orchards in the area. They were planted 2 m apart in holes 40 cm deep and 30 cm wide and filled with topsoil. The intercrops were planted in the inter-rows, immediately after plantain was planted. Plant densities were 1666 plants/ha for plantain, 20 000 plants/ha for maize and 55 000 plants/ha for cowpea. The unit plot size was 10 m x 3 m and consisted of a row of six plantain mats 2 m apart at the centre of the plot and the intercrops were planted on both side of the plantain row.

Each plantain plant received 400 g of N:P:K (20:10:10) three months after planting and 300 g six and nine months after planting for a total of 250 kg/ha (Swennen and Wilson 1985). Maize and cowpea respectively received a total application of 120 kg/ha and 20 kg/ha of N:P:K (20:10:10) (Enwezor *et al.* 1989). The plots were kept free of weeds by hoe weeding when necessary.

Maize was harvested after 112 days, oven dried at 60°C for 24 hours and shelled manually, whereas ripe cowpea pods were picked, sun-dried and shelled by hand. Plantain bunches were harvested 90 days after flowering and the yield per hectare was based on the mean bunch weight. Data on plant height at 7 and 12 months after planting, pseudostem girth at 1 m 12 months after planting, number of leaves 12 months after planting, number of days to flowering, number of hands per bunch, number of fingers per hand and bunch weight were recorded and analysed using an ANOVA and a Duncan multiple range test was performed.

Results

Intercropping initially reduced the height of plantain plants. This effect was the most severe in the plantain with maize and cowpea treatment (Table 1). However at flowering, plant height was not significantly different. There were also no significant differences between the treatments regarding the girth of the pseudostem and the number of leaves.

Plantains in monoculture and intercropped with cowpea fruited significantly earlier than those intercropped with maize and with maize and cowpea (Table 1). Similarly, the mean number of fingers per hand, bunch weight and yield were similar in the plantain monocultures and the plantain/cowpea fields but significantly higher than in the other types of intercropping systems (Table 1).

Intercropping significantly reduced the yields of cowpea and maize in 1998 and 1999 (Table 2). The yields were higher in the monocultures, followed by the two-species intercropping systems and the three-species ones.

Discussion

The yield in the plantain/cowpea fields compared favourably with the yield in plantain monocultures because of the small stature of cowpea and its ability to fix nitrogen. These features minimize competition for light and nitrogen. In contrast, the reduced plantain yields observed in the intercropping systems containing maize are probably due to the high nutrient requirements of maize. Competition for nutrients must have been especially high in the second year when the plantain entered its reproductive phase, bunch development

Table 1. Agronomical data recorded on plantains after one production cycle under various cropping systems

Cropping system	Plant height (m)		Pseudostem girth 12 MAP (cm)	Number of leaves 12 MAP	Number of days to flowering	Number of hands/bunch	Number of fingers/hand	Bunch weight (kg)	Yield (t/ha)
	7 MAP	12 MAP							
Sole plantain	1.6 b	3.9 a	40.6 a	13.0 a	278 a	7.6 a	52 a	11.2 a	18.7 a
Plantain/cowpea	1.3 c	3.9 a	41.7 a	12.9 a	306 b	6.6 a	38 b	9.8 b	16.3 b
Plantain/maize	0.9 d	3.7 a	40.8 a	12.8 a	300 b	6.3 a	36 b	7.2 b	14.8 b
Plantain/cowpea/maize	2.3 a	3.8 a	43.0 a	13.3 a	282 a	7.6 a	54 a	11.8 a	19.7 a

*MAP: months after planting

Means followed by different letters are significantly different at probability 0.05 according to the Duncan multiple range test

Table 2. Yield (t/ha) of plantain, cowpea and maize under various cropping systems

Cropping system	1998		1999		
	Cowpea	Maize	Plantain	Cowpea	Maize
Sole plantain			19.7 a		
Sole cowpea	1384.6 a			1131 a	
Sole maize		4662.4 a			4028.8 a
Plantain/cowpea	1313.7 a		18.7 a	771.5 b	
Plantain/maize		3967.2 b	16.3 b		3661.2 b
Plantain/cowpea/maize	1275.4 a	2923.2 c	14.8 b	698.4 c	2045.8 c

Means followed by different letters are significantly different at probability 0.05 according to the Duncan multiple range test

being demanding of nutrients (Stover and Simmonds 1987, Oko *et al*. 2000).

The initial reduction in height observed in plantains was probably due to competition with the associated crops. The differences in maturity periods between plantain and the other crops may have helped plantain to recover from the initial stress. This observation is consistent with Andrews (1970).

Cowpea yields declined in all the intercropping systems. According to Oko *et al.* (2000), cowpea performs best under little or no shade. The reduction in yields could be attributed to the shade made by the plantain and the maize. There was more shade in 1999 than in 1998. In 1998, the average yield was reduced by 109 kg/ha in the three-species intercropping system compared to sole cropping, and by 433 kg/ha in 1999.

Maize yields were also reduced and the reduction increased with the number of species in the intercropping system and over time. In 1998, the average yield was reduced by 1739 kg/ha in the three-species intercropping system compared to sole cropping, and by 1983 kg/ha in 1999. Oko *et al.* (2000) reported that maize often suffers more from nutrient competition than from any other factor. Also, it is possible that an increase in pests and diseases may have contributed to reducing the yield of the intercrop species.

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J.O. Shiyam, B.F. D. Oko *and* ***W. B. Binang*** *work at the Department of crop science, University of Calabar, Calabar, Nigeria.*

Improved hybrids

Effect of desuckering on pest and disease resistance of FHIA-23 and SH-3436-9

A. Vargas and M. Guzmán

The *Fundación Hondureña de Investigación Agrícola* (FHIA) has developed an important programme of conventional genetic improvement of the Musaceae. This has resulted in considerable numbers of improved hybrids (Rowe 1998, 1999), which include tetraploids of banana (*Musa* AAAA) FHIA–23 (Highgate x SH-3362) and SH-3436 (Highgate x SH-3142). A Cuban selection from the latter gave rise to SH-3436-9.

FHIA-23 possesses good agronomic and organoleptic characteristics and partial resistance to black leaf streak disease and Fusarium wilt (caused by *Fusarium oxysporum* f.sp. *cubense*) (Orjeda *et al*. 1999, Rivera and Dueñas 2002). The hybrid SH-3436-9 has a satisfactory productivity

(Alvarez 1997), fruits with good flavour, partial resistance to black leaf streak disease (Orjeda *et al*. 1999) and a low reproductive index of *Radopholus similis* (J. González 1997, INVIT pers. com.).

There is considerable information worldwide about the reaction to diseases of FHIA banana hybrids. However, very little information is available about the response to management practices to optimize production, such as desuckering and its effect on the hybrids' resistance to diseases such as black leaf streak disease. In a directional system of desuckering, for example, the direction of planting and the density of the original population are maintained for considerable periods with little change, in contrast to traditional desuckering (Pérez 2000).

FHIA-23 and SH-3436-9 could both make a valuable contribution to the production of bananas originating from the subgroup Cavendish, whose cultivars are more susceptible to black leaf streak disease (Guzmán and Romero 1996, Marín *et al*. 2003). The objective of the study was to evaluate the agronomic potential and the reaction of the two hybrids to pests and diseases when cultivated under two systems of desuckering, directional and traditional.

Materials and methods

The experimental work was carried out at the *Centro de Investigaciones Agrícolas 28 Millas*, a property of the *Corporación Bananera Nacional* (CORBANA, S.A.), over three production cycles between May 1998 and November 2001. The altitude of the experimental site is 40 metres above sea level, in the district of Matina, Limón province, Costa Rica. In 1998, 1999, 2000 and 2001, accumulated rainfall was 3480, 3652, 3847 and 3857 mm, mean monthly temperature was 24.4, 24.2, 22.5 and 24.2°C and mean monthly relative humidity was 87, 88, 89 and 89%, respectively.

The soil at the experimental site had been planted for four years with the banana hybrids FHIA-01 and FHIA-02 (*Musa* AAAB). In terms of texture, the soil was classified as clay loam (sand 34%, clay 30%, silt 36%), with a 6.3 pH, 0.1 extractable acidity, 2.8% organic matter, Ca 26.4 cmol/L, Mg 10.1 cmol/L, K 0.7 cmol/L and an effective cation exchange capacity of 37.2 cmol/kg. The soil is classified as an Aquertic Eutrudept (clay inceptisol, with limited drainage and profile) (E. Serrano, CORBANA, pers. com.).

In vitro plantlets were used. Each hybrid was evaluated under two desuckering systems, directional and traditional, in a factorial arrangement on a randomized complete block design with four replicates. Each experimental plot contained 70 plants and the usable plot contained 40 plants.

Planting distance in the field was 2.75 m in a triangular arrangement giving a density of 1371 plants/ha.

After 24 weeks, the shoots that seemed to originate from the lower buds of the corm were removed. In plots with directional desuckering, the sword sucker that most closely maintained the orientation of the planting line was kept and the others removed, when new shoots appeared. In plots with traditional desuckering, the most developed and best positioned sucker was selected at flowering.

For the first and second ratoon crops, the sword sucker that better maintained the direction of the original planting line was chosen, in directional desuckering plots. In the traditional desuckering plots, the most vigorous sucker in the best position in relation to the neighbouring plants at flowering was chosen.

Fertilizers were applied monthly as 15:3:31 ($N:P_20_5:K_2O$) at a rate of 83 g per plant. As a precaution against toppling, plants were secured by means of double strands of polypropylene.

Bagging of the fruit was done 15 days after flower emergence. The last two green hands were removed at the same time. Harvest was 11 weeks after flowering.

Variables related to the severity of black leaf streak disease were evaluated at flowering and harvest on 10 plants per plot using Gauhl's modification of Stover's severity scoring system (Gauhl 1989). The same plants were evaluated over three production cycles. The following variables were measured: days to flowering, height of pseudostem at flowering, girth of pseudostem at flowering (at a height equivalent to 25% of the height of the pseudostem), total number of functional leaves at flowering and at harvest, bunch weight, number of hands, diameter and length of the middle finger of the second hand, number of fingers in the second hand, diameter and length of the middle finger of the last hand, number of fingers in the last hand, youngest leaf spotted, i.e. the leaf number of the first leaf to show a black spot visible on both sides of the leaf but without the presence of a chlorotic

halo (Fouré 1985) and the infection index, i.e. the percentage of plant area affected by black leaf streak disease (Romero 1994).

No attempt was made to control nematodes. Nematode populations and root condition were determined during the third production cycle by sampling the suckers of recently flowered plants, according to the method proposed by Araya and Cheves (1998).

No attempt was made to control weevils. The coefficient of infestation and the degree of corm decay were determined at harvest after the second ratoon crop by using the method proposed by Villardebo (1973).

Chemical control measures were not applied against black leaf streak disease. Necrotic or senescent leaf tissue was removed through sanitary deleafing or removal of leaf tips.

Statistical analysis was carried out for each production cycle taking into account the factorial arrangement of the hybrids x desuckering systems. A simple mean was obtained from data from 10 plants per plot followed by analysis of variance and separation of means for each variable.

Results

There was no difference (P>0.10) between the two desuckering systems for any of the variables evaluated at flowering and harvest in any of the three production cycles. Moreover, the absence (P>0.07) of an interaction between hybrid and desuckering system meant that desuckering could be ignored when comparing the hybrids.

At flowering, FHIA-23 had a taller and thicker pseudostem than SH-3436-9, as well as a higher number of hands and days to flowering in each production cycle (Table 1).

FHIA-23 had a higher bunch weight in the motherplant and first ratoon crops, but did not differ from SH-3436-9 in the second ratoon crop. With the exception of the diameter of the middle finger of the second hand in the first ratoon crop, there were no differences between either hybrid in the dimensions or numbers of fruits in the second and last hand (Table 1).

At flowering, FHIA-23 had a higher number of leaves in the motherplant and first ratoon crops, but the number of leaves did not differ from the ones of SH-3436-9 in the second ratoon crop. At harvest, FHIA–23 had a similar number of leaves as SH-3436-9 in the motherplant crop but a higher number of leaves in the two subsequent ratoon crops. There were no differences in either hybrid in the infection index nor in the youngest leaf spotted either at flowering or at harvest (Table 2).

Irrespective of the hybrid and with the exception of the youngest leaf spotted at harvest and the interval between flowering, where there were no differences between the production cycles, there were differences between production cycles for the remaining variables studied.

In general, the variables plant height, pseudostem girth, number of hands and fingers in the second hand and the youngest leaf spotted at flowering, increased with each production cycle, whereas the infection index decreased.

The only interaction between production cycle and hybrid was with the variables: bunch weight, diameter of the middle finger

Table 1. Agronomic characteristics of hybrids FHIA-23 and SH-3436-9 over three production cycles (n=8 plots and 40 plants per usable plot)

Hybrid	Height of pseudo-stem (m)	Girth of pseudo-stem (cm)	Number of hands per bunch	Days to flowering	Bunch weight (kg)	Diameter* of middle finger of 2nd hand	Length of middle finger of 2nd hand (cm)	Number of fruits in 2nd hand	Diameter* of middle finger of last hand	Length of middle finger of last hand (cm)	Number of fingers in last hand
Motherplant crop											
FHIA-23	3.3 ± 0.1	25.8 ± 0.3	11.3 ± 0.3	365 ± 10	23.4 ± 1.1	40.6 ± 0.4	21.3 ± 0.2	18.2 ± 0.3	33.4 ± 0.5	16.0 ± 0.3	15.1 ± 0.3
SH-3436-9	2.9 ± 0.1	22.3 ± 0.5	9.9 ± 0.3	342 ± 8	20.2 ± 1.2	41.4 ± 0.5	21.6 ± 0.3	17.9 ± 0.7	35.4 ± 0.4	17.2 ± 0.3	14.4 ± 0.3
Prob>F	0.0009	0.0001	0.0151	0.0556	0.0437	0.8838	0.5430	0.4697	0.8798	0.5553	0.8918
First ratoon crop											
FHIA-23	3.9 ± 0.1	30.6 ± 0.4	12.8 ± 0.3	327 ± 7	28.1 ± 0.8	40.5 ± 0.3	21.8 ± 0.1	19.3 ± 0.3	33.5 ± 0.3	16.2 ± 0.2	15.6 ± 0.2
SH-3436-9	3.4 ± 0.1	27.5 ± 0.6	11.5 ± 0.3	284 ± 6	22.7 ± 1.0	39.1 ± 0.4	21.3 ± 0.3	19.0 ± 0.3	33.5 ± 0.4	16.6 ± 0.2	15.3 ± 0.2
Prob>F	0.0001	0.001	0.0004	0.0001	0.0006	0.0461	0.2867	0.3735	0.9288	0.2845	0.1613
Second ratoon crop											
FHIA-23	4.2 ± 0.1	34.5 ± 0.3	12.7 ± 0.3	324 ± 5	22.2 ± 1.0	37.4 ± 0.5	19.9 ± 0.3	19.2 ± 0.3	31.5 ± 0.2	14.8 ± 0.2	15.5 ± 0.2
SH-3436-9	3.7 ± 0.1	31.3 ± 0.6	12.0 ± 0.3	290 ± 6	22.4 ± 1.4	38.2 ± 0.6	20.5 ± 0.4	20.4 ± 0.7	32.3 ± 0.7	15.3 ± 0.2	15.9 ± 0.2
Prob>F	0.0001	0.0007	0.0654	0.0033	0.8495	0.3362	0.2655	0.1552	0.2603	0.1488	0.2814

*The diameter, in inches, is the value multiplied by 1/32th of an inch

Table 2. Response to black leaf streak disease of hybrids FHIA-23 and SH-3436-9 at flowering and harvest over three production cycles (n=8 plots with 10 plants per usable plot)

Hybrid	Flowering			Harvest		
	Number of functional leaves	Infection index	Youngest leaf spotted	Number of functional leaves	Infection index	Youngest leaf spotted
Motherplant crop						
FHIA-23	8.9 ± 0.1	54.2 ± 0.5	2.9 ± 0.1	3.5 ± 0.2	83.9 ± 0.7	1.0 ± 0.0
SH-3436-9	8.7 ± 0.1	53.0 ± 0.9	3.1 ± 0.1	3.5 ± 0.1	85.0 ± 1.4	1.0 ± 0.0
Prob>F	0.0515	0.2367	0.4749	0.9996	0.4846	0.3559
First ratoon crop						
FHIA-23	9.4 ± 0.1	44.7 ± 1.2	3.1 ± 0.1	4.5 ± 0.2	73.9 ± 0.8	1.0 ± 0.0
SH-3436-9	9.1 ± 0.1	44.6 ± 1.1	3.1 ± 0.1	4.0 ± 0.1	72.7 ± 1.5	1.0 ± 0.0
Prob>F	0.0191	0.9022	0.7453	0.0314	0.5468	1.0000
Second ratoon crop						
FHIA-23	8.7 ± 0.2	33.4 ± 1.1	3.8 ± 0.1	4.1 ± 0.1	68.6 ± 2.5	1.0 ± 0.0
SH-3436-9	8.4 ± 0.3	34.2 ± 2.5	3.8 ± 0.1	3.7 ± 0.1	70.0 ± 1.5	1.1 ± 0.1
Prob>F	0.2718	0.5436	0.8961	0.0221	0.4346	0.3539

of the second and last hands and the number of fingers in the last hand (Table 1).

Both hybrids had a high percentage of functional roots, an absence of *R. similis* and low populations of *Helicotylenchus* spp. and *Pratylenchus* spp. The *Meloydogine* population was average in FHIA-23 and low in SH-3436-9 (Table 3).

Both hybrids had, on average, a low coefficient of weevil infestation in the corm (2.3% for FHIA-23 and 1.8% for SH-3436-9). In addition, associated bacterial decay was absent. Sixty six per cent of FHIA-23 corms and 75% of SH-3436-9 corms were completely free of weevil damage.

Discussion

The experiment lasted over three production cycles only, therefore the number of generations was probably insufficient to demonstrate differences between the two desuckering systems and the variations in the composition and distribution of the plant population in the time available. Nevertheless, the results indicate that up to the second ratoon crop, irrespective of desuckering system, the agronomic performance and response to black leaf streak disease of the suckers was similar for both hybrids.

Similarly as found by Orellana *et al* (1999), Alvarez (1977) and Orjeda (2000), FHIA-23 and SH-3436-9 produced very tall robust plants, with a prolonged vegetative cycle in comparison with Cavendish type bananas. Their height, in particular, reduces the ease of management of the hybrids (Daniells and Bryde, 1993) and is associated with considerable losses of plants by wind in the second generation. Nevertheless, Orellana *et al*. (1999) show that the new hybrids are better able to withstand the effects of wind, without the need for supporting guy lines. In the present work, there was no evidence of toppling. However, the experimental site is not known for strong winds and furthermore the leaf tips were shortened soon after flowering.

The highest productivity of FHIA-23 was mostly a result of the higher number of hands per bunch, in agreement with Orellana *et al*. (1999).

The reduced numbers of leaves at flowering in both hybrids could be attributed to the damaging effect of black leaf streak disease and a tendency to a premature folding of the leaves. Similar observations with the hybrids FHIA-01 and FHIA-02 were made by Guzmán and Romero (1996). The weakness in the petioles is in agreement with Simmonds (1952) and Stover and Buddenhagen (1986) and is a disadvantageous character in the improved tetraploids.

In previous studies in Costa Rica by Guzmán (2000a, b), both hybrids had shown

Table 3. Weight of functional roots and nematode populations (n=4) in hybrids FHIA-23 and SH-3436-9 after the second ratoon crop

	Weight of functional roots per plant		Nematodes per 100 g of root			
Hybrid	g	%	*Radopholus*	*Helicotylenchus*	*Meloidogyne*	*Pratylenchus*
FHIA-23	90.0	94.0	0	1800	4300	300
SH-3436-9	91.0	96.8	0	2000	100	0

moderate resistance to black leaf streak disease. However, given the high disease severity encountered in this investigation, it is possible to demonstrate that FHIA-23 and SH-3436-9 both had low resistance and were similar in their reaction to attack by the pathogen, under the climatic and soil conditions of this experiment.

This situation had already been anticipated by Guzmán *et al*. (2000), who found in field conditions and plots with more than 100 plants, that with a high proportion of leaf infection, these hybrids were able to complete their cycle and liberate secondary inoculum. The authors highlighted the risk and the possibility that the frequency of isolates able to overcome resistance may increase with time and as a result disease severity may also increase.

The above study applies mainly to systems of intensive crop management (monoculture and extensive planting). From this perspective, and in accordance with the small effective leaf area of both hybrids, as much at flowering as at harvest, it would be essential to consider a strategy of chemical control for black leaf streak disease, although probably less intensive than that commonly used for bananas of the subgroup Cavendish, which under the same conditions are practically without leaves by harvest (Guzmán and Romero 1998).

Considering the lower fruit quality of tetraploid hybrids compared to Cavendish bananas for export (Shepherd *et al*. 1986, Stover and Buddenhagen 1986), the potential of both materials should be planned within a system of management for local consumption. Given the resistance of FHIA-23 to *Fusarium oxysporum* f.sp. *cubense*, low or zero nematode population and low coefficient of weevil infestation found in this study with both hybrids, their cultivation with a restricted use of agrochemicals should be possible, the feasibility ultimately depending on acceptance by the local consumer.

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The authors *work at the* Dirección de Investigaciones, *CORBANA S.A., Apdo 390-72-10, Guápiles, Limón, Costa Rica. E-mail: alfvarga@corbana.co.cr; mguzman@corbana.co.cr*

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Evaluation of new banana hybrids against black leaf streak disease

V. Krishnamoorthy, N. Kumar, K. Angappan and K. Soorianathasundaram

Erratum
In this article, the disease against which the hybrids were evaluated was Sigatoka disease, caused by Mycosphaerella musicola, and not black leaf streak disease, caused by Mycosphaerella fijiensis.

Black leaf streak disease, caused by *Mycosphaerella fijiensis* Morelet, is one of the most serious fungal diseases affecting banana and plantain production (Stover and Buddenhagen 1986). Developing resistant varieties is considered the most appropriate technology to control this leaf spot disease. Tamil Nadu Agricultural University initiated a genetic improvement programme to incorporate durable resistance to black leaf streak in bananas by using highly resistant diploid bananas and synthetic hybrids. The current study was carried out to evaluate the response of new hybrids to black leaf streak disease.

Materials and methods

The study was conducted at the Department of Fruit Crops, Tamil Nadu Agricultural University in Coimbatore, India, between June 2000 and February 2002. Coimbatore is located at 11°N and 77°E and at an altitude of 427 m. The maximum and minimum temperatures are 31°C and 21°C, respectively, the relative humidity is 85% in the morning and 49% at noon, and the annual rainfall during the experiment was 698 mm. The soil texture is a sandy clay loam.

The hybrids evaluated in this study are shown in Table 1. These hybrids were screened under natural field conditions and planted in the field as described in Orjeda *et al.* (1998).

Suckers of uniform size were selected and planted in a one cubic foot pit at a spacing of 1.8 m x 1.8 m. The plants were irrigated daily with 20 litres of water through a drip system and 110:35:330 g of N:P:K were applied. The nitrogen and potassium were applied through a drip system with a fertigation unit at weekly intervals in 36 equal splits starting on the 9th week. No chemical, biological, cultural control measures against black leaf streak were applied. Desuckering was carried out at monthly intervals in order to encourage the growth of the motherplant. The experimental design was a randomized block design, with five replicates for each hybrid and parental clone.

Disease severity, or the amount of leaf area affected by the disease, was expressed as a grade (0 to 6) using Gauhl's modification of Stover's scale (Gauhl 1994). The following parameters were recorded: the number of functional leaves and the youngest leaf spotted, i.e. the leaf number of the youngest leaf spotted with 10 or more mature lesions (Vakili 1968).

The infection index was calculated as follows:

$$\text{I. I.} = \frac{\sum^{nb}}{(N-1)T}$$

Table 1. Parentage, ploidy and genome of the banana hybrids evaluated

Hybrid number	Parentage	Ploidy	Genome
H-59	Matti (AA) × Anaikomban (AA)	2×	AA
H-65	Matti (AA) × Pisang lilin (AA)	2×	AA
H-66	Matti (AA) × Anaikomban (AA)	3×	AAA
H-89	Matti (AA) × Namarai (AA)	2×	AA
H-110	Matti (AA) × Tongat (AA)	2×	AA
H-201	Bareli chinia (ABB) × Pisang lilin (AA) × Robusta (AAA)	2×	AB
H-203	H-59 (AA) × Ambalakadali (AA)	2×	AA
H-204	H-65 (AA) × Pisang lilin (AA)	2×	AA
H-205	H-66 (AAA) × Ambalakadali (AA)	2×	AA
H-208	H-89 (AA) × Anaikomban (AA)	2×	AA
H-209	H-201(AB) × Ambalakadali (AA)	3×	AAB
H-210	H-201 (AB) × Anaikomban (AA)	3×	AAB
H-211	H-201 (AB) × Pisang lilin (AA)	2×	AA
H-02-01	Ambalakadali (AA) × Anaikomban (AA)	2×	AA
H-02-08	H 201 (AB) × Eraichivazhai (AA)	2×	AB
H-02-11	H-201 (AB) × H-110 (AA)	2×	AB
H-02-12	H-201 (AB) × H-110 (AA)	2×	AB

where n: number of leaves in each grade
b: grade
N: number of grades used in the scale
T: total number of leaves scored.

Resistance was evaluated by measuring disease development (in this case the infection index). Total resistance (immunity) was when no disease (infection index=0) was able to develop in plant tissue. Partial resistance was when infection and disease development was limited, compared to susceptible plants.
The index of youngest leaf spotted was calculated as follows:

$$IYLS = T - \frac{YLS - 1}{T} \times 100$$

where YLS: youngest leaf spotted
T: total number of leaves.

The index of non-spotted leaf area was calulated as follows:

$$INSL = \frac{YLS - 1}{NSL} \times 100$$

where NSL: number of standing leaves.

Table 2. Agronomic performance at flowering of banana hybrids and parental clones exposed to *Mycosphaerella fijiensis* (n=5)

	Number of leaves per plant	Youngest leaf spotted	Infection index	Index of youngest leaf spotted	Index of non-spotted	
Hybrids						
H-203	13.2 bc	11.1 cd	3.8 b	23.1 c	76.9 ab	Tolerant
H-204	17.1 ab	16.2 b	2.0 b	11.8 de	88.2 ab	Tolerant
H-205	13.2 bc	12.1 bc	2.6 b	15.4 d	84.6 ab	Tolerant
H-208	17.2 ab	14.2 b	4.9 b	23.5 c	76.5 ab	Tolerant
H-209	19.3 a	19.3 a	0.9 a	5.3 e	94.7 a	Resistant
H-210	15.1 b	15.3 b	1.1 a	6.7 e	93.3 a	Resistant
H-211	18.2 ab	14.4 b	5.6 b	27.8 c	72.2 ab	Tolerant
H-02-01	14.1 bc	6.7 e	23.8 d	64.3 b	35.7 d	Highly susceptible
H-02-08	17.3 ab	16.2 b	2.0 b	11.7 de	88.2 ab	Tolerant
H-02-11	15.4 b	12.1 bc	4.4 b	26.7 c	73.3 ab	Tolerant
H-02-12	11.5 cd	11.2 cd	1.5 b	9.1 de	90.9 a	Tolerant
Parental clones						
Ambalakadali	15.3 b	11.2 cd	8.9 c	33.3 c	66.7 bc	Susceptible
Anaikomban	14.2 bc	11.2 cd	8.3 c	28.6 c	71.4 ab	Susceptible
Eraichivazhai	15.7 b	13.1 bc	4.4 b	20.0 cd	80.0 ab	Tolerant
Pisang lilin	10.2 d	10.3 cd	1.7 b	10.0 de	90.0 a	Tolerant
H-59	13.3 bc	12.0 bc	2.6 b	15.4 d	84.6 ab	Tolerant
H-65	11.3 cd	10.0 cd	3.0 b	18.2 cd	81.8 ab	Tolerant
H-66	13.7 bc	13.2 bc	1.3 a	7.7 e	92.3 a	Resistant
H-89	9.8 d	8.3 d	3.7 b	22.8 c	77.8 ab	Tolerant
H-110	13.5 bc	13.4 bc	1.3 a	7.7 e	92.3 a	Resistant
H-201	13.6 bc	12.5 bc	2.6 b	15.4 d	84.6 ab	Tolerant
Rasthali (control)	12.0 c	3.3 f	74.0 e	80.3 a	19.2 e	Highly susceptible

Means followed by the same letter are not significantly different ($p \leq 0.05$) according to the Tukey HSD test.

The infection index, index of youngest leaf spotted and index of non-spotted leaf area were arcsin-transformed and the data subjected to an analysis of variance. The means were compared using Waller Duncan's K-ratio test at $p<0.05$.

Various biochemical components and enzyme activities were measured in the leaves at flowering using methods described in the literature: chlorophyll content (Yoshida *et al*. 1971), total soluble protein (Lowry *et al*. 1951), praline (Bates *et al*. 1973), total phenol (Spies 1957), OD phenol (Arnow 1937), bound phenol (Chattopadhyay and Samadar, 1980), chlorogenic acid and tannins (Sadasivam and Manickam 1997), lignin (Chesson 1978), epicuticular wax (Ebercon *et al*. 1977), peroxidase activity (Hartec 1955), polyphenol oxidase activity (Mayer *et al.* 1965), phenylalanine ammonia lyase activity (Ross and Sederoff 1992), catalase activity (Luck 1974) and ascorbic acid oxidase activity (Sadasivam and Manickam 1997).

Results and discussion

In bananas, bunch development depends on the photosynthetic potential of the leaves. Banana plants require more than 70% of active foliage and a minimum of 8 functional leaves for the proper development of fruits (Orjeda 1998).

In the present study, no total resistance was observed in the hybrids and parental cultivars tested (Table 2). H-209 and H-210, and the parental clones H-66 and H-110, were found to be resistant to black leaf streak disease as a result of their low infection index and high index of non-spotted leaf area. 'Anaikomban' and 'Ambalakadali' were classified as susceptible because of their high infection index and relatively low value of youngest leaf spotted, while H-02-01 was classified as highly susceptible because of its very high infection index and small proportion of leaf area free of streaks and spots.

The relationship between the infection index and various biochemical substances was studied. The levels of chlorophyll, reducing sugars and total sugars, and the activity of ascorbic acid oxidase were positively correlated with the infection index, whereas the levels of proline and lignin, and the activity of peroxidase were negatively correlated with the infection index (Table 3). The levels of reducing sugars, total sugar and lignin, and the activity of phenylalanine ammonia lyase, ascorbic acid oxidase and

catalase were negatively correlated with the value for youngest leaf spotted. The leaf area without leaf streaks was positively correlated with the concentrations of total sugars, wax, phenols and lignin, as well as with the activity of phenylalanine ammonia lyase, ascorbic acid oxidase, catalase and polyphenol oxidase.

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The authors *work at the Department of Fruit Crops, Horticultural College and Research Institute Tamil Nadu Agricultural University, Coimbatore – 641003. The address of V. Krishnamoorthy is Krishi Vigyan Kendra, Vriddhachalam, Cuddlore, Tamil Nadu, India.*

Table 3. Correlation coefficients of disease parameters with biochemical substance levels and enzyme activity

Parameters	Infection index	Youngest leaf spotted	Index of youngest leaf spotted	index of non-spotted leaf area
Total chlorophyll	0.540**	0.020	-0.068	0.068
Total soluble protein	0.311	-0.012	-0.053	0.052
Reducing sugars	0.494**	-0.442*	-0.481*	0.481*
Total sugars	0.550**	-0.515**	-0.594**	0.593**
Proline	-0.444*	0.480*	0.542**	-0.540**
Wax	0.138	-0.476*	-0.548**	0.548**
Total phenol	0.260	-0.384	-0.439*	0.442*
OD phenol	-0.142	-0.375	-0.384*	0.386*
Bound phenol	0.269	-0.445*	-0.560**	0.562**
Lignin	-0.445*	-0.519**	-0.592**	0.592**
Phenyl alanine ammonia lyase	0.282	-0.524**	-0.562**	0.564**
Ascorbic acid oxidase	0.515**	-0.549**	-0.612**	0.606**
Catalase	0.332	-0.524**	-0.581**	0.582**
Polyphenol oxidase	0.327	-0.362	-0.438*	0.440*
Peroxidase	-0.431*	0.663**	0.746**	-0.748**

*Significant at probability 0.05
**Significant at probability 0.01

Sensory evaluation

Organoleptic qualities of the fruit of hybrids SH-3640 and CRBP-39

S. Coulibaly and C. Djédji

In Côte d'Ivoire, the research programme on fruits and citrus of the *Centre national de recherche agronomique* (CNRA) currently includes a study of the varietal behaviour of SH-3640 (AAAA), a dessert banana hybrid obtained from the breeding programme of the *Fundación Hondureña de Investigación Agrícola* (FHIA) in Honduras, and CRBP-39 (AAAB), a plantain-type hybrid obtained from the breeding programme of the *Centre Africain de Recherches sur Bananiers et Plantains* (CARBAP) in Cameroun. These hybrids have shown partial resistance to black leaf streak disease. As part of this work, the CNRA's *Station de recherche technologique* has carried out a sensory evaluation of these hybrids in order to determine their acceptability to Ivoirian consumers. The sensory evaluation of new hybrids and new cultivars is a decisive step in the process of varietal selection and creation. This step, which falls between the production of bananas within the research station and the distribution of new plant material to peasant farmers, enables us to

comment on the acceptability of new products by future consumers.

Materials and methods

The tests were conducted on the hybrids SH-3640 and CRBP-39 which were made available to us by the CNRA research station for fruit and citrus at Anguédédou, not far from Abidjan. They were harvested 338 days after setting up the experiment, at their maximum stage of maturation, i.e. at the appearance of one yellow finger on the bunch (Mitra 1997). Dessert bananas ('Poyo', AAA) and plantain bananas (of the False horn type, AAB), purchased at the market and at the same ripening stage as the hybrids with which they were compared (IPGRI-INIBAP/CIRAD 1996) were used as reference samples (Watts *et al.* 1991).

To compare the dessert bananas, the bananas were peeled by hand and cut with a stainless steel knife into 1 cm thick slices. The whole evaluation test was completed within 10 minutes of slicing. A preliminary trial made by two researchers at the station had led to a choice of different possible cooking processes: *foutou* or crushed plantain banana, *foufou* – plantain banana purée, *aloco* – fried plantain banana, and chips. These dishes are made as follows:

Foutou

The bananas are washed, peeled and sliced lengthways into two with a stainless steel knife to cut out the black spots (atrophied seeds). The banana slices are then cut into uniform pieces about 3 cm thick and cooked in boiling water for 20 minutes. After cooling, the slices are mashed in a traditional wooden mortar until a soft paste with a sticky texture is obtained, called *foutou* (Mosso *et al.* 1996).

Foufou

The method of preparation is identical to that of *foutou,* except that instead of mashing, the cut slices are crumbled in the mortar and then mixed with palm oil (about 0.25 L for 1 kg of cooked banana). In this way one obtains a purée called *foufou.*

Aloco

After washing and peeling as before, the banana pulp is cut into uniform slices 1 cm thick. These slices are then fried for 5 minutes in vegetable oil at 160-180°C (Tchango Tchango and Ngalani 1998). The slices thus obtained are soft.

Chips

To make chips, proceed as for *aloco*, but with thinner slices (about 0.3 cm thick) and a shorter frying time (only about 2-3 minutes) (Tchango Tchango and Ngalani 1998). The chips made this way are crisp.

Chips made from the hybrid SH-3640 at the "yellow" ripening stage and from the hybrid CRBP-39 at the "light green" ripening stage were compared with those made from plantain bananas of the False horn type at the same ripeness stage, which had been bought in the market. For the other cooking methods, only the culinary qualities of the hybrid CRBP-39 were evaluated.

The tasting panel

For dishes like chips and *aloco*, whose preparation is quite laborious, the tasting panel was made up from a sample of CNRA staff from Abidjan comprising about ten people of both sexes, various social classes and with an age range of 30-50 years. These people responded to a questionnaire which took account of the features of the dishes to be evaluated. Half of these panellists had previously taken part in tasting tests.

For the other everyday dishes (*foutou* and *foufou*) five households were chosen. The choice of household was made according to the following criteria:

1°) they frequently and regularly eat banana plantain,

2°) they have a reasonable living standard and lifestyle for Côte d'Ivoire,

3°) they have a maximum of five people in the family.

The people in the household wrote down their comments, after being told the criteria to take into account, notably elasticity, sticky character, taste and firmness of the paste.

Evaluation tests

The samples, identified by a three-figure code, were presented in random order to the tasters (Watts *et al.* 1991). The tests had six intensity measurement levels, and all the samples were presented simultaneously to the tasters so that they could retest certain ones if necessary.

The characteristics recorded were: taste, colour, consistency, texture, aroma and after-taste. The scores attributed ranged from 1 to 5 and corresponded to the following assessments: 1=poor, 2=mediocre, 3=average, 4=good, 5=very good. The only exception was for the evaluation of after-taste, where a low score indicated little

Table 1. Mean and standard error of scores (from 1 to 5) given by a tasting panel to the banana hybrid SH-3640 and to 'Poyo', a dessert banana bought in the market.

	Taste	Colour	Consistency	Texture	Aroma	After-taste	Total
SH-3640	3.1±0.9	3.2±0.9	3.4±0.7	2.9±1.0	2.6±0.8	3.3±0.9	15.2±5.2
Poyo	3.0±0.8	3.0±0.7	3.1±0.8	2.7±0.7	3.0±0.9	3.1±1.0	14.8±5.9

after-taste. For the other characteristics, the higher the score, the more the banana was liked. An analysis of variance (ANOVA) was made to determine whether there were any significant differences between the banana types tested (Watts *et al.* 1991).

Results and discussion

Comparison of dessert bananas

The mean values of the scores given by the different members of the tasting panel were very similar (Table 1). According to these results, the banana hybrid SH-3640 was preferred to the dessert banana 'Poyo' bought in the market as regards taste, colour, consistency and texture. Apart from aroma, which was judged inferior to that of 'Poyo', SH-3640 was judged as having a more pronounced after-taste. But it is possible that the scoring of after-taste, which came out opposite to that of the other characters, had been misunderstood.

From the analysis of variance (Table 2) of the results of this test, it appears that for taste and consistency the differences in the scores are not significant at P=5% , either for treatments or between tasters. The F values calculated are below the critical values given by Snedecor. For colour, texture and after-taste, no significant differences were found between treatments; on the other hand differences were found between tasters, but they remained negligible because the differences between the calculated F values and those in Snedecor's table are very small. Only aroma, with a difference of 3 points between the F values, shows a slightly significant difference at the 5% threshold for treatments.

Comparison of chips

The taste and aroma of chips made from plantain bananas of the False horn type purchased in the market at the "yellow" stage of ripeness were judged to be superior to those made from the hybrids and were given higher scores (Table 3). The chips made from banana hybrid CRBP-39 (at the green stage) were the least favoured.

The results of the analysis of variance show that the differences in colour, texture and after-taste are not significant at the 5% threshold (Table 4). On the other hand there were significant differences (at P=5%) for taste, consistency and aroma. Also, there were no differences between tasters at the 5% threshold.

The different assessments by the household tasters agree on everything. They may be summarised as follows:

Table 2. Analysis of variance on data from the tasting panel testing dessert bananas

Characteristic	Source of variation	F value Calculated	F value Table*
Taste	Genotype	0.1020	5.1174
	Tasters	1.9184	3.1789
Colour	Genotype	1.0000	5.5914
	Tasters	5.4500	3.7470
Consistency	Genotype	0.2301	5.3177
	Tasters	3.4400	3.4381
Texture	Genotype	0.6286	5.3177
	Tasters	3.6000	3.4381
Aroma	Genotype	8.2051	5.3177
	Tasters	3.6461	3.4381
After-taste	Genotype	0.4739	5.1177
	Tasters	3.4745	3.1789

*Significant at P=0.05

Table 3. Means and standard errors of scores (from 1 to 5) given by a tasting panel to chips made from plantain bananas of the False horn type and plantain banana hybrids SH-3640 and CRBP-39 at different stages of ripening

	Taste	Colour	Consistency	Texture	Aroma	After-taste	Total
Yellow plantain banana chips from the market	4.0±0.7	3.8±0.6	3.3±1.0	3.2±1.0	3.7±0.7	3.8±0.4	18.0±4.4
Green plantain banana chips from the market	2.8±1.0	3.1±1.0	3.3±1.0	3.2±1.0	2.6±1.0	2.9±0.8	15.0±5.8
Yellow SH-3640 hybrid banana chips	3.2±1.3	2.8±0.9	2.2±0.8	2.3±1.1	3.2±0.9	2.9±1.1	13.7±6.1
Green CRBP-39 hybrid banana chips	2.6±1.2	3.1±1.0	3.0±1.0	3.0±1.0	2.7±1.0	2.9±0.8	14.4±6.0

Table 4. Results of the analysis of variance made on data from the chip tasting panel

Characteristic	Source of variation	F value Calculated	F value Table*
Taste	Genotype	3.2343	2.9604
	Tasters	0.5250	2.2501
Colour	Genotype	2.3033	2.9604
	Tasters	1.4075	2.2501
Consistency	Genotype	4.0062	2.9604
	Tasters	1.7076	2.2501
Texture	Genotype	1.7189	3.0088
	Tasters	1.4703	2.3551
Aroma	Genotype	5.2623	3.0725
	Tasters	6.1934	2.4876
After-taste	Genotype	3.3744	3.0088
	Tasters	2.2654	2.3551

* Significant at P=0.05

Evaluation of hybrid CRBP-39 after boiling in water

- Ripening of the fingers on a banana bunch takes place progressively. For example, two neighbouring fingers in the same row of a given hand can be at the "light green" ripening stage for one and at the "yellow" stage for the other. Between these stages there exist a "watery green" and a "green yellow" stage according to the colour chart in "Descriptors for banana" (IPGRI-INIBAP/ CIRAD 1996). A "medium green" stage, preceding the "light green" stage has also been observed..
- Peeling is easy but the fruit do not have much pulp compared with that of other cultivars.
- In the middle are very few or no black spots (atrophied seeds), which is a considerable advantage during peeling, as the removal of this central part is essential for obtaining attractive *foutou* balls.

As regards culinary qualities, the household tasters noted that, after boiling in water for about 20 minutes, and with fingers at different ripening stages in the same saucepan:

- The fingers at the "yellow" ripening stage are easy to mash as they are very soft. Unfortunately the paste sticks to the mortar, making it difficult to form balls;
- Fingers at the "medium green" and "light green" ripening stage are difficult to mash as they are very hard;
- Fingers at the "green yellow" stage are easy to mash and the paste is easily formed in *foutou* balls.

The household tasters attributed a very good taste to the fruit of CRBP-39, whether boiled or as *foutou.*

In conclusion, these two hybrids possess certain organoleptic qualities: SH-3640 as a dessert banana and CRBP-39 as a cooking-type plantain. Hybrid CRBP-39 was not liked in the form of chips, but after boiling in water, it was very suited to the preparation of *foutou*, especially at the "green yellow" stage. This hybrid has the advantage of progressive ripening of the fingers on a given bunch. Thus these bananas can be eaten over a longer period without significant losses. The continuation of this work will enable us to determine their nutritional qualities.

Acknowledgements

The authors offer their sincere thanks to Dr Kobena Kouman, a research scientist at the CNRA Station at Bimbresso, for his important contribution to this study.

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Souleymane Coulibaly *and* ***Catherine Djédji*** *work at the Station de Recherche Technologique (SRT) of the Centre National de Recherche Agronomique (CNRA), 08 BP 881 Abidjan 08 Côte d'Ivoire. *Corresponding author: Coulibaly Souleymane. e-mail: abj.cnra@aviso.ci*

A preliminary analysis of the scientific literature on wild species of *Musa*

Information from a selection of scientific articles dealing with the description of wild bananas and their distribution has been analysed in order to develop a bibliographic database on wild bananas. Various databases (*Musa*Lit, CAB-Abstracts, Current Contents, etc.) were consulted to draw up this list. Experts in banana taxonomy, notably Dr Edmond De Langhe and M. Markkü Häkkinen, provided additional information, which they possessed as a result of various expeditions to Indonesia and Thailand.

The ultimate aim of this exercise was to incorporate this information into the *Musa Germplasm Information System* (MGIS), a database developed and administered by INIBAP. This contains descriptions of more than 5000 accessions stored in genebanks throughout the world (http://mgis.grinfo.net), most of which are locally-grown varieties. Wild species are under-represented in it, hence the creation of this project aimed at analysing scientific documents on wild species reported or observed by botanists during collecting expeditions or surveys made to determine, among other things, their distribution. The geographical information contained in these documents is however often imprecise. Consequently, only about fifteen articles have been incorporated into MGIS. This preliminary study should be followed up in order to enlarge the literature base from which published data are integrated into the database.

Given that the MGIS was conceived to receive scientific data on plant material held in collections, rather than data extracted from the literature, a list of recommendations has been drawn up in order to make the database more suitable for accepting information originating from scientific literature.

The data incorporated into the MGIS (geographical coordinates, information on banana populations etc.) were then transferred into the GIS software package DIVA-GIS. This programme, developed by Robert Hijmans as part of his work at CIP (*Centro Internacional de la Papa*), is available free (http://www.diva-gis.org/) and can be used for mapping, especially of biodiversity. Maps of the distribution and genetic diversity of bananas in various countries in Asia and the Pacific have been made. This work has improved the state of our knowledge, as the last map illustrating the distribution of *Musa*, dating from 1967, was made by Jean Champion (Figure 1). Since then, species belonging to the section Callimusa have been observed in China (Liu *et al.* 2002 and others belonging to the section Australimusa in Borneo (Hotta 1967).

This work has shown that certain countries such as Myanmar (formerly Burma), Cambodia and Laos – although situated in

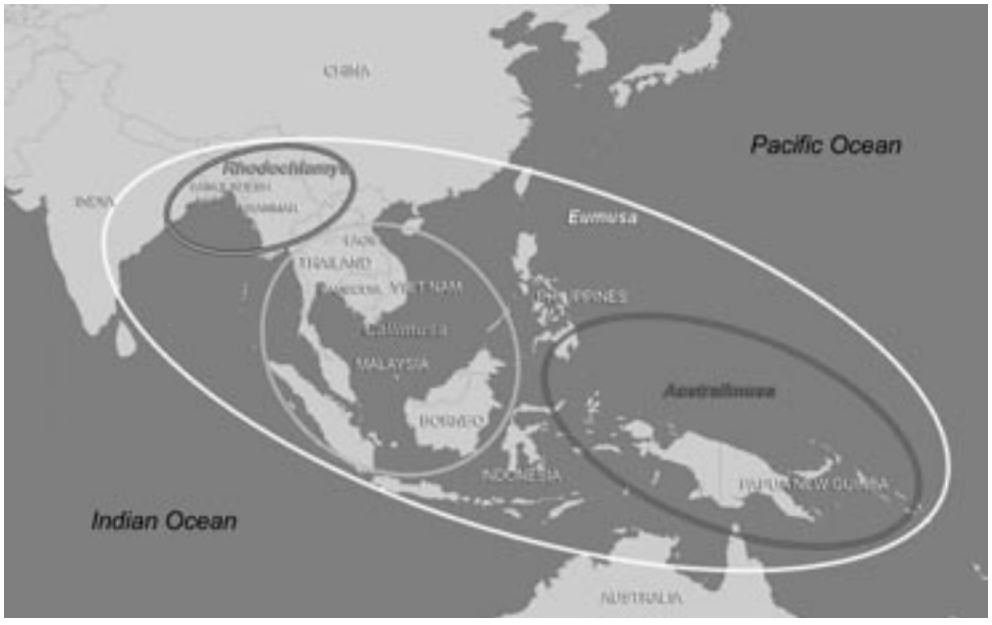

Figure 1 : Distribution of the four sections of Musaceae according to Champion 1967 (adapted by Guinard 2003)

the centre of diversity of the genus *Musa* – possess few data on their indigenous banana species. Furthermore, the habitat of certain species seems to have shrunk over the decades. For example, an expedition led by Argent (1976) in the mid-seventies to Papua New Guinea discovered the presence of *Musa balbisiana* in the Morobe province, but it was not found on a later collecting mission in 1988-9 (Sharrock 1989). During the latter, *Musa balbisiana* was only collected on the island of New Britain, indicating a reduction in its distribution compared with earlier years. *Musa coccinea* is becoming increasingly rare in China due to human activity. This species was widely distributed in the forests of Yunnan province, but during a recent collecting mission, Chinese scientists had difficulty in finding it (Pollefeys *et al.* 2004).

Mapping with the DIVA programme has also enabled us to visualize the distribution of the Australimusa section in Papua New Guinea. For example, we find that *Musa boman* and *Musa lolodensis* are confined to Madang province and the Eastern Highlands, while *Musa peekelii* ssp. *peekelii* seems to be found only on the island of New Ireland (Argent 1976, Sharrock 1989). This kind of information could possibly enable future collecting expeditions to direct their search towards regions where the distribution of *Musa* is less well known, and possibly to develop strategies for conserving them in their natural habitat.

*This work was carried out by **Patrick Pollefeys** as part of a six-month internship at international governmental organizations financed by the Quebec Ministry of International Relations. The work was supervised by **Suzanne Sharrock**, former Germplasm Conservation Scientist at INIBAP and **Elizabeth Arnaud**, Officer in charge of MGIS. The results of this study and the bibliography used are presented in a report "Preliminary analysis of the literature on wild* Musa *species distribution using MGIS and DIVA-GIS" available on the INIBAP website.*

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Focus on organic bananas

Evaluation of the impact of the organic banana project in the Chira Valley, Peru

In 1997, the area cultivated in bananas in the Chira valley, Peru, was at its lowest in 20 years mainly because of low profitability, low market price of 0.23 US dollars per 18 kg box, a monopolistic marketing system, low yields resulting from a lack of technical assistance and credit facilities, losses due to El Niño and a shortage of marketing alternatives.

In 1998, the Peruvian Ministry of Agriculture (MINAG) and INIBAP reached an accord to carry out a farmer participatory organic banana project in the Chira valley, Department of Piura, that would be sustainable and environmentally friendly.

The objective of the project was to improve the income of producers adopting organic cultivation methods, diversify the offer and improve the production and marketing of bananas. The problems of banana production were characterized and various activities implemented, such as technology transfer, access to credit, logistical support, research and organization of banana producers.

The Chira valley is characterized by deep sedimentary soils, gentle slopes and class I clay loam soil suited for banana cultivation. The climate of the region is optimum for the development of organic bananas with mean maximum and minimum temperatures of 32°C and 17°C in summer and winter, respectively, and 7.2 hours of sunlight daily. The relative humidity is less than 65% and the low rainfall (less than 500 mm per year) inhibits the development of black leaf streak disease. The production zone is strategically situated 60 km from the port of embarkation, which is accessible by paved roads. The mean area of production for 98% of producers in the Chira valley is 0.72 hectares.

The objective of the present study was to evaluate the *ex-post* economic impact of the project. The field study was carried out between October 2002 and March 2003 by means of 175 interviews with producers, meetings with focus groups, individual meetings with retailers, field collection of technical, production and marketing data, and compilation of bibliographical and statistical information on banana activity in the region. Sampling was carried out at random with respect to organic and conventional producers.

Achievements

During the project, small-scale producers and local technicians from the public and private sectors received training. Converting to organic banana production reduced usage of synthetic fertilizers by 18 018 MT, which were replaced by nutrients from organic sources such as guano from the islands, cattle manure, worm compost, potassium sulphate and mineralized magnesium, and other sources (Figure 1).

The beneficiaries of the project were 1672 trained small-scale producers representing 38% of all banana producers in the Chira valley. By the end of 1999, the technology had been adopted on 1603 hectares, and certification achieved with the OCIA-USA agency. On the first 210 hectares that complied with the more demanding standards of organic production. In 2000, the production from 115 hectares was exported. By 2002, the technology of organic production had been adopted on about 3100 hectares, of which 1600 were certified by the BSC, Skal and SGS agencies. Of the latter, the production from 823 hectares were exported by the national companies Gronsa, Exbanor and Biorgánika, and by the multinational Dole.

The change in technology resulted in important changes in the income of organic banana producers and conventional producers as well. The latter benefited from the economic activity generated by the project. The real price received for exporting organic bananas in 2002 was 32% higher than the price received in 1999 for selling to the national market (Figure 2).

The production costs per hectare of organic bananas were 92% higher than those of conventional bananas (Figure 3) due to the higher costs of labour and fertilizers.

In 1998, before the start of the organic banana project, the mean net income from the sale of bananas was US$963/ha (Figure 4). In 2002, the mean net income was US$2770. Small-scale producers increased their income by 187% by adopting an organic production technology and diversifying their products for the domestic and export markets.

The real net income per hectare declined by 65% during the transition from conventional to organic production. The effect was due

Figure 1. Certified organic banana plantations in the Chira valley.

Figure 2. Real price paid to producers.

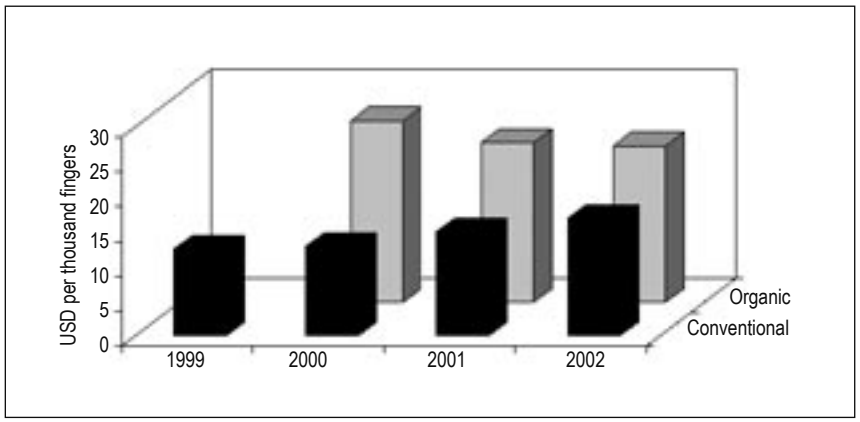
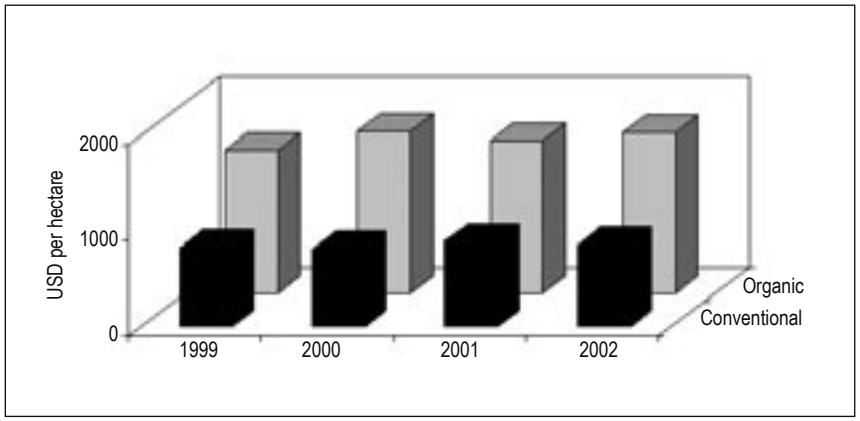


Figure 3. Real production costs.



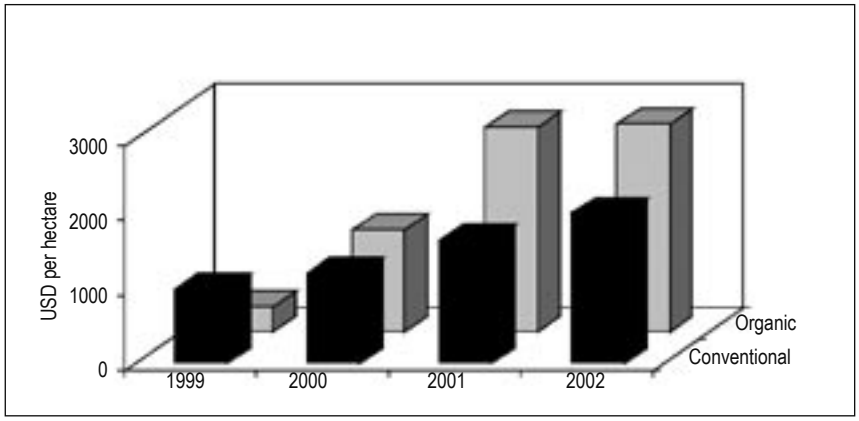


Figure 4. Real net income.

to increased production costs and the fact that organically produced bananas sell for the same price as conventional bananas on the domestic market. The situation started to change in 2000 when the organic bananas were exported at a premium and the price paid on the domestic market for conventional bananas increased. The transition to organic production can take longer and be more detrimental to the producer depending on the initial conditions experienced by the producer involved in the conversion of the production process. The Chira valley producers started to make a profit 15 months after the start of the conversion process, since the producers had already had a period of two years using ecological practices before the start of the three year process required for organic certification and, in some cases, more than three years without using prohibited chemical products.

The reduced supply of bananas on the domestic market caused by the export led to an increase in the prices paid to producers, without necessarily representing an increase in price to the consumer. So conventional producers also benefited from the new dynamics of the banana market and the opening of the export market. In this sense, the 107% increase in real net income of conventional producers in 2002, compared with 1998, was mainly due to the higher price in the domestic market.

In 2002, certified organic producers were unable to export 24% of their organic production because of exporter companies not respecting agreed upon purchase dates. Of the production not exported, 61% fulfilled the minimum requirements for export and was diverted to the domestic market for which the producer received real prices 74% lower than they would have received had these bananas been exported.

Perspectives

The change in the production system and the support for marketing offered by the collaboration between MINAG and INIBAP resulted in the banana going from the 17th most exported fruit in 1999 and to the 3rd in 2002, with an export value of 6.1 million US dollars, followed by mango and mandarin. Banana recorded the highest growth both in value and in volume exported.

The production of organic bananas in the Chira valley will continue to grow as long as the demand for certified organic products abroad continues to grow and that the national and foreign companies improve the system for production and operation with the ultimate aim of guaranteeing a price that is fair to the producer and the integrity of organic production. Similarly, the outlook can improve with participation of the government in strategic sectors, such as field and market research, liberalization of the production and of the guano trade, help to reduce the costs of maritime transport, improve road access and establish clear norms to stimulate investment and the distribution of the generated benefits.

This work was carried out by ***Salomón Soldevilla Canales*** *who works for the Alto Beni Organic Banana Project, Sopocachi, Calle Francisco Bedregal N° 2904 P. B., La Paz, Bolivia.*

In memoriam

A tribute to Georges F. Wilson

Dr Georges F. Wilson, a pioneer of modern research on plantains in Africa, passed away on March 7th in Kingston, Jamaica, after a long illness. He played an important role in the creation of the IITA banana/plantain programme and INIBAP.

He launched the first trials on plantain in Nigeria in the early 70s, when he was Senior Officer of IITA's Farming Systems Research Programme. He perceived the vital importance of the crop in Africa long before it was recognized as such by IITA and worked relentlessly to get African scientists to pull together their research efforts.

He was behind the First International Conference on Banana and Plantain, held

in 1976 at IITA headquarters with support from the Belgian Agency for Development Cooperation. More than 50 African researchers and specialists from all over the world participated. An International Association for Research on Plantain and other Cooking Bananas (IARPCB) was established, with the late Jean Champion as first President, the late Harry Stover as Vice President and George as the secretary.

Thanks to Georges, the concept of a banana research network became a reality. The West African Research Corporation for Plantains (WARCORP) was created with support from IFAD and encompassed scientists from Congo to Guinea. IITA's Onne High Rainfall Substation played an essential role in this network. Only a few people know that Georges can be considered as one of the founding fathers of that station. During a 2nd IARPCB conference held in Abidjan, Côte d'Ivoire, the arrival of black leaf streak disease in Africa generated a lot of discussions, which led to the idea of creating a global network to cope with this new and most serious threat. The idea was supported by the International Development Research Center and Barry Nestel as its principal consultant, and led to the creation of INIBAP.

Georges was a unique personality, a quiet force who achieved goals with great wisdom and modesty. His office was always open to everyone at any time of the day. He generously shared his vast knowledge in agriculture with the younger generations. In collaboration with his friend Edmond De Langhe, he continued to develop African research on *Musa*. He posted Rony Swennen as the first plantain scientist at the Onne station and requested him to collect plantains and bananas from everywhere. This activity led to the creation of the INIBAP Transit Centre. With the recruitment of the late Dirk Vuylsteke, he brought in the first banana biotechnologist at IITA. Dirk and Georges created the first *in vitro* plantain multiplication centres at IITA, with assistance from the World Bank. Georges helped these young scientists become plantain and banana experts who shared his love of Africa. He taught them that there are no problems, only solutions. Most admirably, he remained an optimist and never grew jaded. He also fully enjoyed life with his wife Peju and his son Suen.

We will remember him above all as The Jamaican with the Clark Gable moustache, as the Washington Post described him when highlighting his achievements in plantain research in 1984.

Edmond De Langhe and
Rony Swennen

Thesis

Genetic and cytogenetic mapping in bananas: characterization of translocations

Alberto Vilarinhos

PhD thesis submitted to the *Ecole Nationale Supérieure Agronomique de Montpellier*, Montpellier, France, March 2004

Meiosis irregularities are frequently observed in bananas. In *Musa acuminata*, the main species at the origin of banana cultivars, seven translocation groups have been identified (Standard, North Malaysia, Malaysia Mountains, North A, North B, Indonesia, and East Africa). Inside each group the accessions have the same chromosome structure. In general, translocations create a problem for genetic mapping, the genetic study of the agronomical characters and banana breeding. The objective of this thesis was to establish a tool based on fluorescent *in situ* hybridization of BAC clones (BAC-FISH) to characterize banana translocations and to use this tool characterize translocations in 'Calcutta 4' (2n=2x=22, North A translocation group) and 'Madang' (2n=2x=22, Standard translocation group). To achieve this objective, a banana BAC library was developed, the BAC *in situ* hybridization methodology was adapted to be used with banana chromosomes and a cytogenetic map of banana was started.

The BAC library has 55 152 clones, with an average insert size of 100 Kb. About

1.5% of these clones have chloroplast and mitochondrial inserts. This library covers 9 to 10 times the banana genome. A genetic map of the cross 'Calcutta 4' x 'Madang' was built using 120 makers (20 RFLPs, 81 AFLPs and 19 SSR markers) distributed over 14 linkage groups. The linkage group II was chosen to search for translocations break points. Some characteristics of this group (such as the high number of distorted markers, the group size and a comparison with other banana maps) suggest the presence of translocations. Four BAC clones distributed over the LG II and selected from three RFLPs and one SSR loci were localized on 'Calcutta 4' and 'Madang' chromosomes, using BAC-FISH. The results suggest that the markers of LG II are localized in three homologous chromosome pairs, which differ by the presence of the two linked translocations in 'Calcutta 4'. According to our hypothesis, the markers mMaCIR161-rMaCIR 560, rMaCIR 1125 and rMaCIR 36 are localized on three chromosomes (chromosomes A, B and C) in 'Madang'. In 'Calcutta 4' these markers are localized on only two chromosomes (chromosomes A and B). The marker rMaCIR 1125 localized on the C chromosome in 'Madang', is localized in the proximal position of the B chromosome in 'Calcutta 4'.

In parallel, a global cytogenetic map of the accession 'Calcutta 4' has been started. This cytogenetic map is partial and includes only 16 loci (14 BAC clones selected by RFLP and SSR markers and the ribosome probes 45S and 5S). Six of the 14 linkage groups of the 'Calcutta 4' genetic map have been anchored.

Thesis

Tissue culture of *Musa acuminata* Colla

R. Vidhya

PhD Thesis submitted in 2002 to the University of Kerala, Thiruvananathapuram, Kerala, India

To meet the burgeoning demand for bananas, productivity must be increased. Modem technologies like the use of *in vitro* plants has resulted in synchronous, early and improved productivity. Sword suckers of 'Red banana' were collected from well-maintained fields in Vellayani and Kaliyilkkavila in the Thiruvananthapuram District. Shoot tip explants were double sterilized and inoculated on MS basal medium with 0.2% activated charcoal. After 4 weeks, the sterile cultures were selected, leaf sheaths and shoot tips were isolated and inoculated on MS and MT medium in various concentrations and combinations of auxins and cytokinins.

Pale red friable calli were initiated from shoot tip explants on MT medium with 0.5 mg/L TDZ and red compact calli were obtained on MT medium with 1 mg/L NAA, 2 mg/L BA and 1 mg/L TDZ. Shoot tip explants on MS medium with 2 mg/L 2,4-D produced white friable calli. Leaf sheath explants on MT medium with 1 mg/L NAA and 2 mg/1 BA and 1 mg/L TDZ produced red friable calli. MS medium with 1mg/L NAA and 2 mg/L BA produced pale green, less compact calli.

Rhizogenesis was observed in calli initiated from shoot tip explants on MT medium with 1 mg/L NAA and 2 mg/L BA. Calli initiated from leaf sheath explants on MT medium with 1 mg/L NAA and 1 mg/L BA or 0.1 mg/L TDZ also showed rhizogenesis. Leaf sheath explants on MT medium with 2 mg/L each 2,4-D and BA produced black calli with somatic embryos at different stages of development such as globular, torpedo and bipolar embryos. In suspension culture, MT liquid medium with 1 mg/L 2,4-D and 2 mg/L BA produced the highest number of somatic embryos after 45 days. The somatic embryos were transferred to MT basal medium for further growth.

The terminal male floral buds were collected for anther culture from plants with a bunch. White spongy calli were initiated from anthers after 60 days on MT medium with 2 mg/L each 2,4-D and BA, pale yellow spongy calli were initiated from 2 mg/L 2,4-D and 1 mg/L TDZ and black calli with root initials were produced in 2 mg/L NAA and 1 mg/L BA.

Shoot tip explants were inoculated on MS medium for direct regeneration and multiplication. The primary shoot emerged from the explants within one week, irrespective of the hormone concentration.

Multiple shoots were produced 60 days after inoculation, and 78 and 72 shoot initials, with an average length of 6.95 cm and 6.13 cm, were respectively obtained in MS medium supplemented with either 8mg/L BA alone or 0.1 mg/NAA and 8 mg/L BA. The *in vitro* plantlets from culture flasks were hardened and transferred from the culture room to room temperature. The regenerated plants showed 100% survival. All the plantlets were green during the initial hardening phase. But after 10 days, most of the pseudostems turned red, except for 36 plantlets from 8 mg/L BA alone or with 0.1 mg/L NAA, which remained green.

Morphological characters such as plant height, plant girth, leaf number, leaf length and leaf breadth were recorded at the beginning and after 30, 90, 180 and 270 days. The red plants produced an average of 80 to 90 fruits and the green plants produced similar sized fruits and turned yellow on ripening. Fruit length, fruit girth, fruit weight, bunch weight, number of hands, number of fingers per hand and total number of fruits of the regenerated plants obtained from different hormone concentrations, and established in four ecotypes under 15 treatments, were recorded and a statistical analysis was carried out.

Leaf samples from the plants obtained from MS medium supplemented with 8 mg/L BA or Kin and established in the field and the red and green variants obtained from the *in vitro* plants were used for SDS-PAGE to separate proteins. Isozymes such as esterase, acid phosphatase and peroxidase, and the isozyme patterns in the regenerated plants were analysed. The electrophorogram of esterase and peroxidase were different for the leaf samples of BA and Kin derived plants. The electrophorogram of peroxidase showed 5 major bands for Kin leaf samples but only 3 bands obtained for BA derived plants. All the proteins of the gel experiment showed variability in the banding pattern of total protein.

Banana, an important tropical fruit, provides a good source of carbohydrates, vitamins and minerals. It has long been regarded as an ideal baby food. The carbohydrates content was lower in the red and the green variants (22.98 and 23.12 mg/g) than in the local cultivars 'Robusta', 'Nendran' and 'Rasthali'. The vitamin C content was slightly higher in the red variant. The lowest levels of reducing sugar were obtained from the red variants. There was no difference in the nutritional content of the fruits from the red and the green variants and in the fiber content in the pseudostem of BA or Kin derived samples. The red and green variants were rich in NDF, ADF, hemicelluloses and lignin content.

RAPD analysis was done with 20 random primers from Operon Technologies. Of these, 10 primers gave amplification products. A total of 96 bands were scored, of which 79 bands were polymorphic (83%). After three weeks in vermiculite, the red and green variants showed marked polymorphism at major bands. OPB-13 can be used as a marker to identify red and green variants obtained during the *in vitro* culture of *Musa acuminata*. OPAB-13 can be used for distinguishing the green and red variants. OPB-3 showed monomorphic banding pattern for all the red and the green samples. According to the UPGMA dendrogram, the green and red variants were grouped in separate clusters.

Biotech inputs for improving the yield of banana

Niteen V. Phirke

PhD thesis submitted to North Maharashtra University, India, February 2002

The main objective of this work was to develop a low-cost regime for the qualitative and quantitative improvement of a banana production system that would not compromise soil fertility, the interests of farmers and banana consumers and the health of the ecosystem.

A randomized block design was set up at North Maharashtra University and Bajirao Agro-Tech farm trial sites to evaluate the effect of various biotech inputs, such as the application of a soil conditioner derived

from pseudostem, plant growth regulators, biofertilizers, fly ash, drip irrigation and less chemical fertilizers on the growth and yield of 'Shrimanti' (AAA).

The major outcomes of five years of laboratory and field experiments were:

1. Approximately 4 million MT of pseudostem and leaf biomass per year were used to produce a soil conditioner, using solid-state fermentation for organic carbon and nutrient recycling.
2. Amino acids-based plant growth regulators, produced by hydrolyzing locally available protein-rich by-product, increased the survival rate of transplanted plants and banana productivity.
3. Efficient microbes were isolated from the rhizosphere of elite banana plants and preserved for commercial exploitation in a consortium of biofertilizers.
4. Fly ash has shown potential as a partial substitute for phosphatic and potassic fertilizers and imported micronutrients, in conjunction with phosphate solubilizing fungi and mycorrhizae.
5. Drip irrigation has reduced the quantity of water used, electricity consumption and, as a result, soil salinization.
6. Using these biotech inputs, chemical fertilizers were reduced by 50%, which made possible the conversion of heavily eroded, barren and unused land into cultivable agricultural land.
7. Trials in two geo-climatic conditions at North Maharashtra University and Bajirao Agro-Tech have shown broadly the same trend in observations and productivity, indicating the reliability of integrated plant nutrition management technology.

*Musa*news

Cigar-end rot in Cuba

The disease known as cigar-end rot is characterized by the appearance of dark necrotic tissues on the perianth that spread downwards and become corrugated and covered in conidiophores and conidia. The pathogen takes its name from the ash-like aspect of the disease. In Cuba, the disease is common in the cooking plantains, the clones 'Macho ¾' and 'CEMSA ¾' being most affected.

In the region of the *Instituto de Investigaciones en Viandas Tropicales*, Villa Clara province, Santo Domingo, cigar-end occurs on the fruits of FHIA-01 (AAAB) as blackish spots and sunken lesions with sinuate irregular borders, sunken in the centre, and watery in appearance and consistency (Figure 1). Coalescence of lesions gives rise to continuous areas, which spread to affect two thirds of the finger. Lesions are restricted by the cortex and the underlying flesh remains unaffected.

Figure 1. Lesions produced by Verticillium (Stachylidium) theobromae *(Turc.)*

Symptoms start as a dull reddish discolouration of the peduncle of the fingers, which can extend to the point of insertion with the main stem. The fingers do not rot or deteriorate, remaining firm until maturity, which is delayed. The concave part of the finger is always more affected than the convex, presumably because of the spread of the fungal propagules by dew or rain.

Sections of tissue were transferred to humid chambers at 28°C to favour production of fungal structures. After four days of incubation, a sparse dullish or hyaline mycelium was seen on the lesions and, under the compound microscope, was identified as *Verticillium (Stachylidium) theobromae* (Turc.)

The fungus is characterized by the production of single upright conidiophores 100–400 nm x 4–6 nm, septate, cylindrical, bright yellow with verticillate branches terminating in masses of conidia embedded in a mucilage, and the conidia are hyaline, cylindrical and 4-6 nm x 2 nm.

Source: Lilián Morales Romero Instituto de Investigaciones en Viandas Tropicales *(INIVIT) and Lidcay Herrera Isla,* Facultad de Ciencias Agropecuarias*, UCLV, Cuba.*

Propping up toppled plantain plants

Damaged and uprooted plantain plants were propped up at a homestead in Ipaja Lagos, Nigeria. Y-shaped supports were used at various points along the pseudostem.

In 1997, a plant propped up 90 cm above the ground at 45°, produced offshoots but the roots were eaten up by termites after a drought and it fell under its weight. Another propped up plant slipped from its support after eight weeks to come to rest on a fence at an angle of 65°. The pseudostem withered at week 12 and produced 10 fingers at week 18.

In 1998, a plantain plant was supported almost vertically, at 80°. It started to grow 18 months later. The length of the pseudostem increased from 165 cm to 180 cm and almost one month later the plant produced three fingers. The pseudostem girth remained unchanged at 37.5 cm.

In 2001, two plants came resting on a fence at 40° and 60°. The plant propped up at 60° produced a sucker while the other withered, like all the toppled plants that had not been propped up.

Source: Godwin Norense Osarumwense Asemota, Windhoek, Namibia
asemotagno@hotmail.com

A toppled plantain plant propped by a fence (Goodwin Asemota)

Jean Champion and the creation of INIBAP

Dr Jean Champion, whose death was reported in the December 2003 issue of INFO*MUSA*, played a little known but significant role in the creation of INIBAP. He was part of a small group without whose expertise and enthusiasm the network might never have come into existence.

In the early 1980s, members of the Consultative Group for International Agricultural Research (CGIAR) were involved in discussions regarding the creation of several new International Agricultural Research Centres (IARCs). A number of banana and plantain producing countries suggested that *Musa* was the most important food crop that was not receiving attention from the CGIAR. At that time, most donor countries thought that bananas were mainly an export commodity marketed by multinational companies and the importance of bananas and plantains as a food crop in developing countries was not fully recognized. This situation started to change when black leaf streak disease, which had a devastating impact on small-scale producers, spread rapidly around the world.

At the end of 1982, a group of major donors meeting in Washington asked the Canadian International Development Research Centre (IDRC) to carry out a study on the rationale and feasibility of developing some form of research support for bananas and plantains under the umbrella of the CGIAR. IDRC recruited a consultant to discuss possible options with producing countries and potential donors and his report was presented by IDRC to a meeting attended by 16 donors in Washington in November 1983. The meeting arrived at a consensus that some form of international initiative to support banana/plantain improvement would be appropriate and that this should be implemented through a networking approach rather than by creating a large multidisciplinary institute in any one location. IDRC was asked to consult further with national banana research programmes, banana specialists and donor agencies and to present a formal proposal to the CGIAR at its next meeting in May 1984.

A major element in this consultation process was a meeting that took place at Gatwick Airport in December 1983 when a group of four global experts on *Musa* met with the IDRC consultant to offer their views on some key questions that had arisen in the country and regional consultation process. The issued highlighted covered identifying the most important gaps in technical knowledge regarding food banana production, suggesting global and regional priorities for research, developing an international strategy for breeding, and

discussing the information technology needs of the new institute, training needs and the optimal structure of an international network. Dr Champion played a key role in this consultation whose findings set the framework for both the approval for creating INIBAP by the CGIAR in May 1984 and for defining the policies and programmes approved by the initial Board of Trustees of INIBAP.

Before INIBAP could be formally created, it was necessary to identify a host country for its headquarters. This was a difficult decision because *Musa* production was divided fairly equally between Africa, Asia and the Latin America/Caribbean regions but none of the regions had a very strong *Musa* programme, apart from a Central American group belonging to a multinational corporation. The strongest national centre of excellence was CIRAD (*Centre de coopération internationale en recherche agronomique pour le développement*), with staff in Montpellier and overseas locations. Some donors were concerned about locating the lead institute for a tropical crop in Europe and were had doubts about the proposed networking model.

This situation led to more dialogue and consultation. With CIRAD, where Jean Champion was one of the most senior and best respected scientists, and a number of producing countries supporting the candidature of Montpellier, the French Government offered it as the location for INIBAP headquarters. The rest, as they say, is history.

Barry Nestel, Consultant

Yes, there were bananas in Cameroon more than 2000 years ago

The arrival of the first cultivated bananas in Africa has been a matter of speculation for over a century. While it is commonly accepted that they originated from "somewhere in the East", the timing of their introduction and the responsible human agents have never been determined with certainty.

Three theories have been competing to explain the introduction of bananas to Africa. Bananas were introduced by the Portuguese at the end of the 16th century, by Arab or Persian traders around the 8th century or earlier, or by the Austronesian-speaking people who settled in Madagascar early in the first millennium, making possible a subsequent introduction to the continent. The third theory, advanced by the late Norman Simmonds, an authority on bananas, has steadily been gaining ground. Common to all theories, is the belief that bananas did not reach the African continent before the Christian Era, 2000 years ago.

Recently, we recovered phytoliths from refuse pits excavated in central Cameroon and identified them as coming from a cultivated banana after a comparative study of the genus *Musa* and *Ensete* (Mbida *et al*. 2001). They were dated to ca. 2500 Before Present (BP). If confirmed, such finding would shed a different light on the early evolution of agriculture in humid tropical Africa. For example, agriculture in the rainforest would not have relied on yam, which is generally not very productive in the absence of a dry season, but could have developed around plantains, which prefer such environment.

The timing of the first banana cultivation in Africa is highly relevant to the genetics of the edible banana. The AAB plantains and the East African AAA cooking bananas comprise narrowly defined groups of cultivars, morphologically classified as being on the same level as the AAA Gros Michel, the AAB Silk and the ABB Pisang awak, for example. Yet they, like the AAB Maia maoli group of the Pacific, display a diversity exceeding that of any comparable group of triploids, with more than 50 East African AAA and over 100 plantain cultivars. Was such diversity generated through somatic mutations over long periods of time or are these triploids more susceptible to the type of stresses that generate these mutations? The fact that mutation rates in the laboratory are much higher than those in the field (Vuylsteke *et al*. 1991), points to a long presence and cultivation of plantains in Africa.

It is inevitable that the data supporting the revolutionary idea of an ancient cultivation of bananas in Africa will be critically examined. In a note published in the 2004 issue of Azania, the journal of the British Institute in Eastern Africa, Jan Vansina, a well-known authority on African history, expresses serious reservations about this finding (Vansina 2004). He writes that "one can only accept that the earliest evidence in Africa for the cultivation of edible seedless bananas in Africa dates from the later sixth century CE and perhaps even as late as the ninth century CE."

Vansina argues that bananas could not have been cultivated in West Africa 2500 BP, based on the hypothesis that AAB plantains originated on the Indian subcontinent. However, chemo-taxonomic research and cytoplasmic DNA-analysis demonstrate that the AAB plantains (as well as the East African AAA cooking bananas) originated in New Guinea and the surrounding islands (Horry 1989, Lebot *et al*. 1993, Carreel 1994, Carreel *et al*. 2002). Moreover, the presence in Asia of only a few plantain varieties and the absence of East African AAA cooking bananas, makes clear that the India subcontinent cannot be at the origin of the unique diversity found in humid tropical Africa.

Vansina does not seem to be aware of another introduction pathway (De Langhe and de Maret 1999), which places the most likely area for the introduction of bananas to Africa in the equatorial zone, such as present-day Tanzania. From there the bananas would have diffused across the continent from East to West, eventually reaching present-day Cameroon. Speculations about early banana cultivation in more northern parts of the continent would therefore become irrelevant.

Vansina believes that the phytoliths found in Cameroon belong to the genus *Ensete* - the so-called African false banana – rather than *Musa.* In his article, he states that "no direct laboratory comparison at all was made with phytoliths used in earlier studies especially in Southeast Asia" (Vansina 2004). When we submitted our paper (Mbida *et al.* 2001), we were aware of only two studies of general relevance to *Musaceae* (Tomlinson 1959, Tomlinson 1969) and one specific study about New Guinea (Wilson 1985). We referred to these papers, as well as to reference collections published for the American (Piperno 1988), Asian (Kealhoffer and Piperno 1998) and African continents (Runge 1996, Runge 1997).

The Wilson paper does not support Vansina's statement that "it is practically impossible to distinguish between phytoliths of *Musa* (bananas) and other Musaceae (in this case *Musa ingens*)" (Vansina 2004). Even if Wilson found it difficult to discriminate between *M. ingens* and other *Musa* sections, he apparently did not introduce the genus *Ensete* in the study[1]. Yet, the differentiation of *Ensete* phytoliths from those of any *Musa* phytolith was the very point of our study (Mbida *et al.* 2001). Incidentally, Wilson's indications on early banana cultivation have recently been confirmed by Denham *et al.* (2003), and banana domestication may have started at Kuk (Papua New Guinea) as early as 10 000 BP.

Vansina's critique that "the comparative material used is too limited", seems to reflect a misunderstanding of the methodological requirements for this type of specific study. Since the phytoliths found at Nkang could have belonged to native African *Ensete* species, an extensive comparative study was undertaken to investigate whether the morphology of *Ensete* phytoliths could be distinguished from the one of the genus *Musa*. Several samples of *Ensete gilletii* and *Ensete ventricosum,* the only African species[2], were examined. Since *E. gilletii* is typical of the Cameroon landscape, a specimen from a plant growing there was introduced in the reference collection, in addition to the specimen from the International *Musa* Germplasm collection. No striking variation in phytolith form was noticed among the examined *Ensete* samples.

On the other hand, *Musa* phytoliths, if present in Africa in ancient times, would necessarily point to an introduction of banana plants from outside the continent. Introduced cultivars could have belonged to any of the banana cultivar genome, i.e. AA, AAA, AAB and ABB. Representative cultivars of these genome groups were examined for their phytoliths. We reject the contention that the reference material was limited.

Careful examination of phytolith morphology led us to conclude (1) that variation in phytolith form is hardly noticeable *within* each genus and (2) that the form widely differs *between* the two genera (Mbida *et al.* 2001). All but one of the observed characteristics were mutually exclusive. Consequently, the two phytolith populations for *Ensete* and *Musa,* respectively, are so widely distinct that statistical analysis is not even needed.

Moreover, the applied phytolith observation methodology has never been criticised by specialists or in archaeobotany in general, even though the topic has been presented at numerous conferences and meetings since the publication of our article (Vrydaghs *et al.* 2003).

[1] *Ensete glaucum* apparently does not grow at the altitude of Kuk and the surrounding highlands.

[2] The distribution area of a third species, *Ensete homblei*, is confined to a restricted region in Katanga, Congo DR and Zambia (Simmonds 1960).

In conclusion, we stand by our previous conclusion that the phytoliths of the Nkang site, dating from ca 2500 BP, belong to the genus *Musa* and point to banana cultivation in that part of Africa. However, we accept that the Nkang phytolith finding needs to be substantiated by more specimens, preferably from other sites. Hence we hope that our debate encourages more archaeologists to look for banana phytoliths in humid tropical Africa.

C.M. Mbida, H. Doutrelepont, L. Vrydaghs and H. Beeckman work at the Royal Museum of Central Africa in Tervuren, Belgium, R.L. Swennen, R.J. Swennen and E. De Langhe at the Katholieke Universiteit Leuven *in Leuven, Belgium, and P. de Maret at the University of Brussels in Brussels, Belgium. (Author for correspondence: rony.swennen @kuleuven.ac.be)*

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Table 1. Classification of a new species, *Musella splendida*

	Musella lasiocarpa	***Musella splendida***
Origin	Yunnan province, southern China	Ha Giang province, northern Vietnam
Plant size	Small, less than 60 cm tall	Medium, 1.0 to 1.2 m high
Rhizome	Rhizomatous	Not rhizomatous
Leaf length-width ratio	< 3	> 3
Inflorescence	Conical, deltoid	Ovate
Male bud	Markedly imbricated, bracts tightly attached to bud	Apex of bud open, individual bracts spread apart precociously
Bract color	Yellow, yellow-orange	Bright yellow
Flower arrangement	Biseriate	Uniseriate
Basal flowers	Female	Hermaphrodite
Fruit shape	Ovoid	Ovate
Dissemination	Seeds, suckers	Suckers
Reference	Wu, D.L. and W.J. Kress. 2000. Musaceae. In C.Y. Wu and P.H. Raven (eds), Fl. China 24:314-318	R. Valmayor and L.D. Danh. 2002. Classification and Characterization of *Musella splendida* sp. nov. Phillip. Agri. Scientist 85(2):204-209

Taxonomical debate

In our December 2002 issue, we reprinted an article from "The Philippine Agricultural Scientist", in which Ramon Valmayor and Le Dinh Danh announced the classification of a new species, *Musella splendida* R. Valmayor & L.D. Danh sp. nov. Before publishing the letter from a reader disputing the classification, we present a summary of the characteristics the authors used to differentiate their new species from *Musella lasiocarpa* (Franchet) (Table 1).

Musella splendida – a response to Valmayor and Danh

The prospect of a new *Musella* (Valmayor and Danh 2002) is exciting to Musaceae enthusiasts worldwide, but the authors do not present a convincing case. My concern centres on the fact that the authors base their separation of *Musella splendida* on a description of *Musella lasiocarpa* that they assume covers the entire species in all situations. They refer to no living or herbarium specimens of *M. lasiocarpa* and ignore the possible influence of edaphic, climatic and biotic factors on the growth of *M. lasiocarpa*. They also ignore the possibility of intraspecific variation in *M. lasiocarpa* and that their material might fall within this range.

Although the authors rely heavily on plant height to differentiate their new species, they do not give the basis for their measurements and none of their photographs contain a scale. The INIBAP banana descriptors specify that height should be measured from the base of the pseudostem to the emerging point of the peduncle. Precision in the matter of stature is especially important with *Musella,* in which the leaves are rather upright and thus contribute significantly to the overall height of the plant. In the vegetative phase, only about 30% of the height is pseudostem, the rest is leaf.

In dealing with such a plastic character as plant stature, the influence of growing conditions is crucial. Valmayor and Danh's knowledge of *M. lasiocarpa* seems to derive exclusively from C. Y. Wu who describes a plant "less than 60 cm tall". Valmayor and Danh mention but do not refer specifically to Franchet's (1889) type description of *M. lasiocarpa*, which also states that *M. lasiocarpa* rarely exceeds 60 cm. Franchet's paper includes an illustration of *M. lasiocarpa* that may possibly be a faithful reproduction of the plant found by the Abbé Delavay in 1885. However, Franchet's drawing lacks a scale and looks like none of the *M. lasiocarpa* plants that I have seen. According to Franchet's drawing, it seems that the height of the plant, almost completely lacking a pseudostem, is 60 cm from ground to leaf tip. Baker (1893) agreed with this and if Wu's height measurement is, as I suspect, derived from Franchet, then the literature does indeed indicate that *M. lasiocarpa* is a very small banana. But is this generally true of the plant *in vivo*? A plant of *M. lasiocarpa* growing "sur les rochers de Loko-chan" at 1200 m (Franchet 1889) will look different from a plant in "fertile forest soil with abundant moisture" at 118 m in northern Vietnam.

At the time of writing this, the height from the base of the pseudostem to the emerging point of the peduncle of a male-phase *M. lasiocarpa* in my greenhouse (in south-west UK) was 45 cm and the inflorescence was 25 cm on top (Figure 1). In full leaf, just before flowering, my plant was about 1.3 m overall, i.e. from the base of the pseudostem to the tip of the tallest leaf held at its natural angle. *M. lasiocarpa* can be bigger than this. I supplied two plants of *M. lasiocarpa* to Mr Wim Kea of Amstelveen, Holland. They grew to 2.5 m or more. I submit that *M. lasiocarpa* is a much larger plant than Valmayor and Danh suppose.

In the female phase, the pointed tips of individual bracts of *M. lasiocarpa* can indeed be "spread apart precociously,

Figure 1. Plant of Musella lasiocarpa *in the author's garden in south-west UK. The scale is 1 m long.*

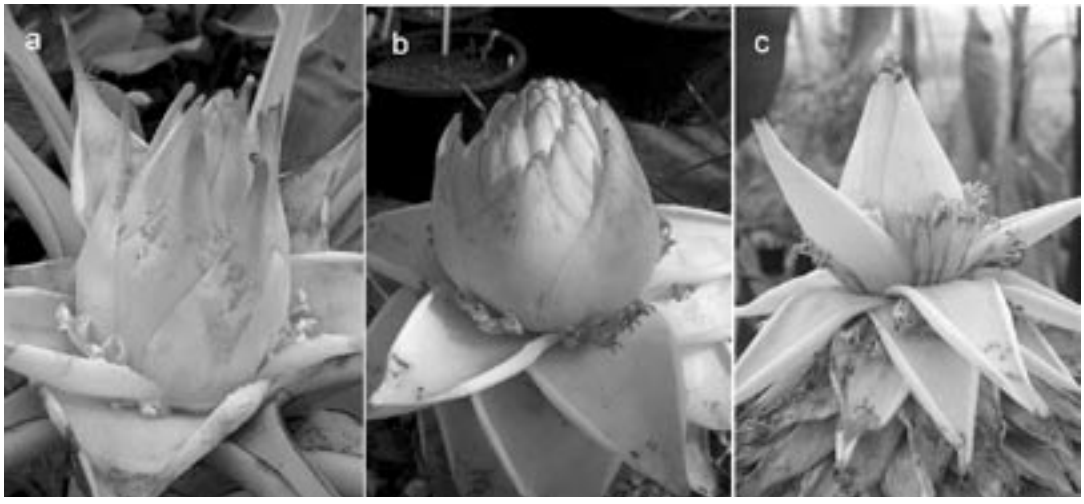

Figure 2. a) Female-phase inflorescence of M. lasiocarpa in the author's greenhouse in June 2002. b) Male phase of the same inflorescence in April 2003. c) Late male phase of the same inflorescence in July 2003

prior to folding down at the base" (Figure 2a), a character by which Valmayor and Danh (2002) differentiate *M. splendida*. But the bract character changes as the inflorescence matures, a process that in *M. lasiocarpa* takes months. In the male phase (Figure 2b), the bracts of *M. lasiocarpa* are much smaller, thinner and "markedly imbricated". The character of the inflorescence changes again in the late male phase (Figure 2c). This change in bract character can be seen in Valmayor and Danh's own photographs (*cf.* Figures 2, 3, 5 and 6 in Valmayor and Danh 2002). I think that the female phase bract character in *M. lasiocarpa* may be variable and depend upon whether the plant is in full leaf or leafless at the onset of flowering.

Valmayor and Danh's "interesting *Musella* specimens" (*cf.* Figure 9 in Valmayor and Danh 2002) are, I submit, random photographs of *M. lasiocarpa*. It is premature to suggest that Figure 9 is evidence of possible further species of *Musella*. One can quickly find many more photographs of *M. lasiocarpa* on the Internet showing yet more variation between plants of the species. This variation is either environmental or related to the age of the inflorescence when photographed.

I am also not sure that the fruit shown in Figure 8 (Valmayor and Danh 2002) can be described as parthenocarpic. The large air spaces visible in the cross section seem to indicate that the fruit is undeveloped. I have seen *M. lasiocarpa* produce the same type of fruit when it had not been pollinated. Moreover, if *M. splendida* is parthenocarpic, by what mechanism is this "species" disseminated in the "vast forests" of northern Vietnam?

Valmayor and Danh (2002) state that *M. splendida* has hermaphrodite basal flowers and contrast this with *M. lasiocarpa* which is said to have female basal flowers. Valmayor and Danh do not properly describe the hermaphrodite flowers of *M. splendida,* nor does Wu properly describe the female flowers of *M. lasiocarpa*. "Female flowers are borne at the base of the inflorescence" writes Wu cited by Valmayor and Danh (2002). That is hardly diagnostic. Indeed, the paucity of Wu's publication on *M. lasiocarpa* is one reason why the Royal Horticultural Society (2003) persists in referring to the plant as *Musa lasiocarpa*, following Simmonds (1960). Incidentally, Simmonds, who obviously did not know the plant at all well, based his inclusion of the plant in *Musa* on perianth characters, not on its being rhizomatic and polycarpic. On my *M. lasiocarpa* the female flowers have rudimentary filaments and the male flowers rudimentary styles. It is necessary to describe the hermaphrodite flowers of *M. splendida* since Musaceae flowers can be structurally hermaphrodite but functionally hermaphrodite, female, male or even sterile. One might argue that the term should be restricted to flowers that are functionally hermaphrodite, i.e. that can be selfed to produce viable seed, as in *Musa velutina*. If Valmayor and Danh are using the term in this precise sense then what is the explanation for the hermaphrodite flowers of *M. splendida* not setting seed? Valmayor and Danh make no comment on this or on the presence or viability of any pollen produced by these hermaphrodite flowers.

In conclusion, I believe that it is premature to claim a new *Musella* species from Vietnam when populations of *Musella* in China, Laos, Myanmar and Vietnam are so inadequately characterized. There may be other species of *Musella* awaiting discovery, but on the evidence they present, Valmayor and Danh do not convince me that *M. splendida* is one of them.

I have a *M. lasiocarpa* from Kunming, Yunnan, courtesy of Prof. Hu Zhihao, and I deposited *in vitro* shoot cultures of the same with the INIBAP Transit Centre in Leuven. There is botanically interesting (Versieux 2002), and perhaps horticulturally useful, variation in *M. lasiocarpa*, which, incidentally, can be purchased from garden centres in the UK and US for around 15 US$.

David Constantine, 2 High Street, Ashcott, Somerset, TA7 9PL, UK,
e-mail: drc@globalnet.co.uk

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Books: Stover R.H. & N.W. Simmonds. 1987. Bananas (3rd edition). Longman, London, United Kingdom.

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Recent publications

Strosse H., R. Domergue, B. Panis, J.V. Escalant and F. Côte. 2003. Banana and plantain embryogenic cell suspensions (A. Vézina and C. Picq, eds). INIBAP Technical Guidelines 8. The INIBAP, France.

Carlier J., D. De Waele and J.V. Escalant. 2003. Global evaluation of *Musa* germplasm for resistance to Fusarium wilt, *Mycosphaerella* leaf spot diseases, and nematodes: Performance evaluation (A. Vézina and C. Picq, eds). INIBAP Technical Guidelines 7. INIBAP, France.

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INIBAP addresses

• Headquarters:

Parc Scientifique Agropolis II
34397 Montpellier Cedex 5 - FRANCE
e-mail: inibap@cgiar.org
Fax : (33) 467 61 03 34
Director: **Dr Richard Markham**
e-mail: r.markham@cgiar.org
Coordinador, *Musa* Genetic Improvement:
Dr Jean-Vincent Escalant
e-mail: j.escalant@cgiar.org
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e-mail: n.roux@cgiar.org
Coordinador, *Musa* Agroecosystems and Channels for Added Value: **Dr Charles Staver**
e-mail: charles.staver@cgiar.org
Coordinator, Information/Communications:
Ms Claudine Picq
e-mail: c.picq@cgiar.org
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Accountant: **Mr Emmanuel Gonnord**
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Regional Coordinator: **Dr Franklin E. Rosales**
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Associate Scientist, Nematology: **Mr Thomas Moens**
c/o CATIE
Apdo 60-7170 Turrialba, Costa Rica
Tel./Fax: (506) 556 2431
e-mail: inibap@catie.ac.cr

• Regional Office for Asia and the Pacific

Regional Coordinator: **Dr Agustín Molina**
Associate Scientist, *Musa* technology transfer:
Dr Inge Van Den Bergh
c/o IRRI, Rm 31, GS Khush Hall
Los Baños, Laguna 4031
Philippines
Fax: (63-49) 536 05 32
e-mail: a.molina@cgiar.org

• Regional Office for West and Central Africa

Regional Coordinator: **Dr Ekow Akyeampong**
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Mr Josué Tetang Tchinda
Associate Scientist, *Musa* technology transfer:
Ms Kim Jacobsen
c/o CARBAP - BP 12438
Douala, Cameroon
Tel./Fax: (237) 342 91 56
E-mail: inibap@camnet.cm

• Regional Office for Eastern and Southern Africa

Regional Coordinator: **Dr Eldad Karamura**
Associate Scientist: *Musa* technology transfer:
Dr Guy Blomme
PO Box 24384
Kampala, Uganda
Fax: (256-41) 28 69 49
e-mail: inibap@imul.com

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Katholieke Universiteit Leuven
Laboratory of Tropical Crop Improvement
Kasteelpark Arenberg 13,
B-3001 Leuven
Belgium
Fax: (32-16) 32 19 93
e-mail: ines.vandenhouwe@agr.kuleuven.ac.be