“Conventional” banana and plantain breeding

Rodomiro Ortiz
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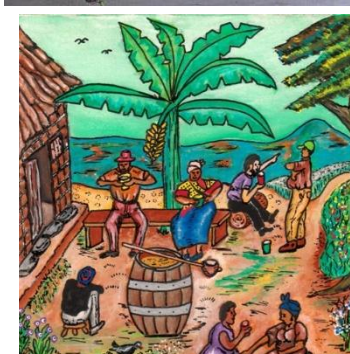
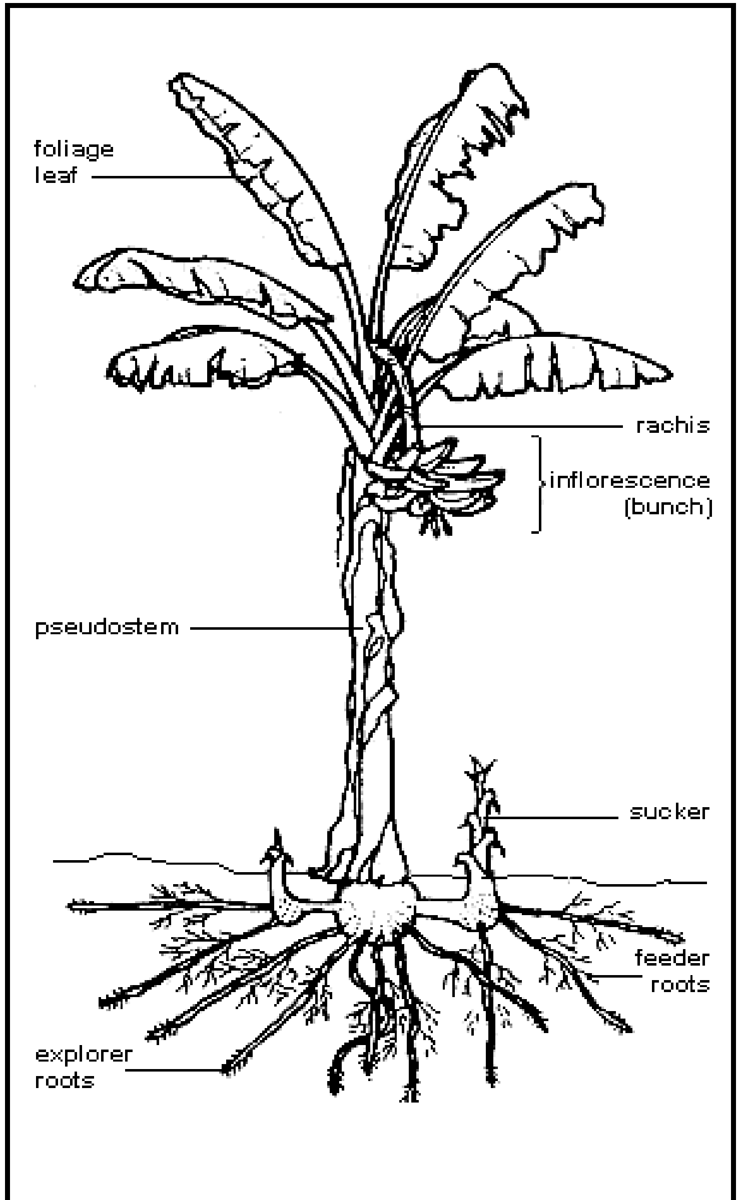
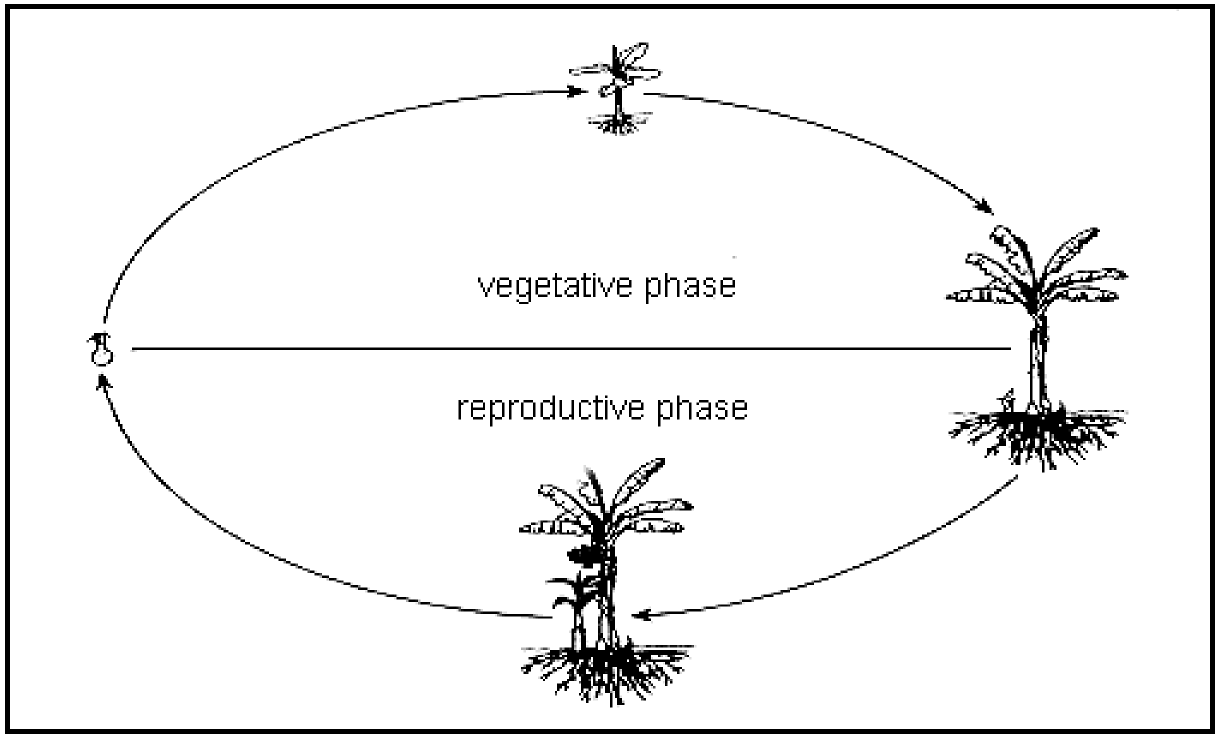
OVER 25% OF HUMAN
GENES ARE THE SAME AS
THOSE OF A BANANA
GET OVER YOURSELF

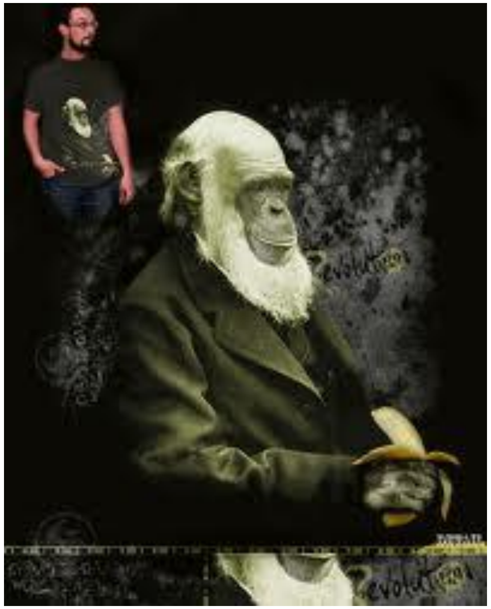

BANANA
FLOWER
$1.49/LB



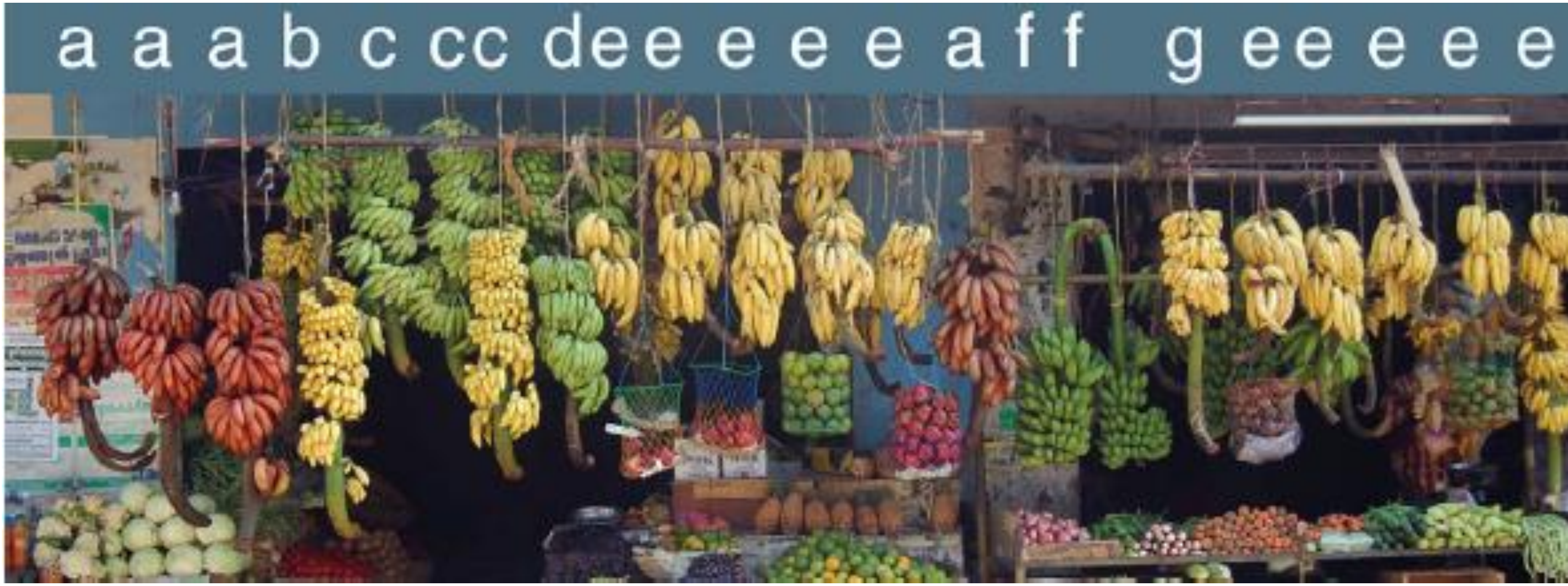
Improving plantain and banana-based systems


foliage
leaf
rachis
inflorescence
(bunch)
pseudostem
sucker
feeder
roots
explorer
roots


vegetative phase
reproductive phase



Scientific classification	
Kingdom:	Plantae
Division:	Angiosperms
Class:	Monocots
Clade:	Commelinids
Order:	Zingiberales
Family:	Musaceae
Genus:	*Musa*



Most of the cultivars are wild collections made by farmers of spontaneously occurring mutants with parthenocarpic fruit production, which were brought into cultivation and then multiplied and distributed by vegetative propagation

There are well over **a thousand domesticated *Musa* cultivars and their genetic diversity is high,** indicating multiple origins from different wild hybrids between two principle ancestral species: ***M. acuminata*** (A genome) and ***M. balbisiana*** (B genome)

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doi:10.1093/aob/mcm191, available online at www.aob.oxfordjournals.org

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REVIEW

Domestication, Genomics and the Future for Banana

J. S. HESLOP-HARRISON* and TRUDE SCHWARZACHER

Conspectus of the Family *Musaceae*, Classification, Distribution, and Uses of *Musa* Species

Genus	Chromosome No. (2*n*)	Section	Distribution	Species	Uses and Utilization
Ensete	9	–	Asia (India, China, Thailand, India Philippines	*E. superbun* (Roxb.) Cheesman, *E. glaucum* (Roxb.) Cheesman	Fiber, vegetable, ornamental
			Africa	*E. ventricosum* (Welw.) Cheesman, *E. Livingstoniana*, *E. proboscidea*, *E. gilletti* (De Wild) Cheesman, *E. buchanani*, *E. homblei* (Bequaert) Cheesman, *E. perrieri* (Claverie) Cheesman	
Musa	10	*Australimusa*	Queensland, Polynesia, Philippines, Australia	*M. lolodensis* Cheesman, *M. peekelii* Lauterb, *M. maclayi* von Muell. Ex Mikl-Maclay, *M. jackeyi* W. Hill, *M. bukensis* Argent, *M. textilis* Née, *M. Fehi*	Fiber, dessert fruit
		Callimusa	Indo-China, Malaysia, Philippines, Indonesia	*M. coccinea* Andrews, *M. violascens* Ridely, *M. gracilis* Holttum, *M. beccarii* Simmonds, *M. erecta*, *M. borneënsis* Beccari, *M. coccinea* Andrews, *M. exotica* R. Valmayor, sp. now *M. Flavida*, *M. hotta*, *M. gracilis* Holttum, *M. salaccensis* Zoll	Ornamental
	11	*Eumusa*	All banana growing countries and continents	*M. acuminata* Colla, *M. balbisiana* Colla, *M. schizocarpa* Simmonds, *M. basjoo* Sieb, *M. flaviflora* Cheesman, *M. itinerans* Cheesman, *M. flavicarpa*, *M. sikkimensis* Kurz, *M. cheesmani* Simmonds, *M. nagensium* Prain, *M. halabanensis* Meijer, *M. ochracea* Shepherd	Food, fruit, vegetable, fiber, and medicinal applications
	11	*Rhodochlamys*	India, Malaysia, Indo-China, Myanmar, Cambodia, Vietnam, Philippines, Thailand	*M. ornata* Roxb., *M. rosea* Baker, *M. rubra* Wall. Ex Kurz, *M. mannii* H. Wendl. Ex Baker, *M. velutina* H. Wendl. and Drude, *M. laterita* Cheesman, *M. sanguinea* Hook. f., *M. aurantiaca* Mann ex Baker, *M. rosacea* Jacq.	Ornamental

EUMUSA
Musa schizocarpa

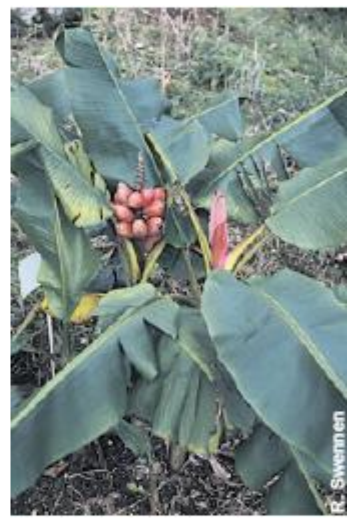
EUMUSA
Musa basjoo

CALLIMUSA
Musa coccinea

AUSTRALIMUSA
Musa peekelii

RHODOCHLAMYS
Musa laterita

RHODOCHLAMYS
Musa ornata



RHODOCHLAMYS
Musa velutina

AUSTRALIMUSA
Musa textilis

Musa ingens

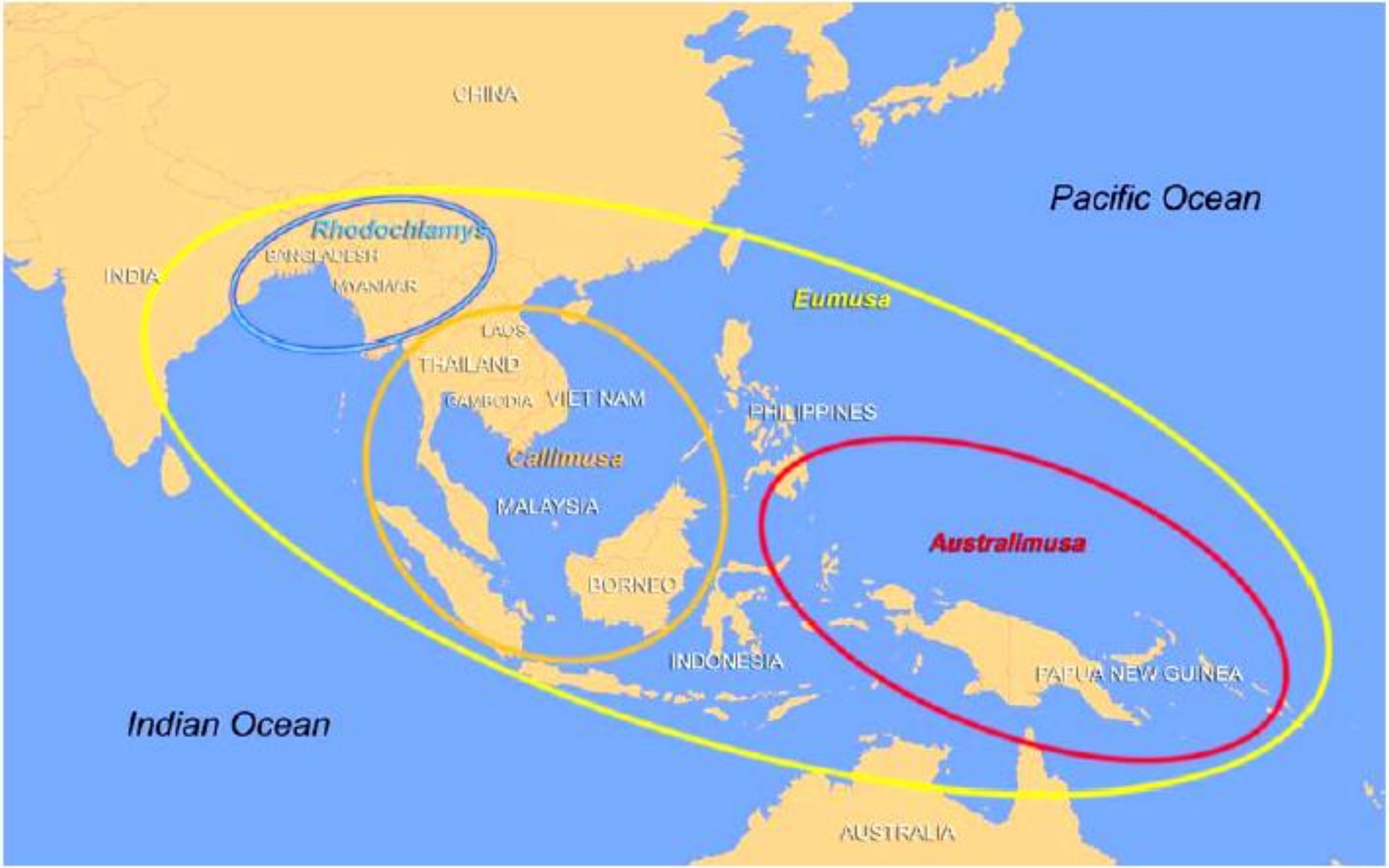
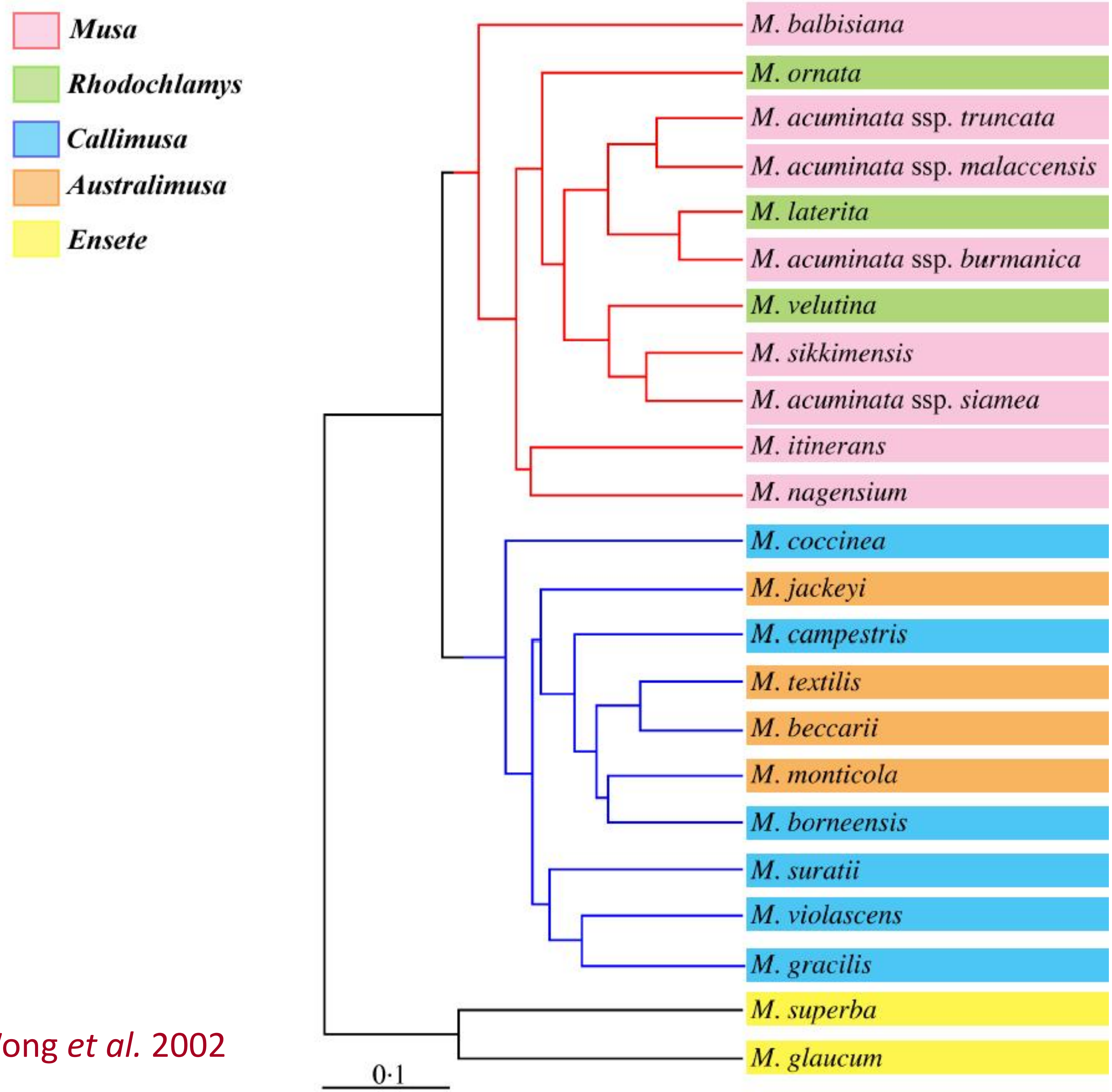
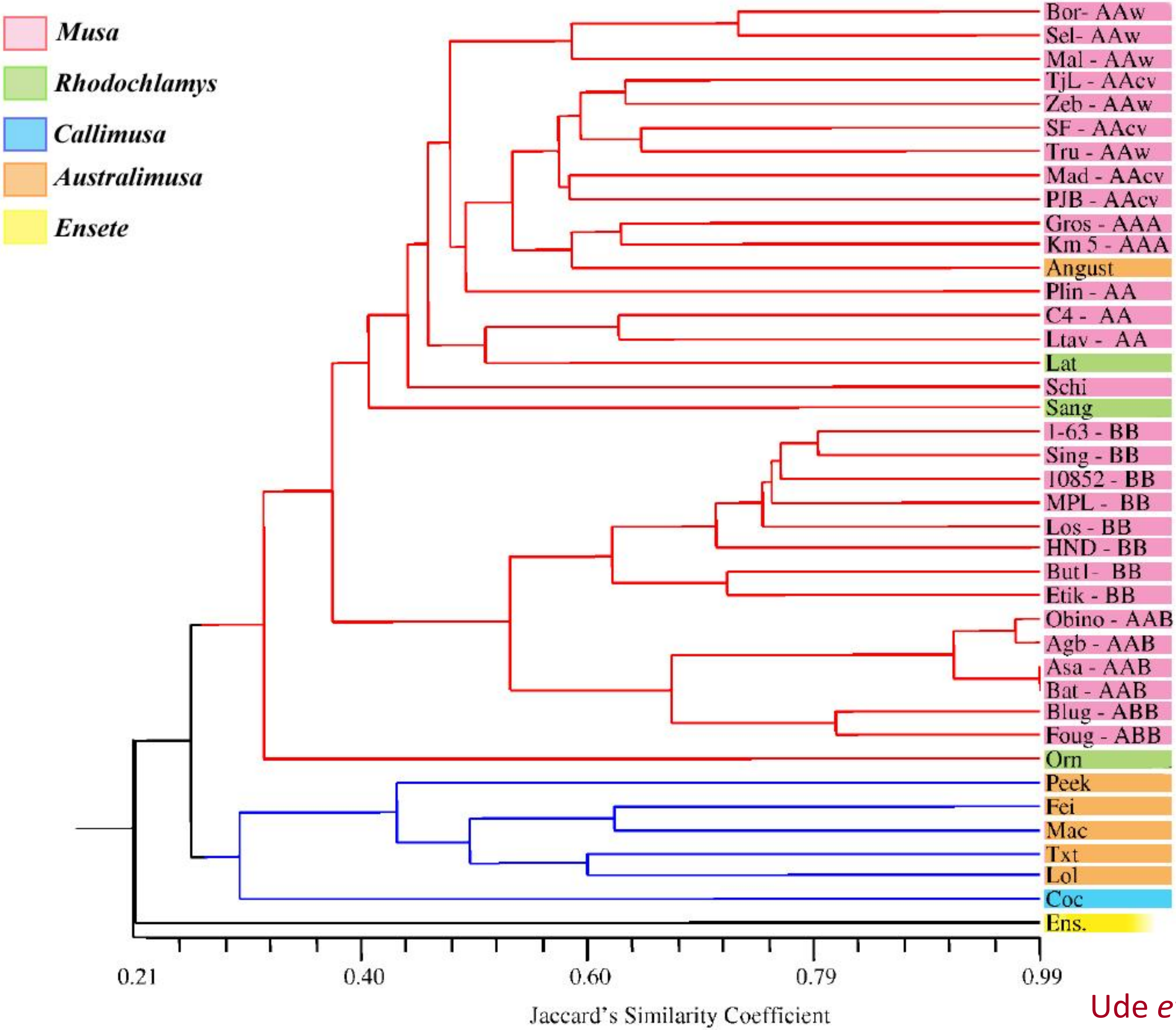


Figure 1. Distribution of *Musa* sections (Champion 1967, adapted by Guinard 2003).



Wong *et al.* 2002



Ude *et al.* 2002

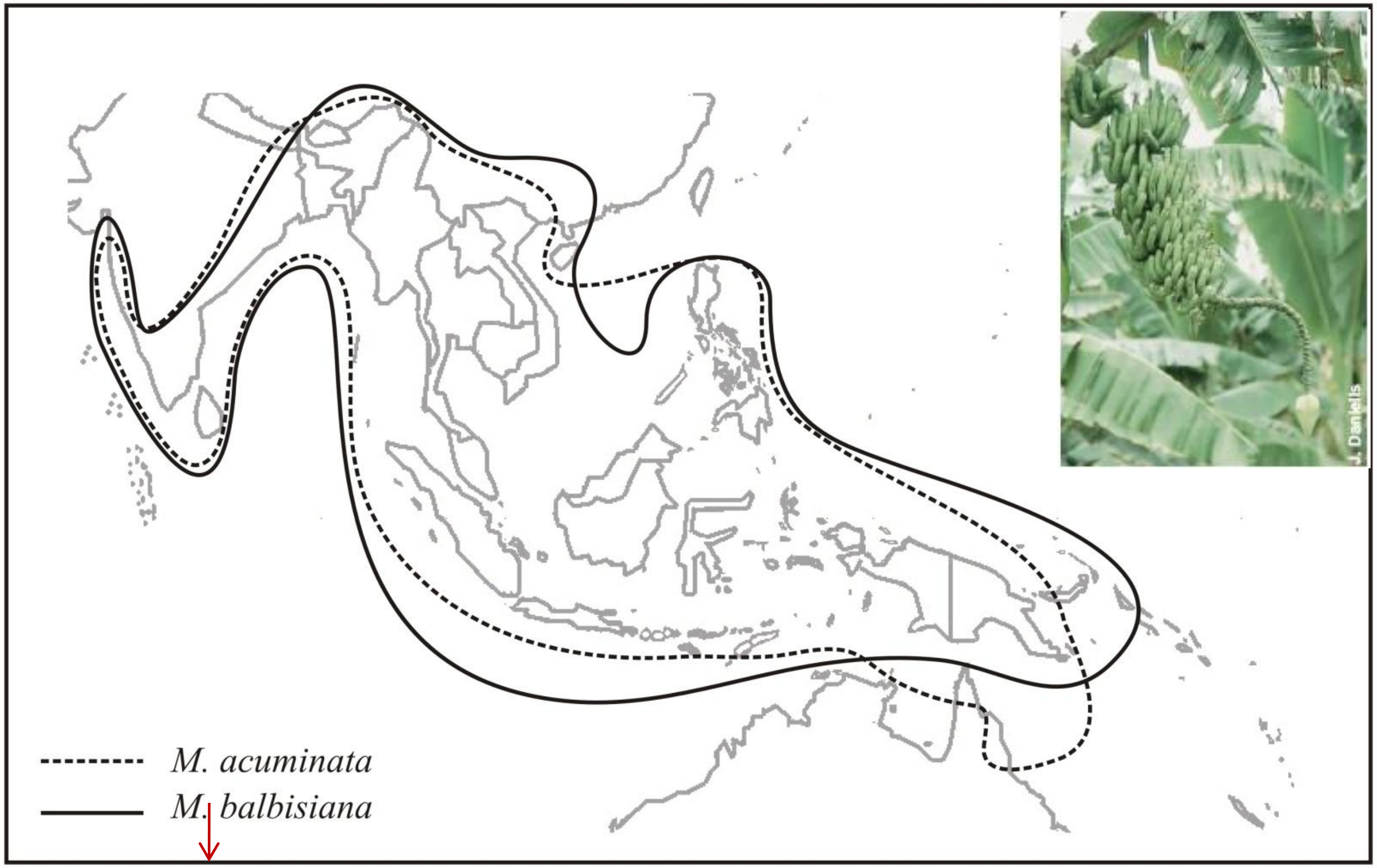


Fig.1. South and southeast Asia showing approximate range of distribution of *M. acuminata* and *M. balbisiana*

Distribution data from various sources, Constantine 2003; Wu & Kress 2000

Comparison between wild banana ancestors

Trait	*M. acuminata*	*M. balbisiana*
Color of pseudostem	Black or grey-brown spots	Unmarked or slightly marked
Petiole canal	Erect edge, with scarred inferior leaves, not against the pseudostem	Closed edge, without leaves, against the pseudostem
Stalk	Covered with fine hair	Smooth
Pedicels	Short	Long
Ovum	Two regular rows in the locule	Four irregular rows in the locule
Elbow of the bract	Tall (< 0.28)	Short (> 0.30)
Bend of the bract	The bract wraps behind the opening	The bract raises without bending behind the opening
Form of the bract	Lance- or egg-shaped, tapering markedly after the bend	Broadly egg-shaped
Peak of the bract	Acute	Obtuse
Color of the bract	Dark red or yellow on the outside, opaque purple or yellow on the inside	Brown-purple on the outside, crimson on the inside
Discoloration	The inside of the bract is more bright toward the base	The inside of the bract is uniform
Scarification of the bract	Prominent	Not prominent
Free tepal of the male flower	Corrugated under the point	Rarely corrugated
Color of the male flower	White or cream	Pink
Color of the markings	Orange or bright yellow	Cream, yellow, or pale pink

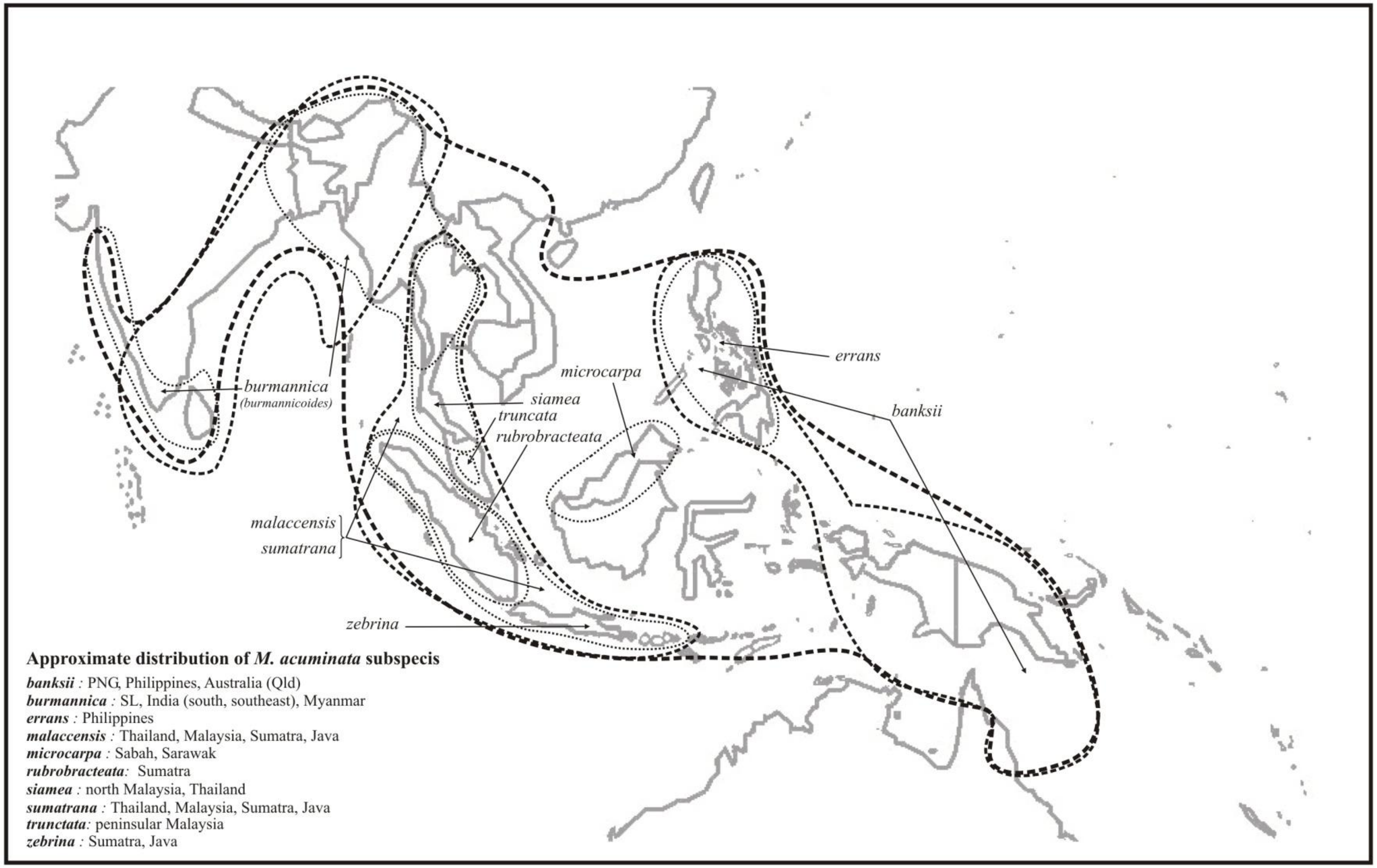


Fig.2. Approximate distribution of *M. acuminata* subspecis

Data from various sources, Jones 2000; Daniells et al. 2001; Constantine 2003

Musa acuminata ssp. *truncata*

Musa acuminata ssp. *malaccensis* Selangor

Musa acuminata ssp. *microcarpa* Borneo

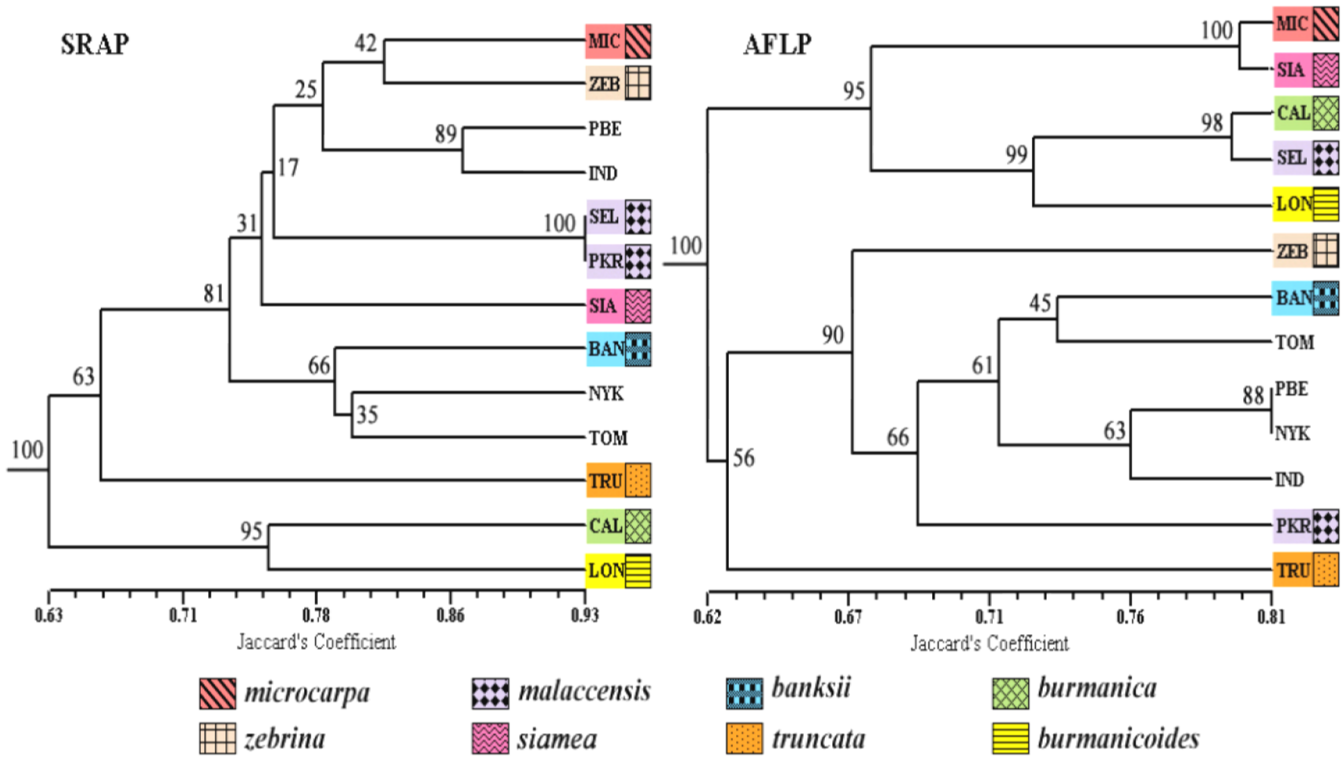
Musa acuminata ssp. *siamea* Pa Rayong

Musa acuminata ssp. zebrina

Musa acuminata ssp. *burmannicoides* Calcutta 4

Musa acuminata ssp. *banksii* Hawain No.2

Musa acuminata ssp. *burmannica* Long Tavoy



Dendrogram of genetic similarities and relationships among *M. acuminata* subspecies using SRAP and AFLP UPGMA cluster analysis. Arabic numbers indicate bootstrapping

Youssef et al. 2010

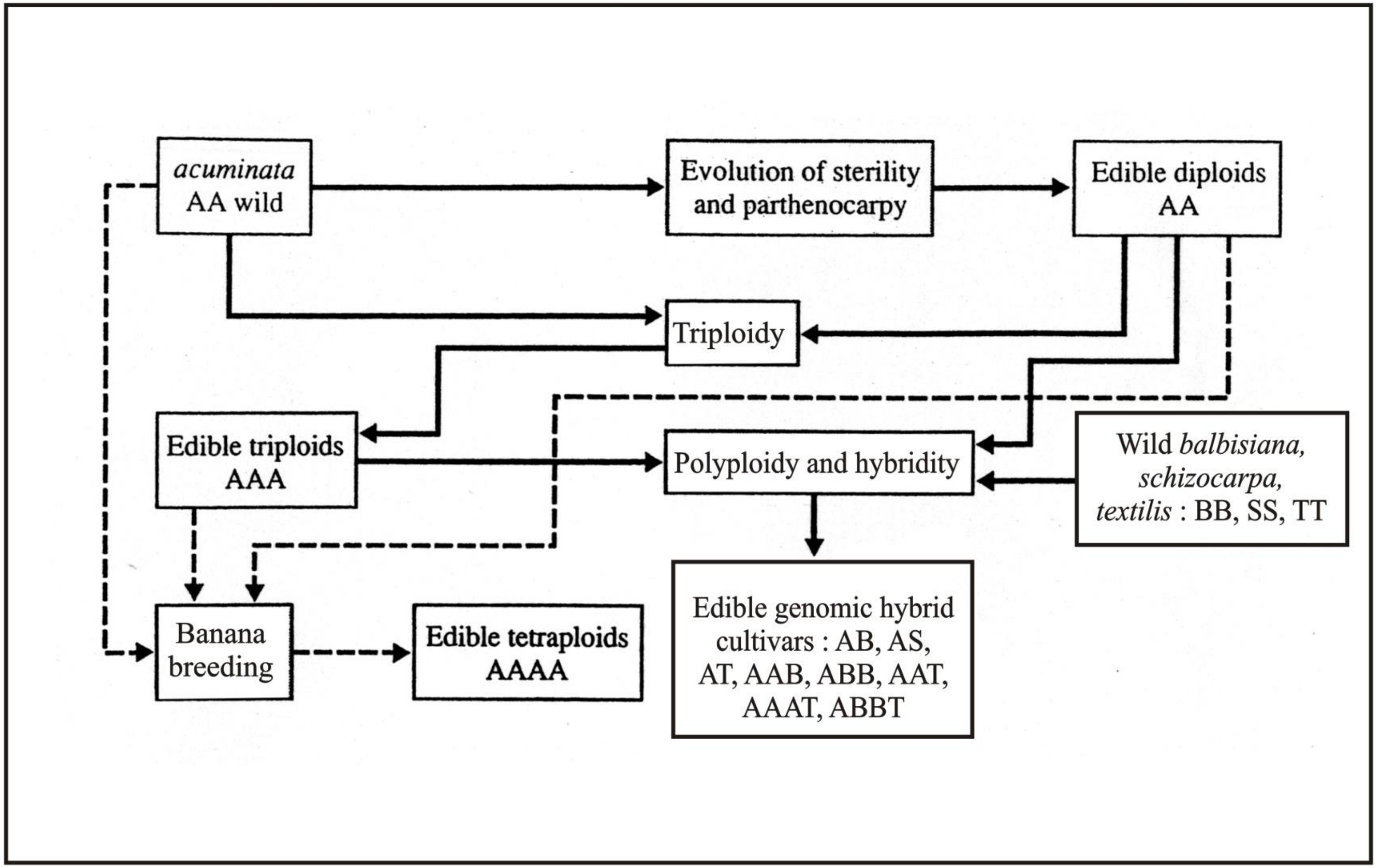


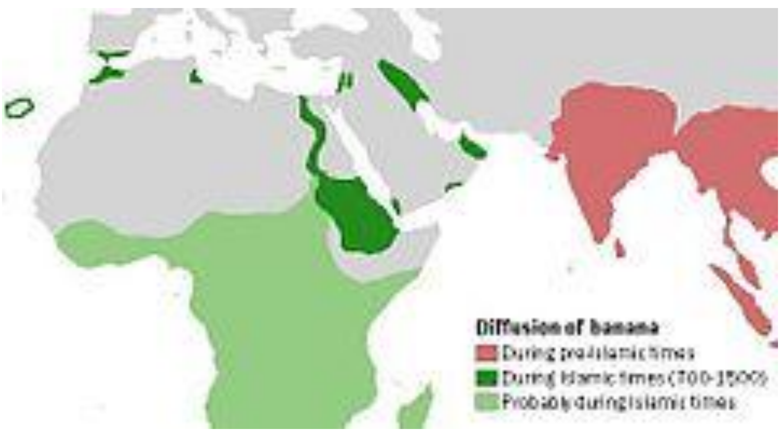
Fig.3. Evolution of the cultivated bananas

Modified from Simmonds 1995

Original native ranges of the ancestors of modern edible bananas. *Musa acuminata* is shown in green and *Musa balbisiana* in orange

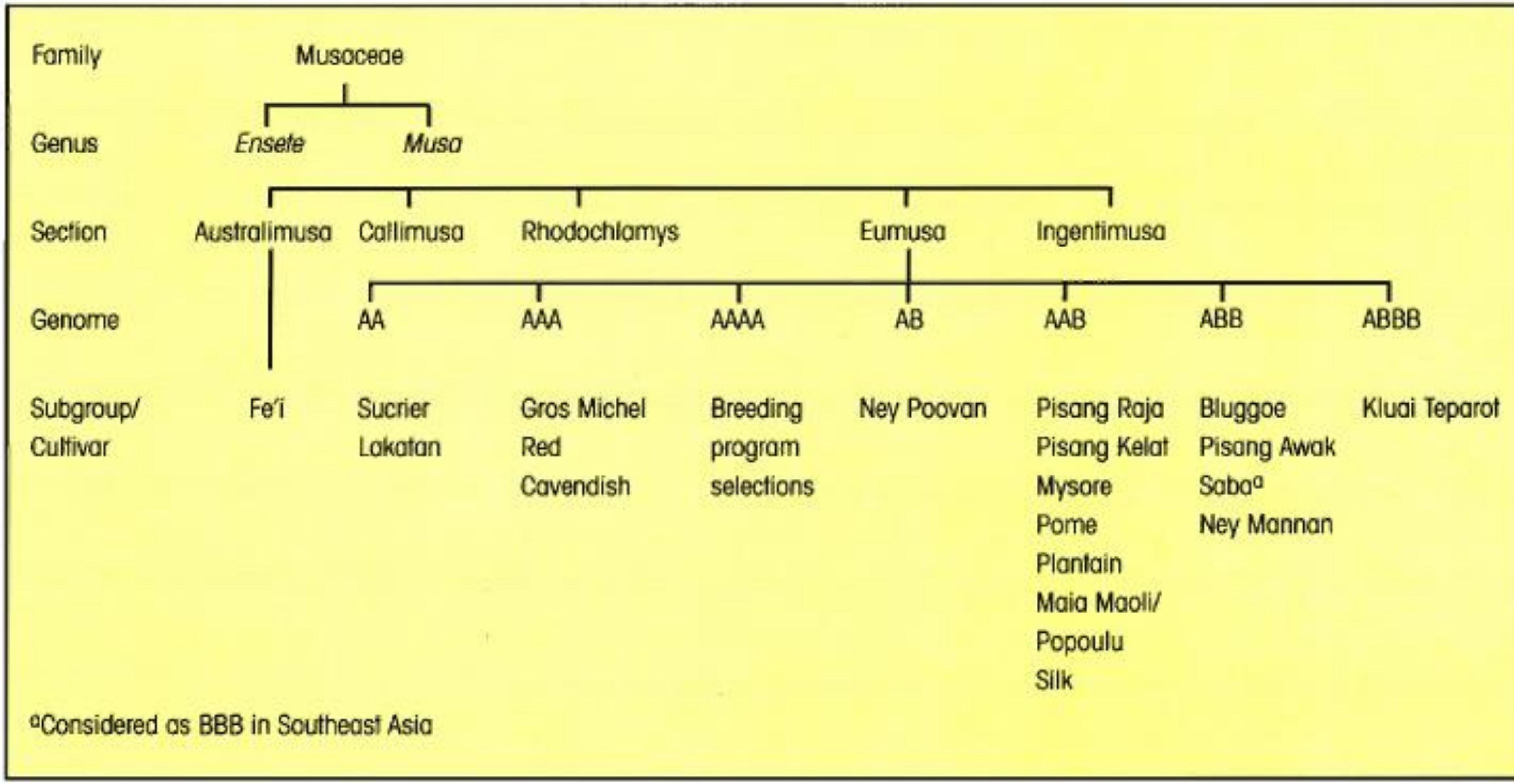
Musa acuminata

Musa balbisiana



Actual and probable diffusion of bananas during Islamic times (700–1500 AD)

Systematic position of *Musa* cultivars



- Global banana production is based on **large-scale vegetative propagation of a small number of genotypes**, which derive from only a few ancient sexual recombination events

- These genetically restricted and inflexible clones are particularly **susceptible to pathogens, pests, and to climate changes**

- The **challenge for *Musa* improvement** is to produce resistant and sterile polyploid hybrids through **genetic recombinations of fertile parents that meet consumer expectations for each cultivar type**

Multidisciplinary perspectives on banana (*Musa* spp.) domestication

www.pnas.org/cgi/doi/10.1073/pnas.1102001108

Xavier Perrier[a], Edmond De Langhe[b], Mark Donohue[c], Carol Lentfer[d], Luc Vrydaghs[e], Frédéric Bakry[a], Françoise Carreel[f], Isabelle Hippolyte[a], Jean-Pierre Horry[a], Christophe Jenny[g], Vincent Lebot[h], Ange-Marie Risterucci[a], Kodjo Tomekpe[a], Hugues Doutrelepont[e], Terry Ball[i], Jason Manwaring[i], Pierre de Maret[j], and Tim Denham[k,1]

Left to right: plantains, Red, Latundan, and Cavendish bananas

Gros Michel [AAA]
cv. Highgate

Cavendish [AAA]
cv. Grande Naine

Cavendish [AAA]
cv. Williams

Cavendish [AAA]
cv. Dwarf Parfitt

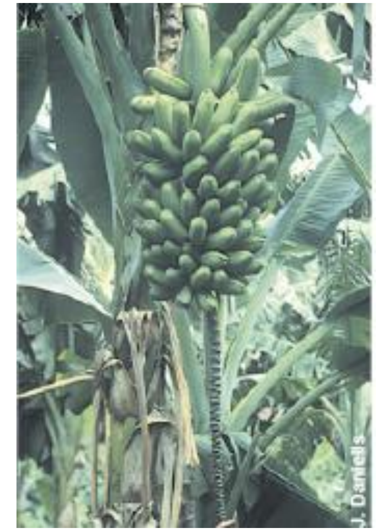
Top 10 banana nations(in million t)	
India*	26.2
Philippines	9.0
China	8.2
Ecuador	7.6
Brazil	7.2
Indonesia	6.3
Mexico*	2.2
Costa Rica	2.1
Colombia	2.0
Thailand	1.5
World Total	**95.6**

Red[AAA]
cv. Mossi

Mutika Lugujira [AAA]
East African
Highland Cooking Banana

Mutika Lugujira [AAA]
East African
Highland Beer Banana

Silk/Pome [AAB]
Prata Ana
Banana



Maia Maoli/
Poupoulu [AAB]
Banana

French Plaintain
[AAB]

French Horn
Plaintain [AAB]

False Horn
Plaintain [AAB]

Horn
Plaintain [AAB]

Asian Cooking
Banana[ABB]

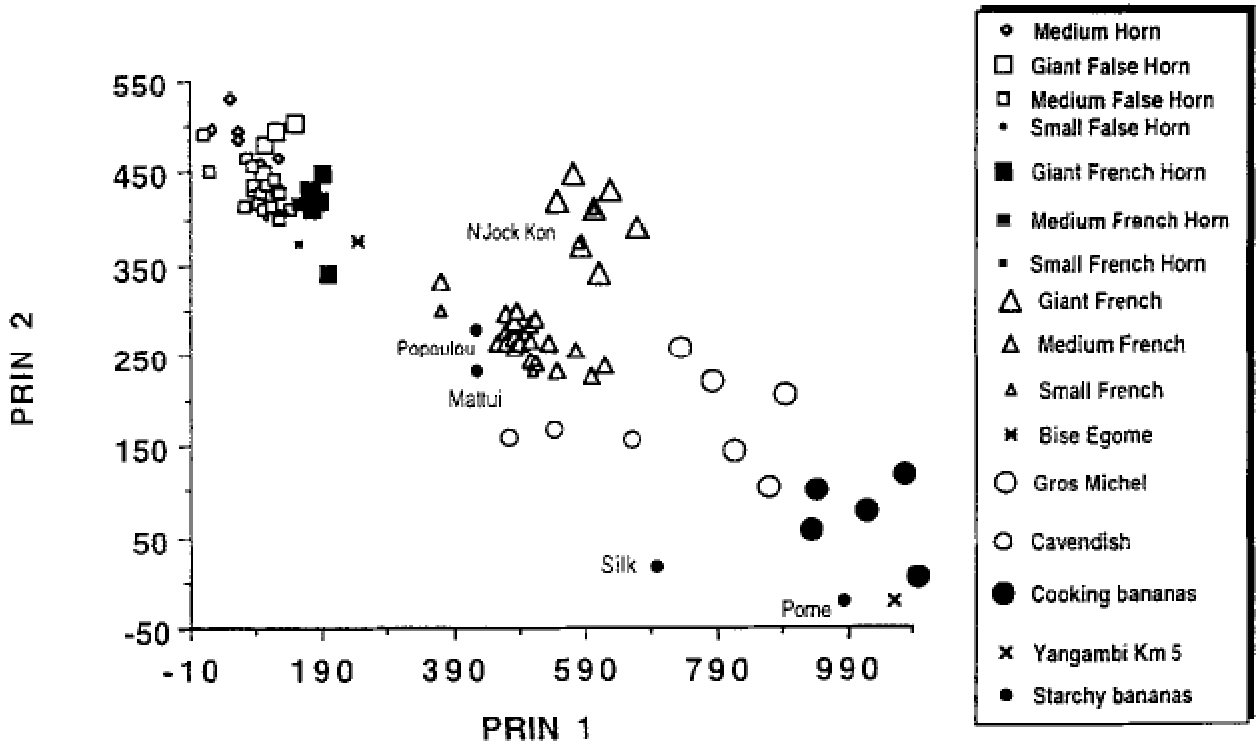


Fig. 1. Positions of PC scores of different *Musa* triploid cultivars based on growth and yield parameters.

Multivariate pattern of quantitative trait variation in triploid banana and plantain cultivars

Julian O. Osuji [a], Bosa E. Okoli [a], Dirk Vuylsteke [b], Rodomiro Ortiz [c,*]

Scientia Horticulturae 71 (1997) 197–202

TABLE 1. PLANTAIN (*MUSA* SPP., AAB) GROUPS ACCORDING TO THEIR INFLORESCENCE AND FRUIT CHARACTERISTICS.

Group	Inflorescence	Hermaphrodite flowers	Presence of male bud	Number of hands*	Fruits	
					Number	Size
French	Complete	Many	Yes	6–10	Many (70–130)**	Small (0.15–0.25)***
French Horn	Incomplete	Many	No	7–8	Medium (41–80)	Large (0.21–0.28)
False Horn	Incomplete	Few	No	5–11	Medium (23–70)	Large (0.26–0.46)
Horn	Incomplete	None	No	1–4	Few (18–45)	Very large (0.29–0.45)

* Nodal clusters bearing fruits

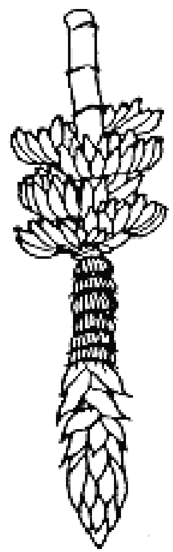
** Number of fruits in parentheses (Swennen and Vuylsteke 1987).

*** Fruit weight (kg) in parentheses (Swennen and Vuylsteke 1987).

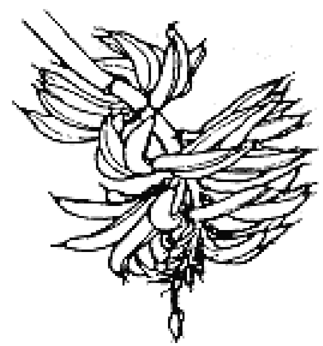
PHENOTYPIC DIVERSITY AND PATTERNS OF VARIATION IN WEST AND CENTRAL AFRICAN PLANTAINS (*MUSA* SPP., AAB GROUP MUSACEAE)[1]

RONY SWENNEN, DIRK VUYLSTEKE, AND RODOMIRO ORTIZ

Economic Botany 49(3) pp. 320–327. 1995



French plantain



False Horn plantain

Horn plantain

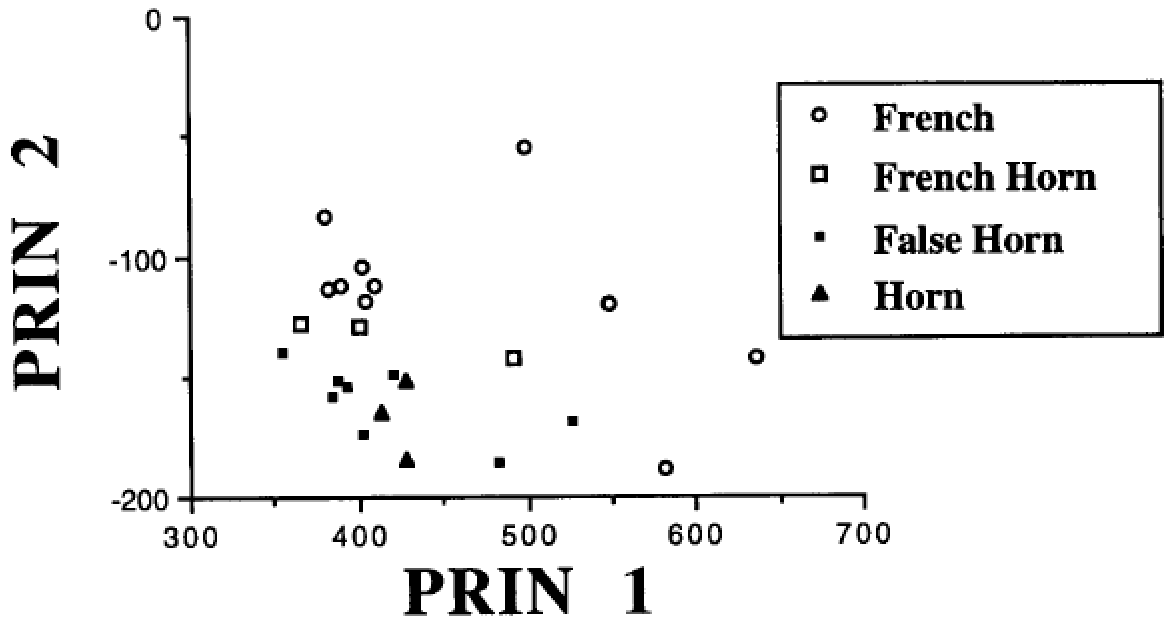
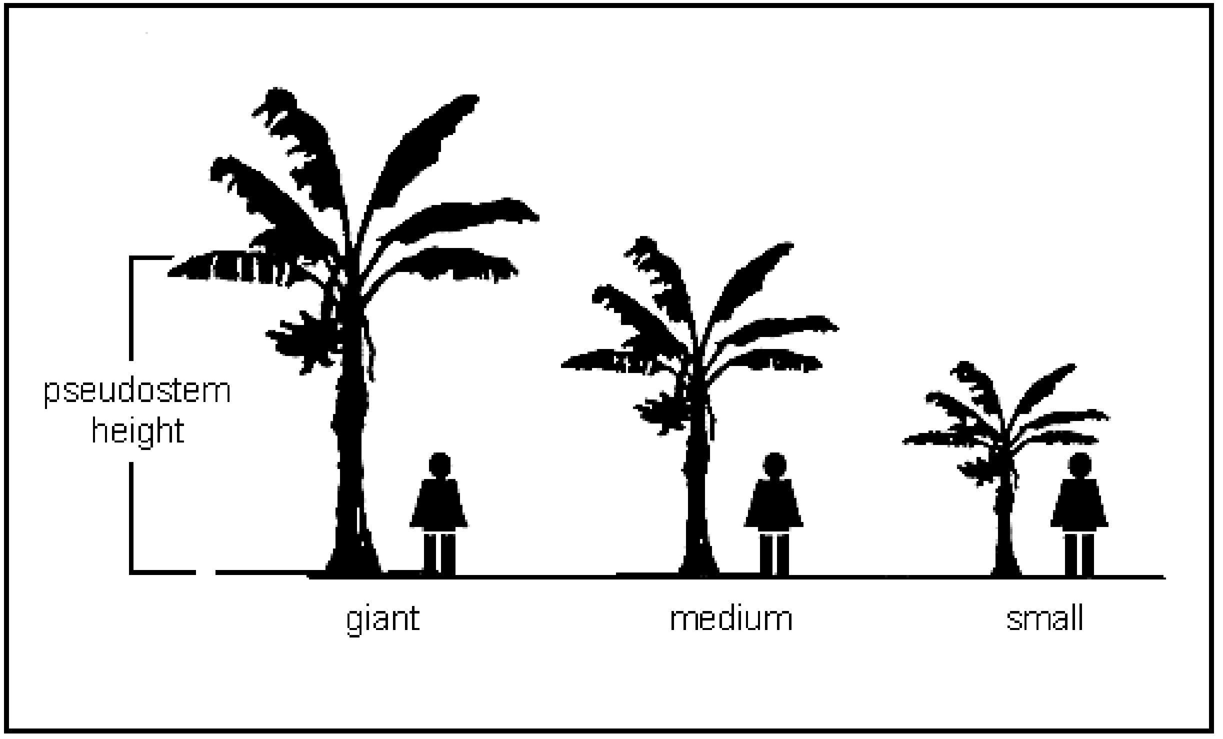


Fig. 1. Plot of the first (PRIN1) and second (PRIN2) principal components from analysis of vegetative and bunch traits of West and Central African plantains. Symbols based on their bunch type.

Phenotypic Diversity and Patterns of Variation in West and Central African Plantains (*Musa* spp., AAB Group Musaceae)[1]

Rony Swennen, Dirk Vuylsteke, and Rodomiro Ortiz

Economic Botany 49(3) pp. 320–327. 1995



In plantain, plant height depends on the number of leaves produced before flowering:

- giant cultivars have more than 40 foliage leaves
- medium cultivars have 32-40 foliage leaves
- small cultivars have less than 32 foliage leaves

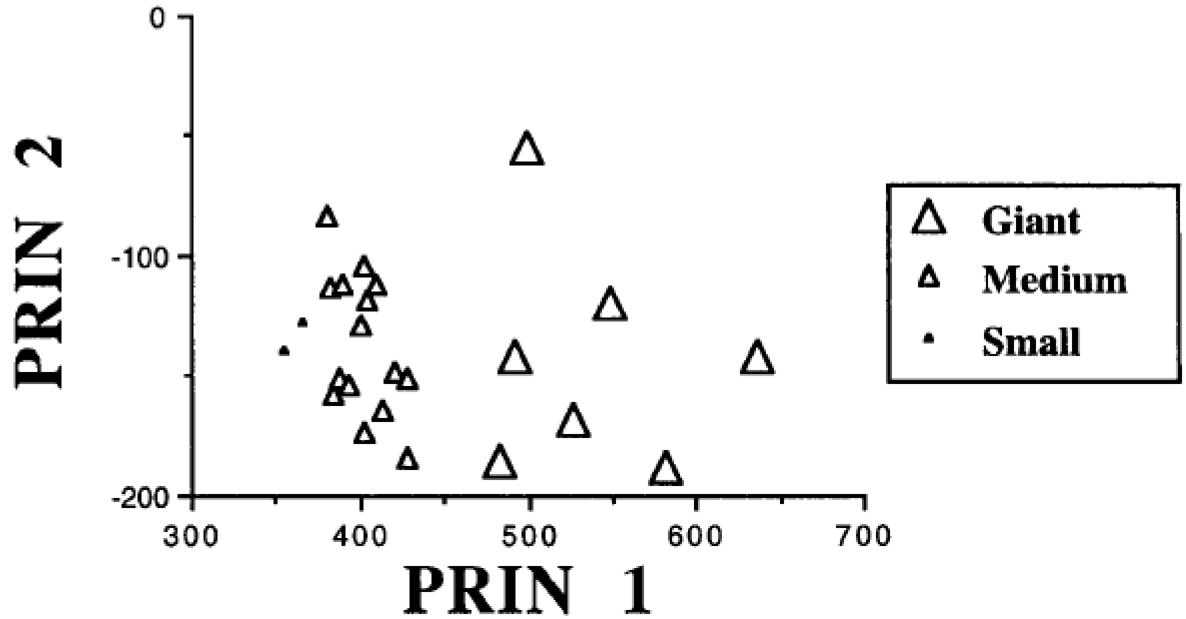


Fig. 2. Plot of the first (PRIN1) and second (PRIN2) principal components from analysis of vegetative and bunch traits of West and Central African plantains. Symbols according to their plant stature.

PHENOTYPIC DIVERSITY AND PATTERNS OF VARIATION IN WEST AND CENTRAL AFRICAN PLANTAINS (*MUSA* SPP., AAB GROUP MUSACEAE)[1]

RONY SWENNEN, DIRK VUYLSTEKE, AND RODOMIRO ORTIZ

Economic Botany 49(3) pp. 320–327. 1995

R. Ortiz · S. Madsen · D. Vuylsteke

Classification of African plantain landraces and banana cultivars using a phenotypic distance index of quantitative descriptors

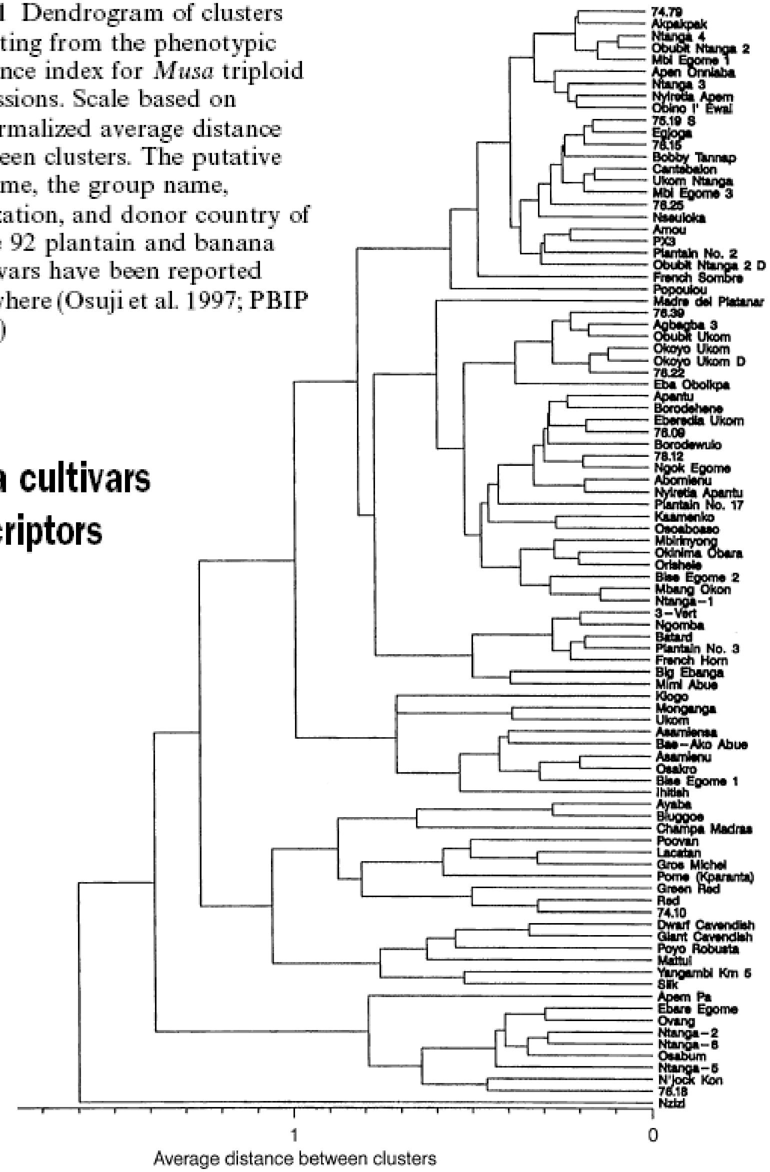
Theor Appl Genet (1998) 96: 904–911

Table 2 Analysis of variance between and within *Musa* clusters for the phenotypic distance index based on quantitative morphological descriptors

Source of variation	Mean square	Expected mean square
Between clusters	0.130579***	$\sigma^2_W + n\sigma^2_C$
Within clusters	0.001380	σ^2_W

*** Indicates that the source of variation was significant according to respective F-test at $P < 0.001$, while n is the weighted mean for the total number of comparisons within each cluster (i.e., 72.611)

Fig. 1 Dendrogram of clusters resulting from the phenotypic distance index for *Musa* triploid accessions. Scale based on a normalized average distance between clusters. The putative genome, the group name, utilization, and donor country of these 92 plantain and banana cultivars have been reported elsewhere (Osuji et al. 1997; PBIP 1997)



Poor correlation between RAPD based estimates of genetic diversity and a phenotypic index based on agronomic characters

Poor correlation between RAPD analyses and morphotype group (based on bunch type and stature).

Traditional designations of plantain landraces based on morphotype do not provide a true reflection of overall genetic divergence.

The level of genetic divergence within morphogroups based on bunch type suggests that True Horn plantains are derived from False Horn plantains which in turn are derived from French plant

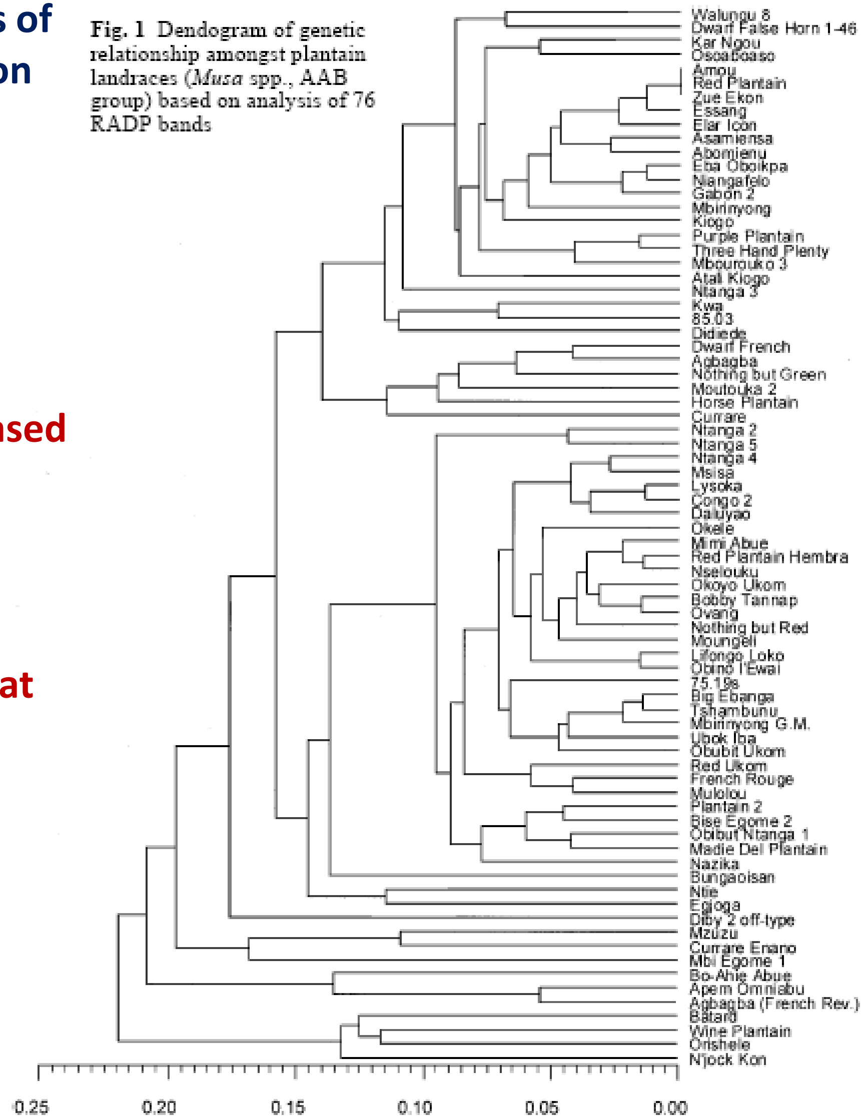


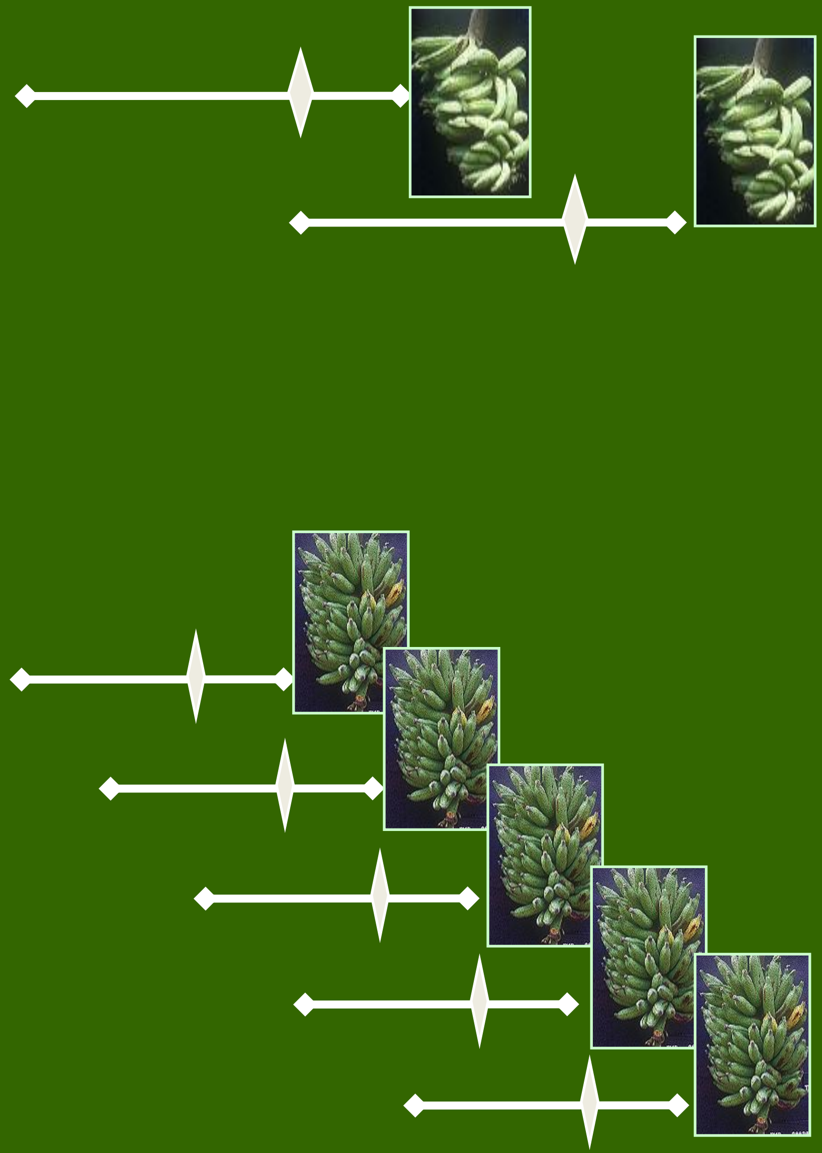
Fig. 1 Dendogram of genetic relationship amongst plantain landraces (*Musa* spp., AAB group) based on analysis of 76 RADP bands

H.K. Crouch · J.H. Crouch · S. Madsen
D.R. Vuylsteke · R. Ortiz

Theor Appl Genet (2000) 101:1056–1065

Comparative analysis of phenotypic and genotypic diversity among plantain landraces (*Musa* spp., AAB group)

Breeding objectives



High and stable yield

Fruit processing quality

R-Black sigatoka

R-Nematodes

R-*Fusarium* wilt

R-Weevil

R-Viruses (BSV)

Earliness

Short H-H intervals

Short stature

Good roots

Pisang Jari Buaya [AA]

Pisang Ceylan [AAB]

Cardaba [AAB]

Gros Michel [AAA]

Cavendish cv. Grand Naine [AAA]

Yangambi Km 5 [AAA]

FHIA-17 [AAA * AA]

FHIA-21 [AAB * AA]

BITA-3 [AAB * AA]

GCTCV-119 AAA SV

FHIA-23 [AAA * AA]

SH 3436-9 [AAA * AA] SV

CRP 39 [AAB * AA]

Goldfinger [AAB * AA]

BITA-2 [ABB * BB]

Pedigree of FHIA-25

Cardaba 'Gaddatu' X ***M. balbisiana***

SH-2952 *(4x) primary* X **SH-2741** *(2x)*

SH-3217 X SH-3142

SH-3386 *(3x) secondary, dwarf* X **SH-3362** *(2x)*

PJB X SH-1734

SH-3648 *(4x) secondary* X **SH-3142** *(2x)*

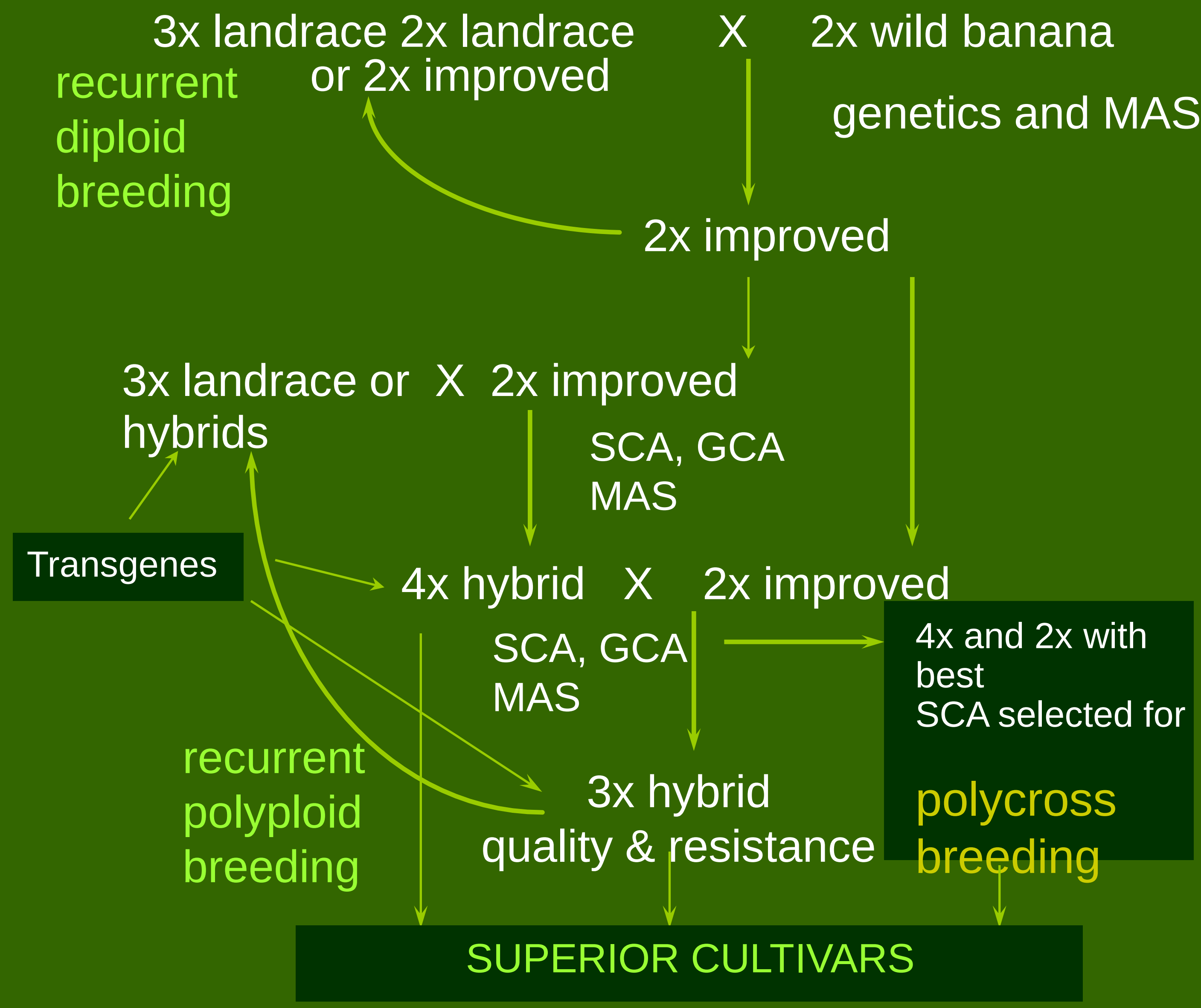
SH-3775 (FHIA-25)

(3x) tertiary

Phil Rowe (1939 – 2001)

The *Musa* improvement process at IITA

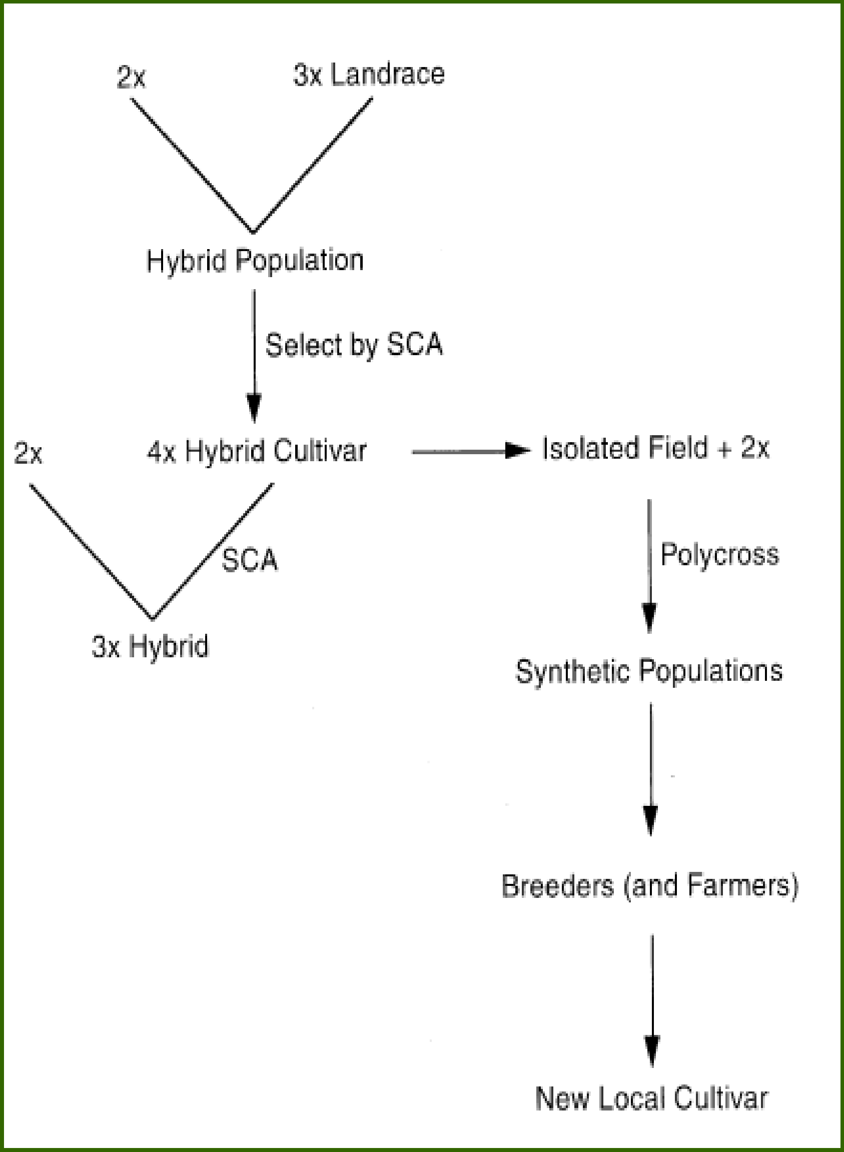
Musa x = 11 chromosomes



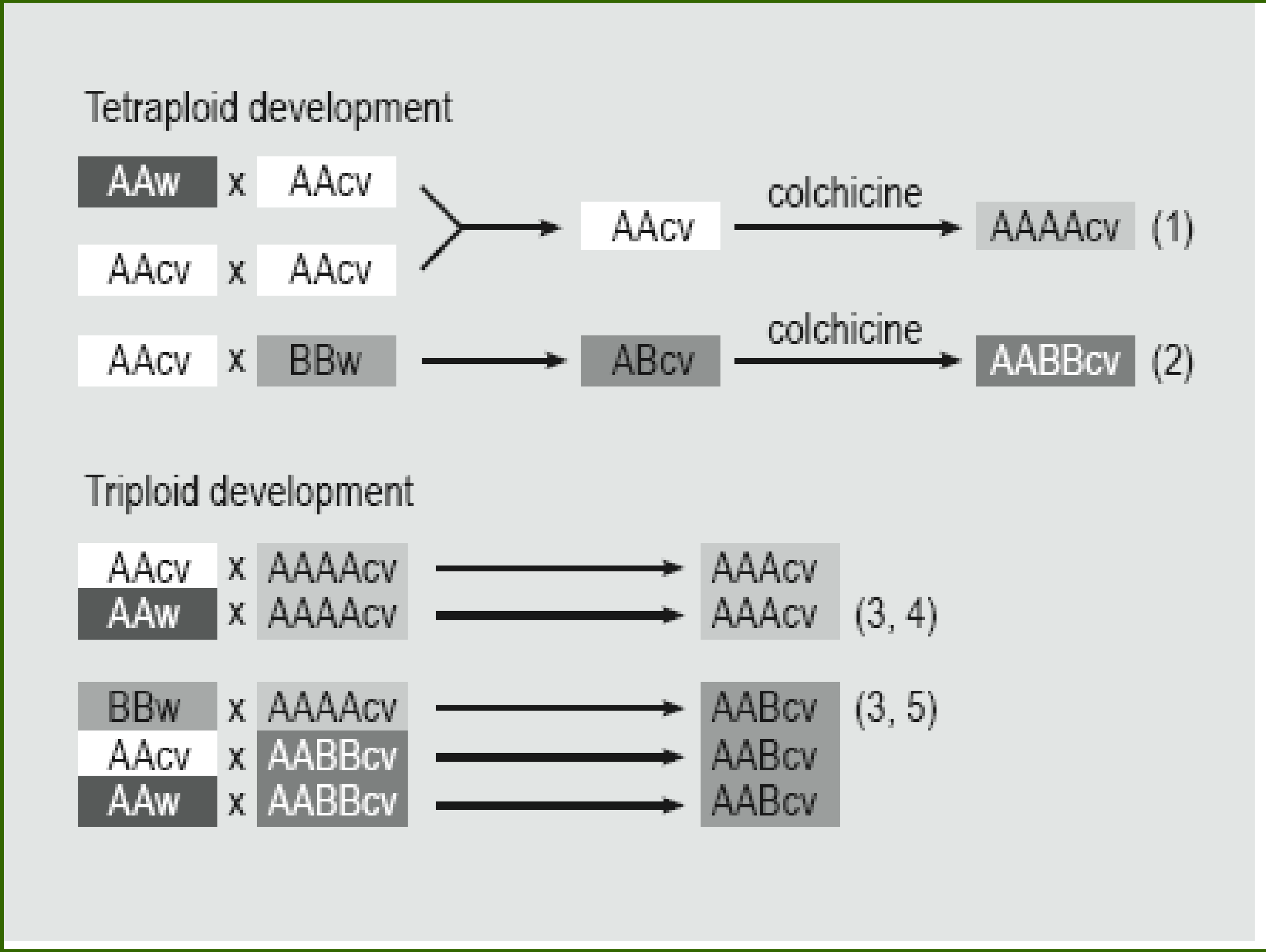
West African plantain breeding

Cross	Bobby Tannap	French Reversion	Obino l'Ewai
Pollination blocks			
(pollinations at flowering, i.e. 12–15 months after planting; seed harvest and fruit ripening in store room 3–4 months after flowering)			
Bunches pollinated	701	194	990
Total seedset	14,184	215	4871
Seeds bunch $^{-1}$	20	1	5
In vitro *germination and roguing nursery*			
(at least 3 months in tissue culture laboratory for embryo germination and rapid micropropagation, and 8 weeks in roguing nursery)			
Total euploids	70	9	42
Total tetraploids	7	1	23
Early and preliminary on-station yield trials			
(3–4 years of on-station testing and 2–6 months for registration in *HortScience*)			
Total selected tetraploids	2	1	10
Selection intensity (%)			
—bunch $^{-1}$ pollinated	0.3	0.5	1
—seedset $^{-1}$	0.01	0.5	0.2
—euploid hybrid $^{-1}$	3	11	24

Evolutionary *Musa* breeding



4x/2x breeding scheme used by CIRAD and CARBAP



Sorting out ploidy and genome combinations

M. acuminata (*AA*) x *M. balbisiana* (*BB*)

↓

Hybridization
Polyploidization
2n gametes

↓

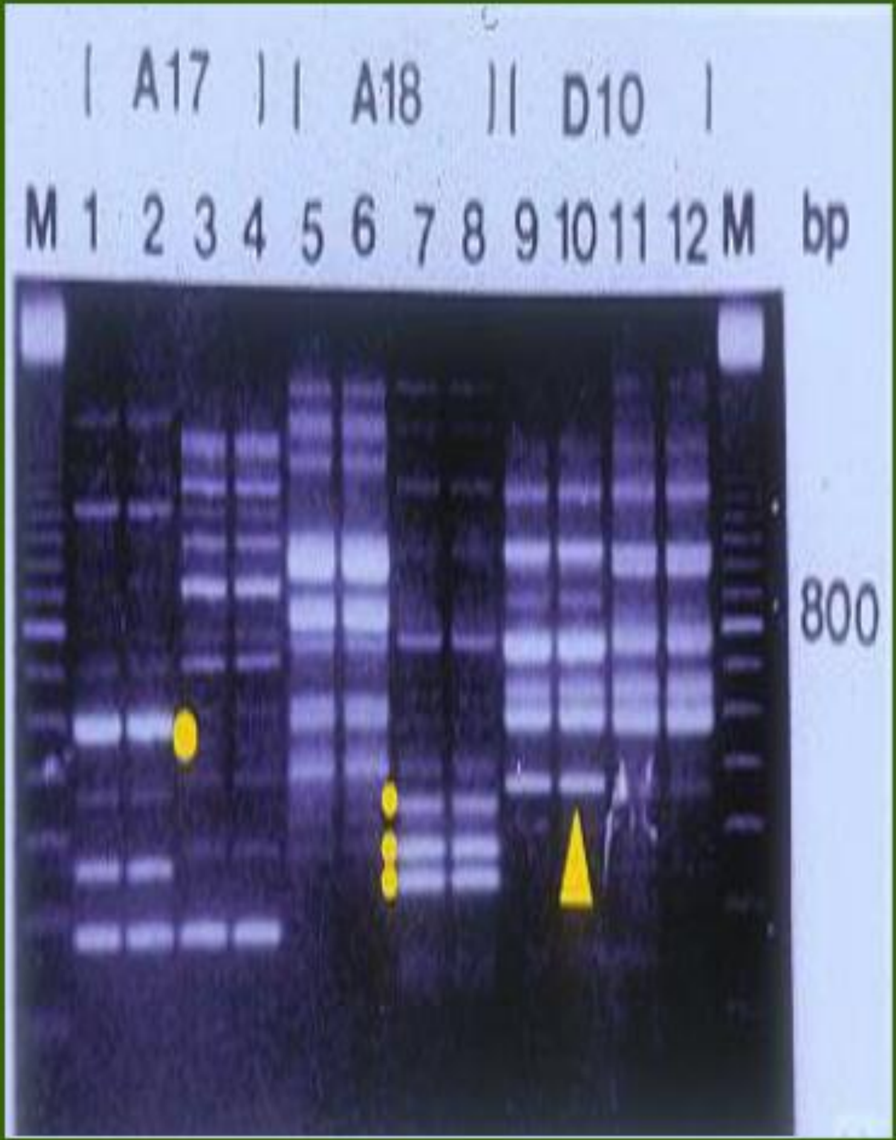
AAA	*AAB*	*ABB*	*AB*
Dessert	Plantain	Cooking	*AAAB*
Highland		banana	*AABB*
			ABBB

Gametes and genotypes in 4x – 2x breeding

TETRAPLOIDS (AAB x AA)	DIPLOIDS (AAB X AA)	
AAAB	AA	or AB
0	0	0
A	A	A
B	AA	B
AA		AB
AB		
AAA		
AAB		
AAAB		

Progeny:		
	Nullisomics	AO, BO
	Diploids	AA, AB
	Triploids	AAA, AAB, ABB
	Tetraploids	AAAA, AAAB, AABB
	Pentaploids	AAAAA, AAAAB, AAABB
	Hexaploids	AAAAAB, AAAABB

Genome composition

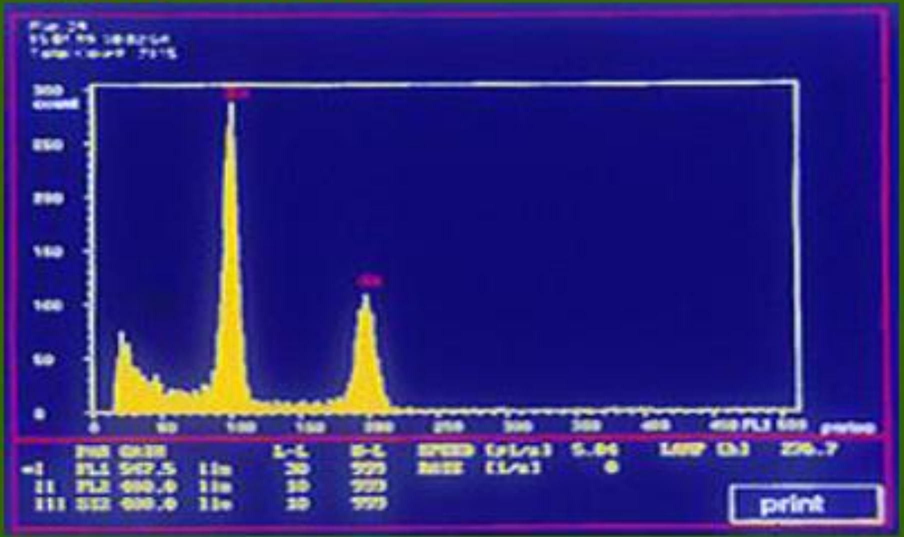


RAPD markers that are specific for the A and B genomes have been identified, cloned and sequenced

They do not rely on scoring morphological traits, can be used at any stage of the plant, and provide an objective way for genome classification in *Musa*

Breeders can now screen for genome profile in the nursery and do not require the land space and labor for field maintenance of the plants

Ploidy analysis and cytogenetics



Flow cytometry is a precise, rapid, and convenient tool for ploidy analysis

Silver staining of chromosomes

Genetic bridges have been built

Combining ability and parental selection in 4x–2x breeding

Maternally inherited traits: Growth habit

Paternally inherited traits: Productivity

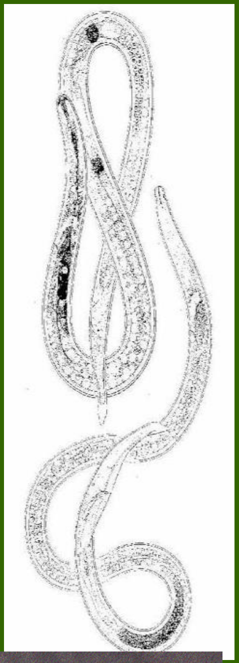
$$H_{ij} = \frac{c_i(1 + F_{ii})P_i + c_j(1 + F_{jj})P_j}{c_i(1 + F_{ii}) + c_j(1 + F_{jj})} \times \left(1 - \mathrm{Ln}\frac{2 - F_{ij}}{\sqrt{(F_{ii})(F_{jj})}}\right)$$

Additive component

Nonadditive component

Diploid Population Improvement

Breeding triploid hybrids from crosses between diploid parents through USP (2n gametes) was demonstrated



Utilization of germplasm enhanced

Resistance to nematodes

- Single root inoculation method for nematode screening and non-destructive method for root assessment developed
- Resistance to *Radopholus similis* identified in >10 diploid hybrids that had been selected for resistance to black sigatoka and good plant and bunch characteristics

Promising diploid and polyploid hybrids with resistance to *R. similis* identified using an early screening technique based on inoculation of individual roots in Nigeria

Hybrid	Pedigree	Reproductive ratio
Tetraploid x diploid		
25333-S66	4698-1 x 5105-1	1.400 (2.449)
25333-S88	4698-1 x 5105-1	0.839 (5.392)
25257-11B	4698-1 x 5105-1	0.889 (1.098)
25281-1A	2796-5 x 5105-1	1.136 (1.987)
Triploid x diploid		
PITA 14 (7152-2)	Mbi Egome 1 x Calcutta 4	1.596 (2.791)
A10-SPS-548-9	Obino l'Ewai x Calcutta 4	1.713 (2.996)
Diploid x diploid		
25291-1	2829-62 x 9128-3	0.115 (0.577)
25291-S50	2829-62 x 9128-3	0.771 (0.951)
25291-S58	2829-62 x 9128-3	0.000 (0.000)
25291-S62	2829-62 x 9128-3	0.793 (0.979)
25291-S89	2829-62 x 9128-3	0.431 (1.278)
25273-1	2829-62 x 9128-3	0.249 (1.246)
25273-19	2829-62 x 9128-3	0.411 (3.080)
5105-1	Pisang lilin x Calcutta 4	0.391 (0.683)

Pedigree of the diploid banana hybrid population used

Nyamwihogora (3*x*) x Long Tavoy (2*x*)
(aaabbb: S) (AAbb: S)

SH-3362 (2*x*) x Calcutta-4 (2*x*)
(AaBb: R) (AABB: R)

TMB2x 6142-1 (2x) x TMB2x 8075-7 (2x)
(Aabb: S) (AaBb: R)

Diploid segregating hybrid offspring

Gametic and zygotic configurations in a diploid banana hybrid population

Gametes from TMB2x 8075-7 (R)

Gametes 6142-1 (S)	¼ AB	¼ Ab	¼ aB	¼ ab
½ Ab	1/8 AABb (R)	1/8 AAbb (S)	1/8 AbBb (R)	1/8 Aabb (S)
½ ab	1/8 AaBb (R)	1/8 Aabb (S)	1/8 aaBb (PR)	1/8 aabb (S)

Scale for Assessing Host Plant Resistance to Nematodes (comparisons as per Dunnett's test)

Comparison w/ Valery (S)	Comparison w/ Km 5 (R)	Host Plant Resistance	Observed segregation
Significantly different	Not different	Resistant	37
Not different	Significantly different	Susceptible	31
Significantly different	Significantly different	Partially resistant	13
Not different	Not different	Inconclusive	-

$X^2_{(2df)}$ = 4.488 ns

Black sigatoka leaf spot

Also known as black leaf streak, causes significant reductions in leaf area, yield losses of 50% or more, and premature ripening, a serious defect in the fruit

Understanding Host Plant Resistance to Black Sigatoka

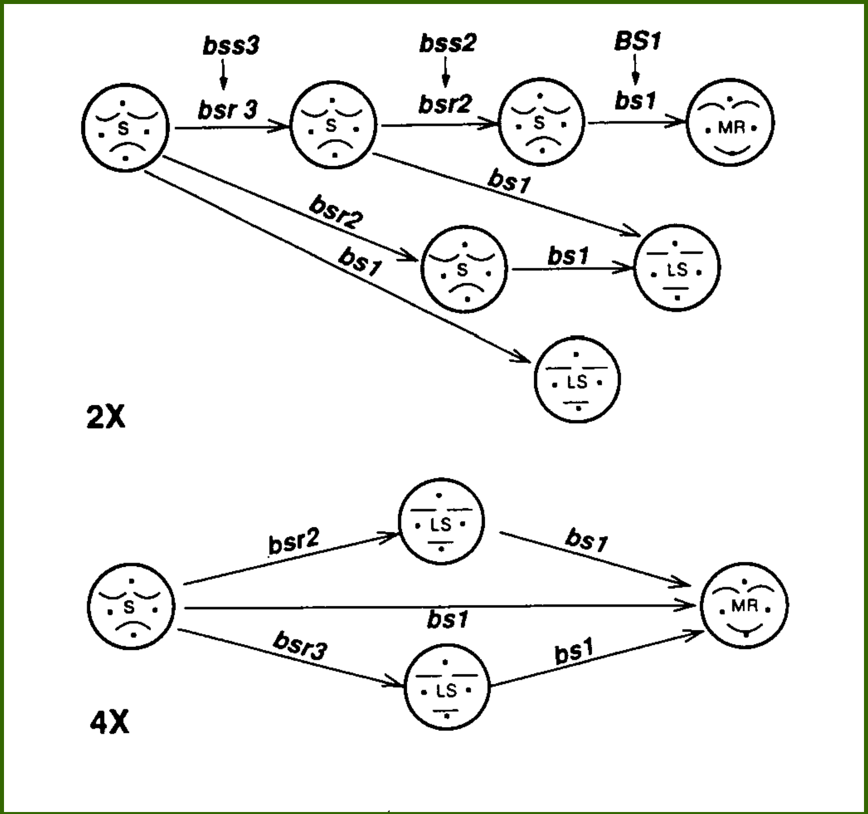
- Model: one major recessive R gene (*bs*$_1$) and other two enhancing R minor additive alleles
- What does *bs*$_1$ does
- Any hope for durable resistance (“a matter of time”)

[Challenging the textbook: resistance mechanism (hypersensitivity or partial resistance), host-plant/pathogen interaction (vertical or horizontal), genetic model (mono-, oligo-, multi-genic)]

R. Ortiz · D. Vuylsteke

Theor Appl Genet (1994) 89:146–152

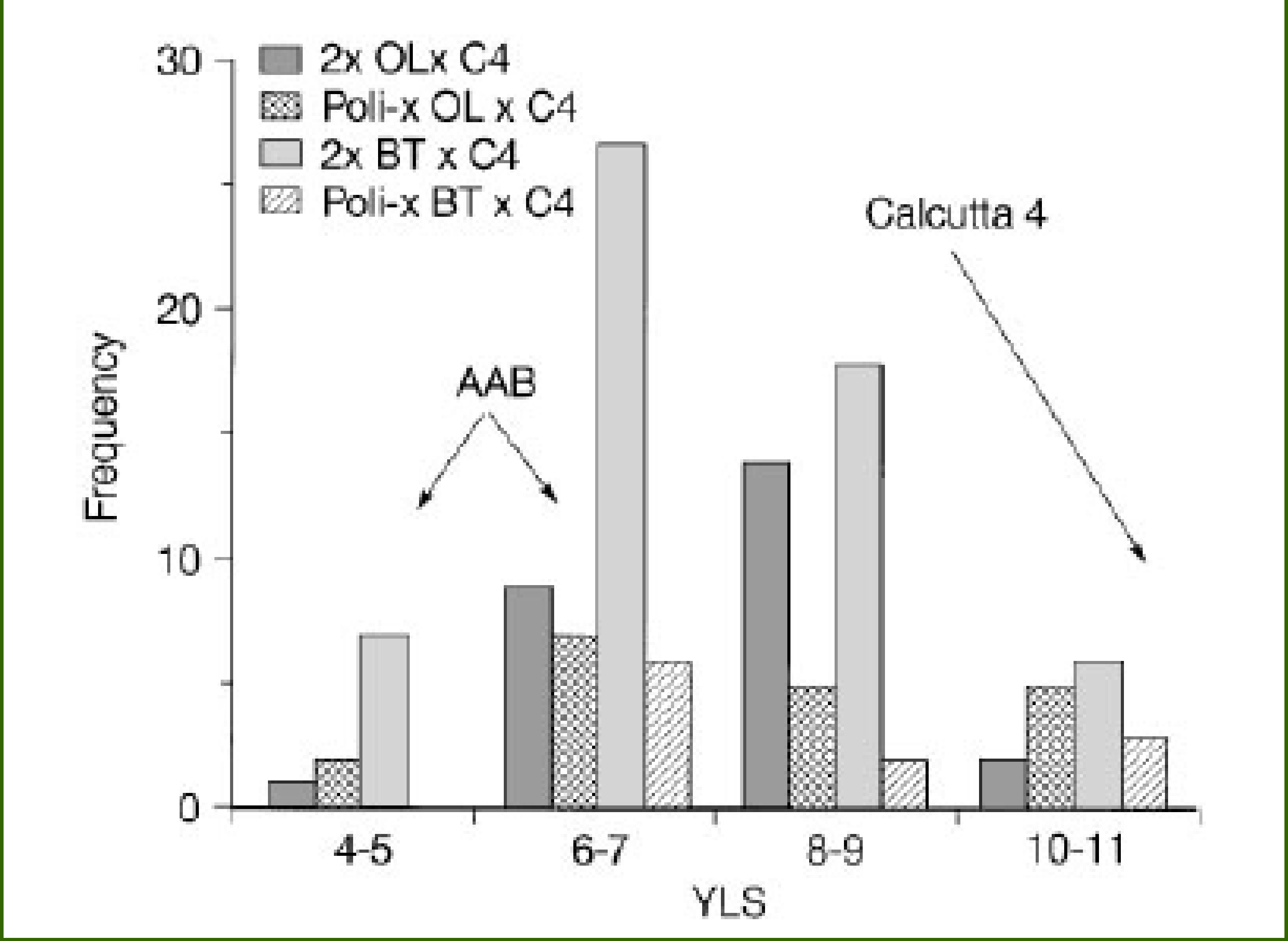
Inheritance of black sigatoka disease resistance in plantain-banana (*Musa* spp.) hybrids



Genotype of the *bs*$_1$ locus in two 3*x*-2*x* segregating populations

Ploidy	Genotype
Obino l'Ewai × Calcutta 4	
Diploid	11 heterozygous: 15 homozygous recessive
Triploid	2 simplex: 1 nulliplex
Tetraploid	8 duplex: 8 nulliplex
Bobby Tannap × Calcutta 4	
Diploid	25 heterozygous: 33 homozygous recessive
Triploid	2 simplex: 1 nulliplex
Tetraploid	6 duplex: 2 nulliplex

Frequency distribution for youngest leaf spotted (YLS)



Analysis of variance of genetic effects of *bs_1* locus on youngest leaf spotted

bs_1 locus genotype	Degrees freedom	Mean square	*bs_1* intra-locus net	Degrees freedom	Mean square
Environ-ment (E)	1	22.17 ***	Environ-ment (E)	1	23.26 ***
bs_1 allele freq.	3	51.78 ***	Net locus Effect (I)	4	49.06 ***
E x *bs_1* freq.	3	3.08 ns	E x I	4	4.05
CV (%)		21.0	CV (%)		20.2

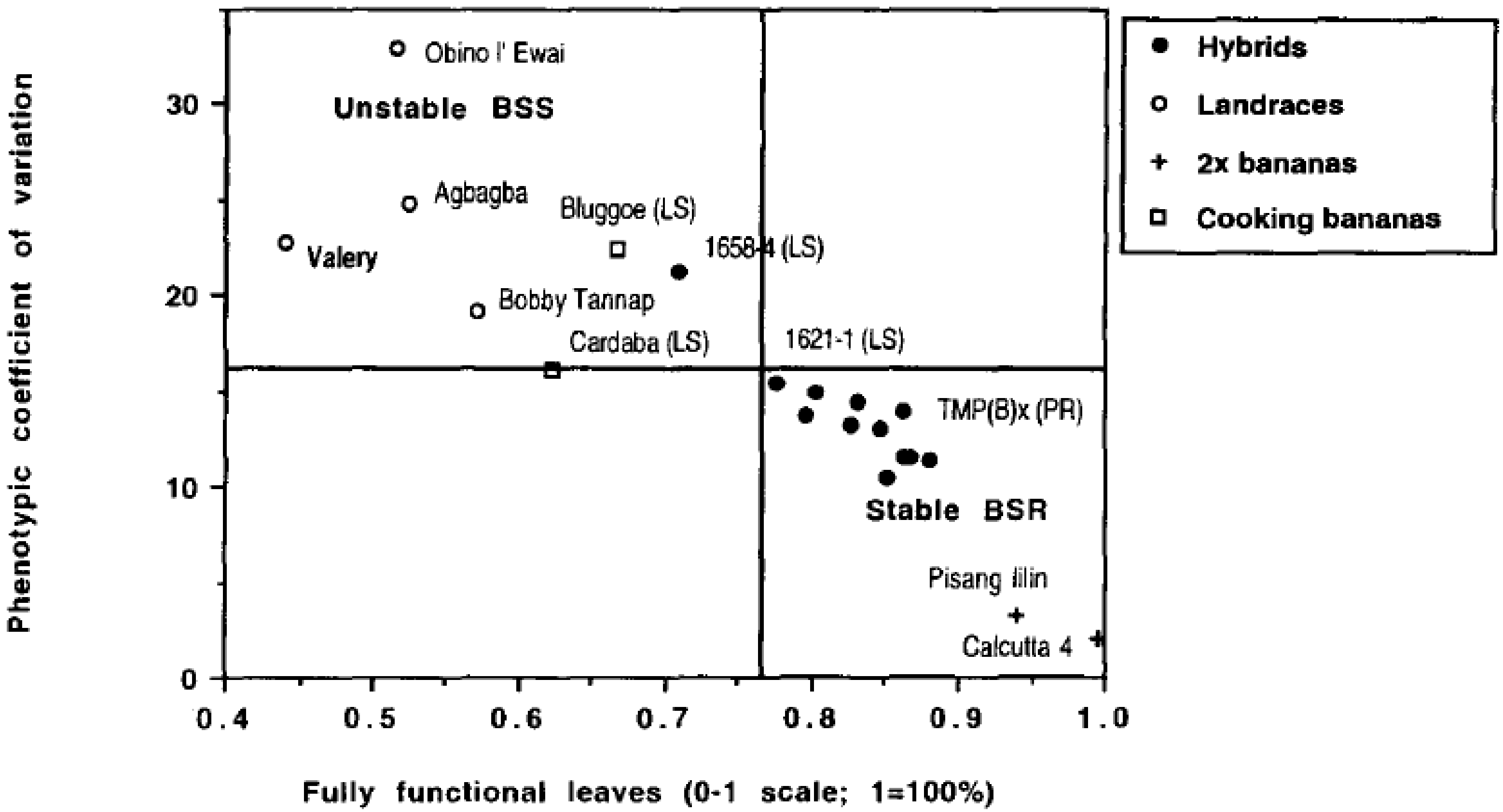
Genetic effects of *bs_1* locus on host plant resistance to black sigatoka

bs_1 allele freq.	Youngest leaf spotted	Net intralocus interactions	Youngest leaf spotted
4	10.1 (PR +)	4	10.1 (PR +)
2	8.2 (PR -)	2	8.6 (PR -)
1	7.0 (S)	1-0	6.2-7.1 (S)

Kathelyne Craenen · Rodomiro Ortiz
Theor Appl Genet (1997) 95:497–505

Effect of the *bs_1* gene in plantain-banana hybrids on response to black sigatoka

Homeostatic host plant response to black Sigatoka in plantain hybrids



Plant Varieties and Seeds (1997) **10**, 39–57

Developing new plantain varieties for Africa

Norman Simmonds (1922 – 2002)

Advances in *Musa* genetics and plant ideotype

Kenneth Shepherd (1927 – 2001)

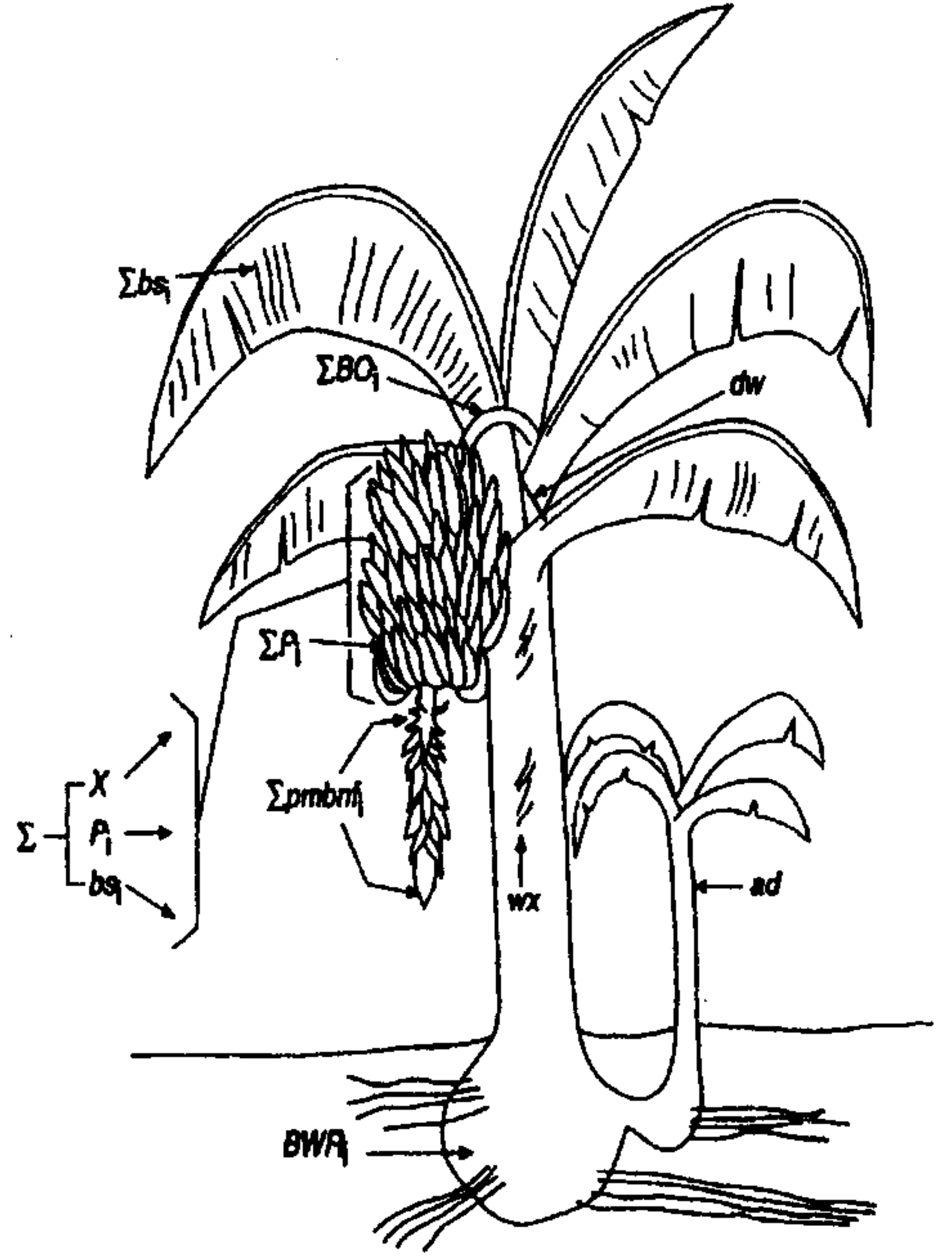
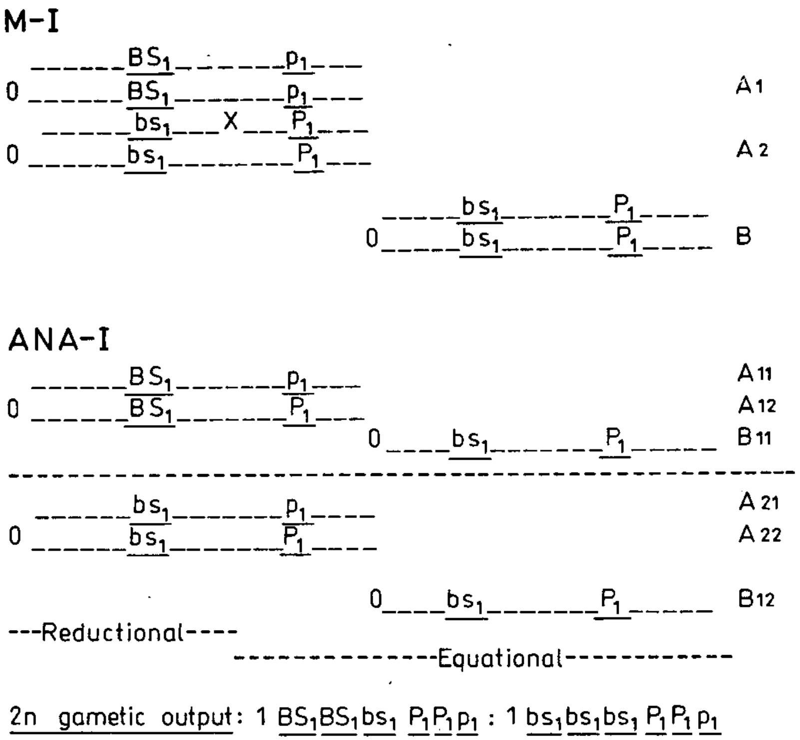


Fig. 1 First-division segregation in second-division restitution (SDR) 2n eggs of plantain (*Musa* spp., AAB group) for a locus close to the centromere (BS_1). No second-division segregation occurs for the P_1 locus, which is located far away from the centromere (at least after the first cross over) due to omission of the second meiotic division. O = centromere; X = cross over



Segregation at Microsatellite Loci in Haploid and Diploid Gametes of *Musa*

Hutokshi K. Crouch, Jonathan H. Crouch,* Robert L. Jarret, Perry B. Cregan, and Rodomiro Ortiz

Crop Sci. 38:211–217 (1998)

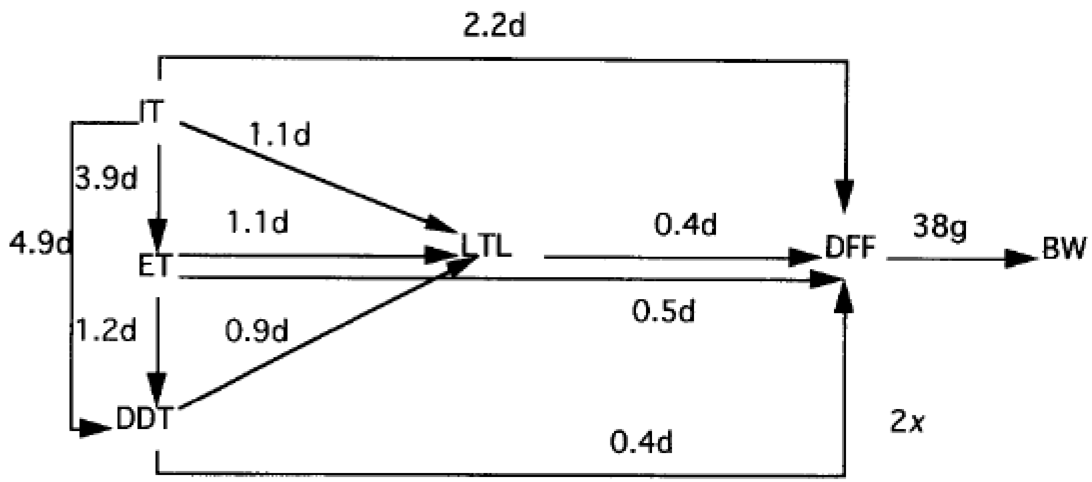
Hereditas 126: 255–259 (1997)

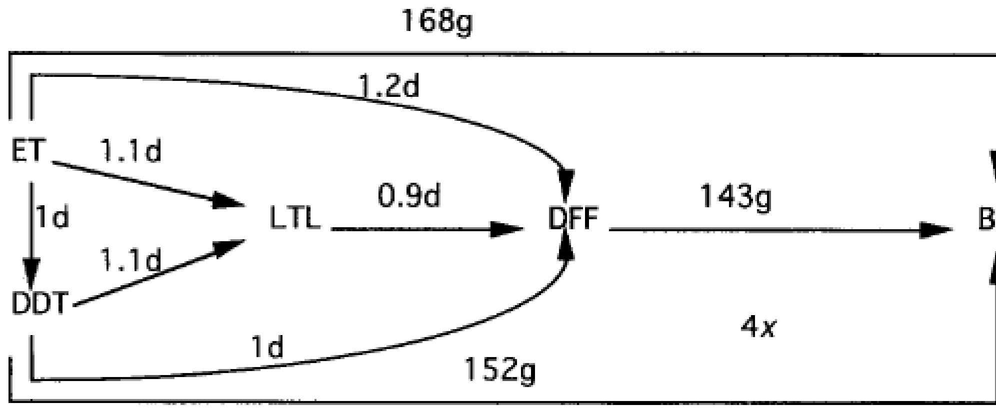
Ploidy manipulations and genetic markers as tools for analysis of quantitative trait variation in progeny derived from triploid plantains

RODOMIRO ORTIZ, KATHELYNE CRAENEN and DIRK VUYLSTEKE

Trait	Multiple regression model	Standard error
Bunch weight (BW)	BW (kg) $= 4.4\ X + 3.5\ A_1 + 4.2\ D_2 - 5.5\ A_2 + 6.3$	2.4 kg $plant^{-1}$
Number of hands (H)	$H = 3.61\ D_1 + 3.1$	1.2 hands
Number of fruits (F)	$F = 55.3\ D_1 + 44$	31.3 fruits
Av. fruit weight (AFW)	AFW(g) $= 58.0\ X + 33.2\ A_1 + 49.4\ D_1 - 7.3\ A_2 - 65.5$	22.4 g
Fruit length (FL)	FL (cm) $= 4.2 - 10.2\ A_1 - 7.0\ D_2 + 6.5\ A_2 - 0.01\ (A_1 \times D_2)$ $+ 9.3\ (A_2 \times D_1)$	2.4 cm
Fruit circumference (FC)	$2.9 - 8.0\ A_1 - 4.7\ D_2 + 4.4\ A_2 + 0.4\ (A_1 \times A_2) - 0.2\ (A_1 \times D_2)$ $+ 6.2\ (A_2 \times D_1)$	1.2 cm

X = ploidy level, A_1 = effect of allele substitution in P_1 locus, A_2 = effect of allele substitution in bs_1 locus, D_1 = effect of dominance (i.e., intra-locus interaction) in P_1 locus, D_2 = net effect of intra-locus interaction in bs_1 locus





Influence of black Sigatoka disease on the growth and yield of diploid and tetraploid hybrid plantains

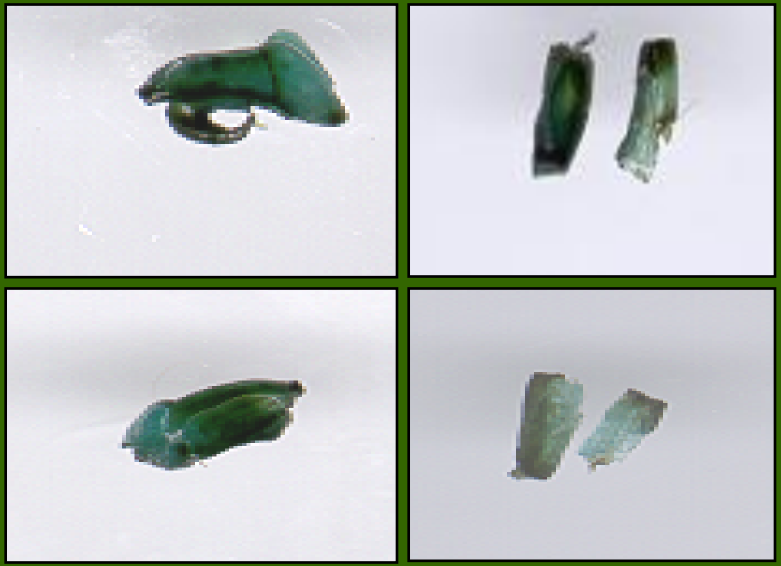
Kathelyne Craenen and Rodomiro Ortiz*

Crop Protection Vol. 17, No. 1, pp. 13–18, 1998

Engineering host plant resistance

A protocol for rapid, efficient, and genotype-independent *in vitro* regeneration of *Musa* from apical shoot meristem was developed and standardized

Transient expression of GUS (*uid* A) gene achieved in apical shoot tip following *Agrobacterium* mediated transformation



African Journal of Biotechnology Vol. 7 (10), pp. 1438-1445, 16 May, 2008

Rapid and efficient production of transgenic East African Highland Banana (*Musa* spp.) using intercalary meristematic tissues

Leena Tripathi[1]*, Jaindra Nath Tripathi[1] and Wilberforce Kateera Tushemereirwe[2]

Expression of sweet pepper *Hrap* gene in banana enhances resistance to *Xanthomonas campestris* pv. *Musacearum*
Leena Tripathi, Henry Mwaka, Jaindra Nath Tripathi, Wilberforce Kateera Tushemereirwe
Molecular Plant Pathology 11 (6) pp. 721–73 (2010)

GM- plants established in confined field trial 5 months after planting

Banana plantation damaged by *Xanthomonas* wilt

GM Bananas: first harvest shows promise

- The first harvest of genetically modified bananas planted in Australia, in the South Johnstone area south of Cairns, has been picked (March 2010)
- The bananas are part of a project by Queensland University of Technology to improve the nutritional content of bananas, as a way of combating malnutrition in Africa, particularly in Uganda, where bananas are a staple food and very low in nutrients
- Initial results of the harvest show promise. Professor James Dale, head of the project at QUT's Centre for Tropical Crops and Biocommodities, told ABC News that the initial results of testing on the biofortified Cavendish bananas were "exciting"
- "This first planting is demonstrating that at least one of the combinations of genes we're putting is working really well for pro vitamin A, and we're concentrating on that," said Dale

http://www.ausfoodnews.com.au/2010/03/18/gm-bananas-first-harvest-shows-promise.html

AFN
THOUGHT FOR FOOD

Issues about genetic engineering

Appetite
doi:10.1016/j.appet.2011.06.001 |

Attitudes, perceptions, and trust. Insights from a consumer survey regarding genetically modified banana in Uganda

Enoch M. Kikulwe[a], Justus Wesseler[b] and Jose Falck-Zepeda[c]

Survey among 421 banana-consuming households between July and August 2007

Results show a **high willingness to purchase GM banana among consumers**

Sole consumers are more skeptical about the unknown health effects the GM technology may generate compared to adopters

β-Carotene content of selected banana genotypes from Uganda

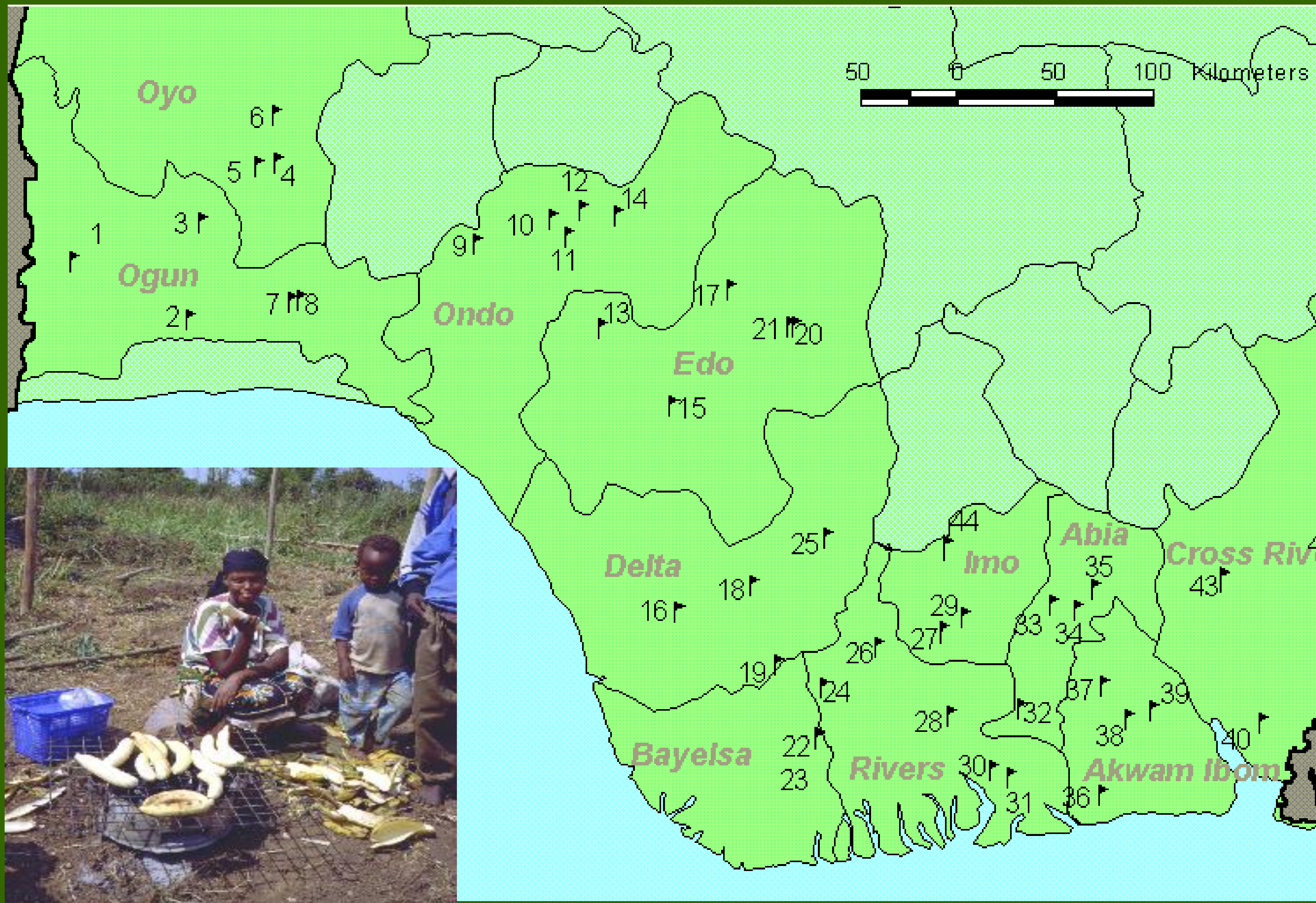
Robert Fungo[1] and Michael Pillay[2*]

There was **wide variability in β-carotene levels** within and among the different groups of banana

Banana genotypes from **Papua New Guinea (PNG) had the highest levels of β-carotene:** as high as 2594.0 µg/100 g edible pulp

African Journal of Biotechnology Vol. 10(28), pp. 5423-5430, 20 June, 2011

Efficient partnerships for successful farmer delivery



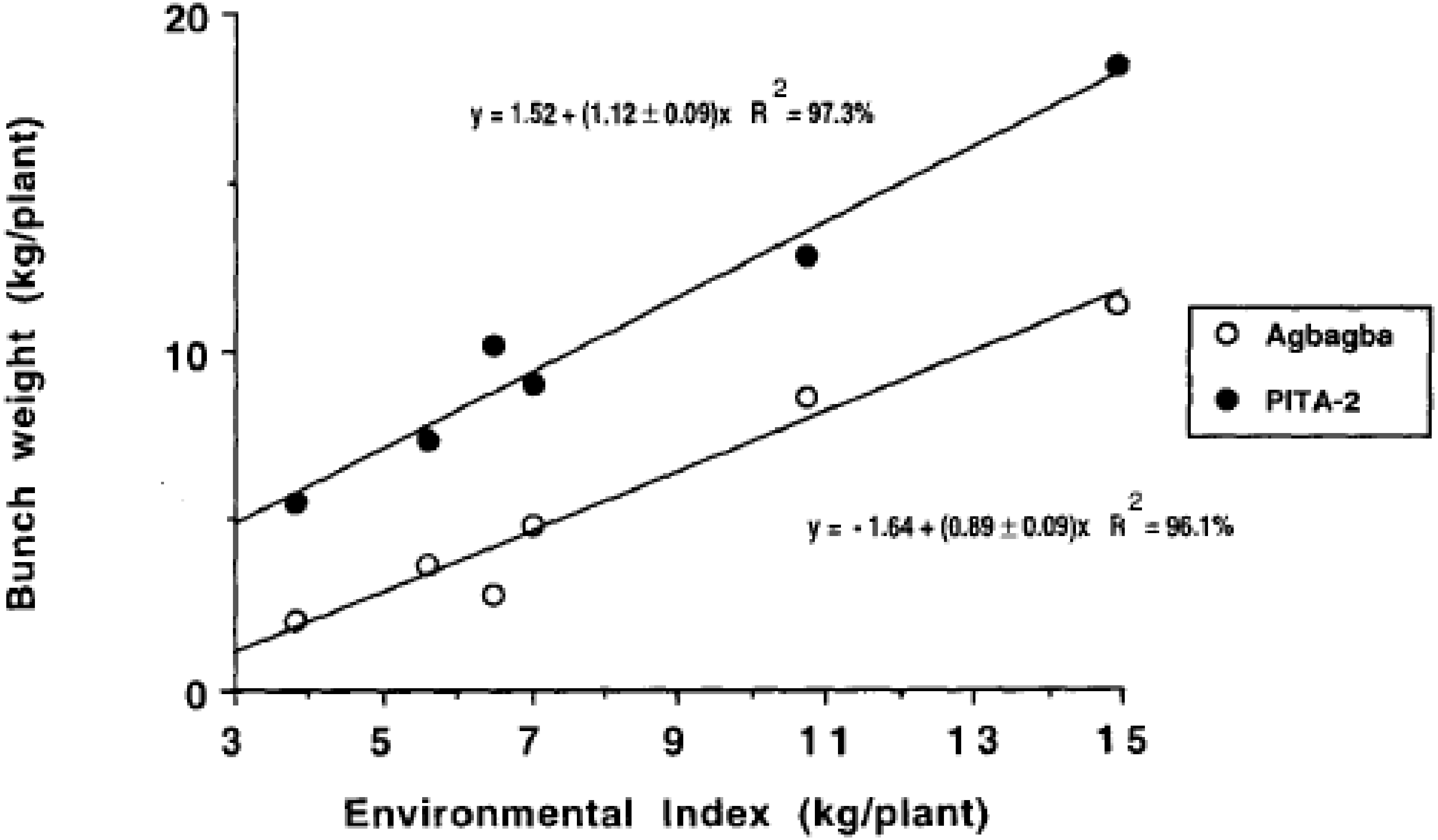
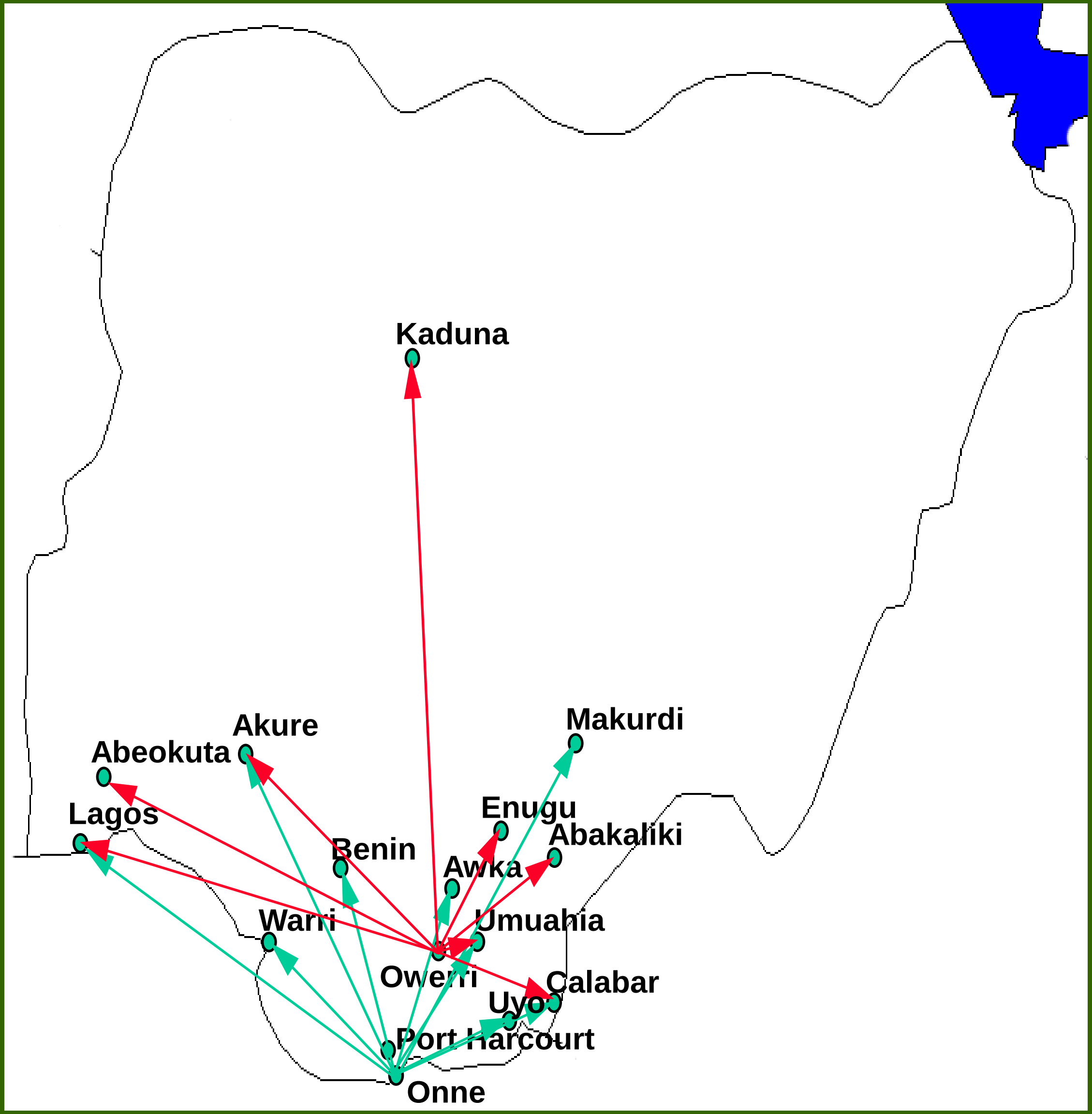


Figure 8. Yield stability of the False Horn plantain landrace Agbagba and the black sigatoka resistant tetraploid hybrid PITA-2 (also known as TMPx 548-9) in on-farm trials in southeastern Nigeria (1994).

Efficient partnerships for successful delivery



Plants distributed to 710 villages, 30 000 farmers

NGOs: 68% of the villages, 99% of the farmers, 90% of the plants

SHELL: 59 farmers per village

AGIP: 27 farmers per village

GOs: 4 farmers or less per village

HortScience 33(2):360–361. 1998.

'PITA-14': A Black Sigatoka–Resistant Tetraploid Plantain Hybrid with Virus Tolerance

Rodomiro Ortiz[1] and Dirk Vuylsteke[2]

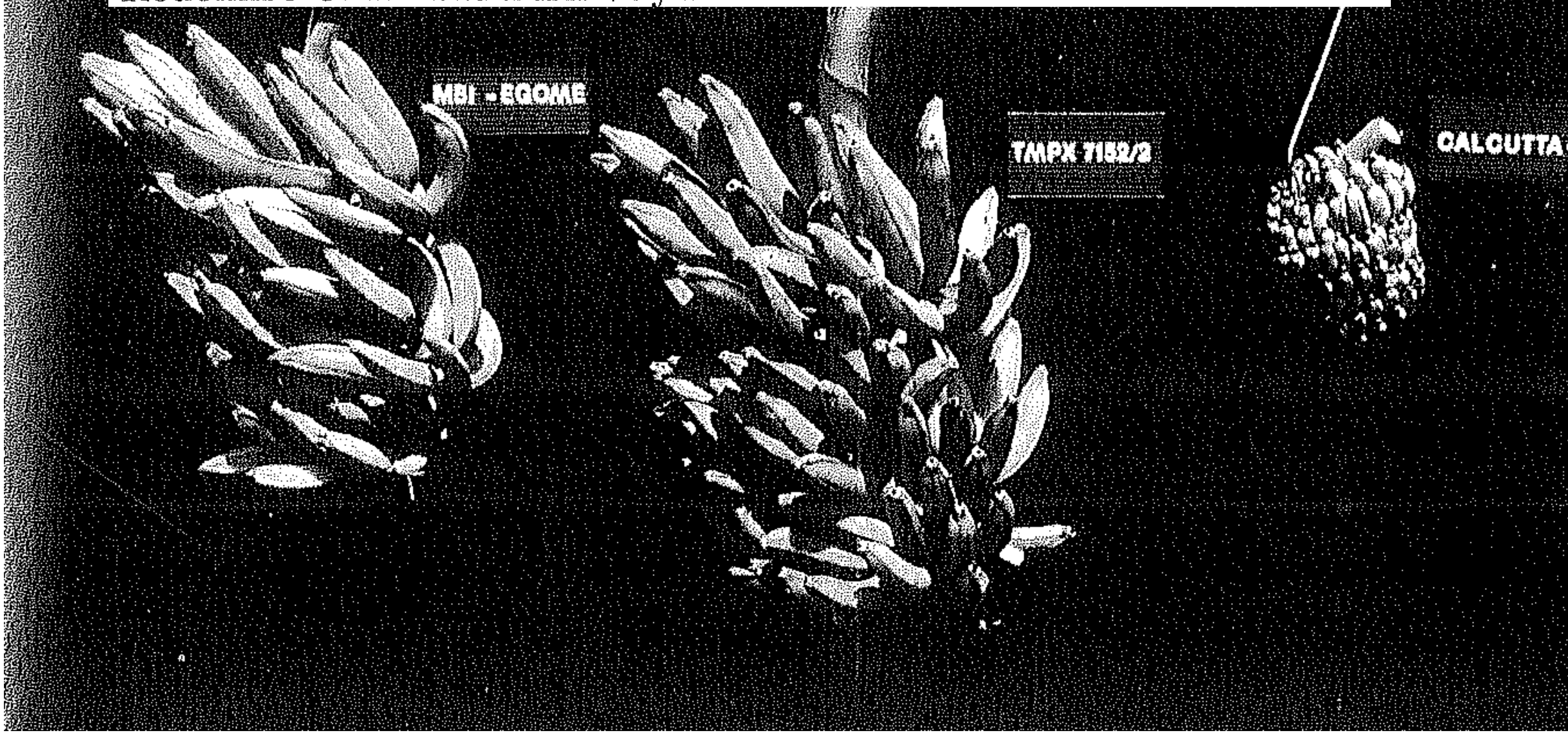


Fig. 1. Black sigatoka–resistant tetraploid plantain hybrid 'PITA-14' (**center**), obtained from crossing the triploid susceptible French plantain 'Mbi Egome-1' (**left**) with the highly resistant wild diploid banana 'Calcutta-4' (**right**). The bunch of 'PITA-14' weighed 22 kg, while the bunch of its maternal parent weighed 13.5 kg.

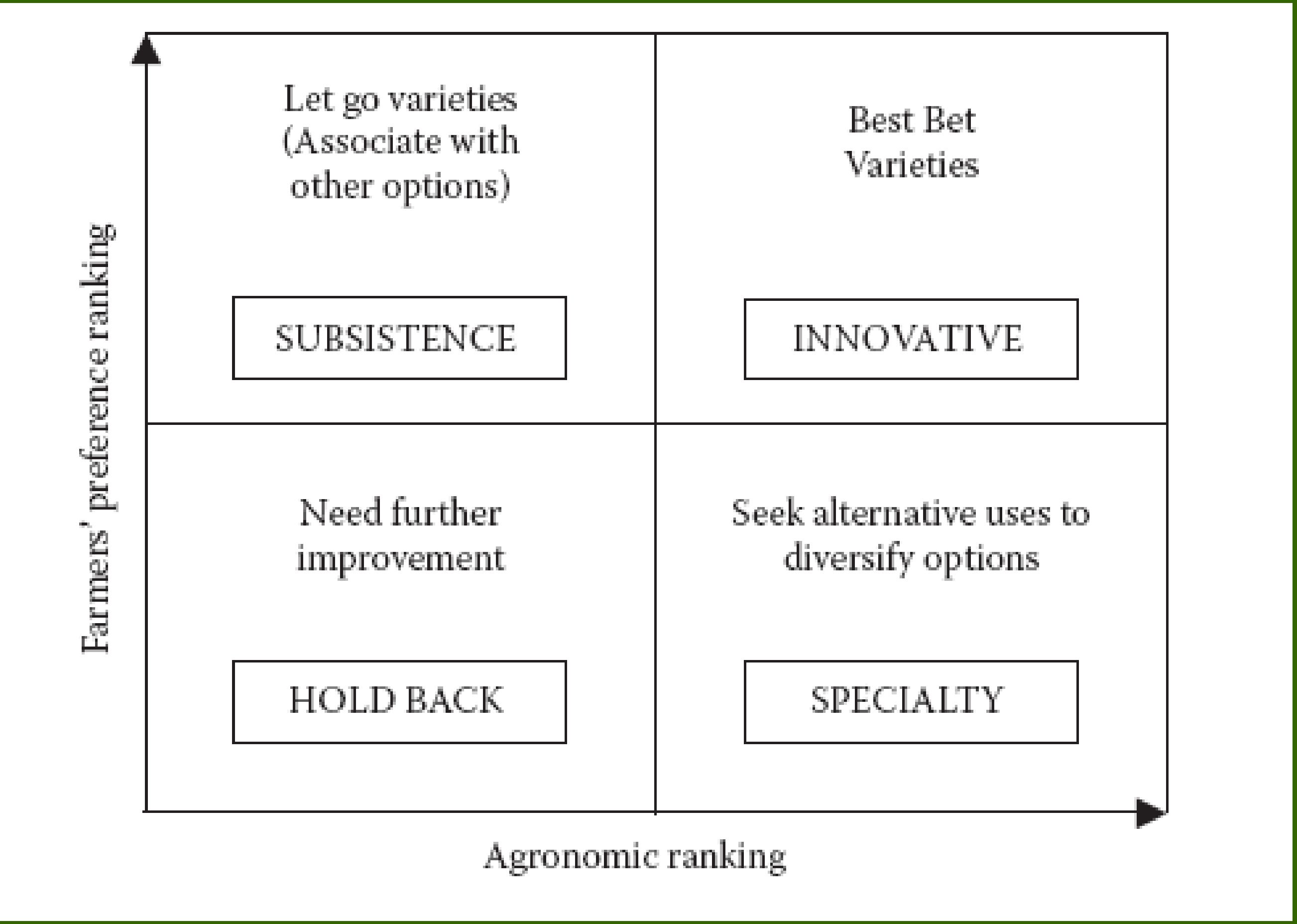
African Journal of Biotechnology Vol. 4 (10), pp. 1045-1053, October 2005

Agroeconomic evaluation of black Sigatoka resistant hybrid plantains under smallholder management systems

J.I. Lemchi[1*], C.I. Ezedinma[1], M. Tshiunza[2], Tenkouano[2], B.O. Faturoti[2]

- **Performance of the hybrids under farmer-managed systems, using PITA14 (a hybrid) and Agbagba (best landrace)**
- **Average black Sigatoka resistant index was 96% for PITA14 against Agbagba's 48%**
- **The mean bunch weight was 13.3 kg for PITA14 and 7 kg for Agbagba.**
- **83% of the farmers harvested 124 bunches from 81 mats of PITA14, while 55% harvested 62 bunches from 52 mats of Agbagba.**
- **Each farmer obtained an equivalent of US$ 8.62 from PITA14 and US$ 4.33 from Agbagba**
- **The post harvest technology attributes were ranked higher for the hybrid**
- **The combination of disease resistance and increased yield by the hybrid is suggestive of its high adoption potential**

Schematic representation of the outcome of farmer participation in cultivar selection



HortScience 33(2):358–359. 1998.

'BITA-3': A Starchy Banana with Partial Resistance to Black Sigatoka and Tolerance to Streak Virus

Rodomiro Ortiz[1] and Dirk Vuylsteke[2]

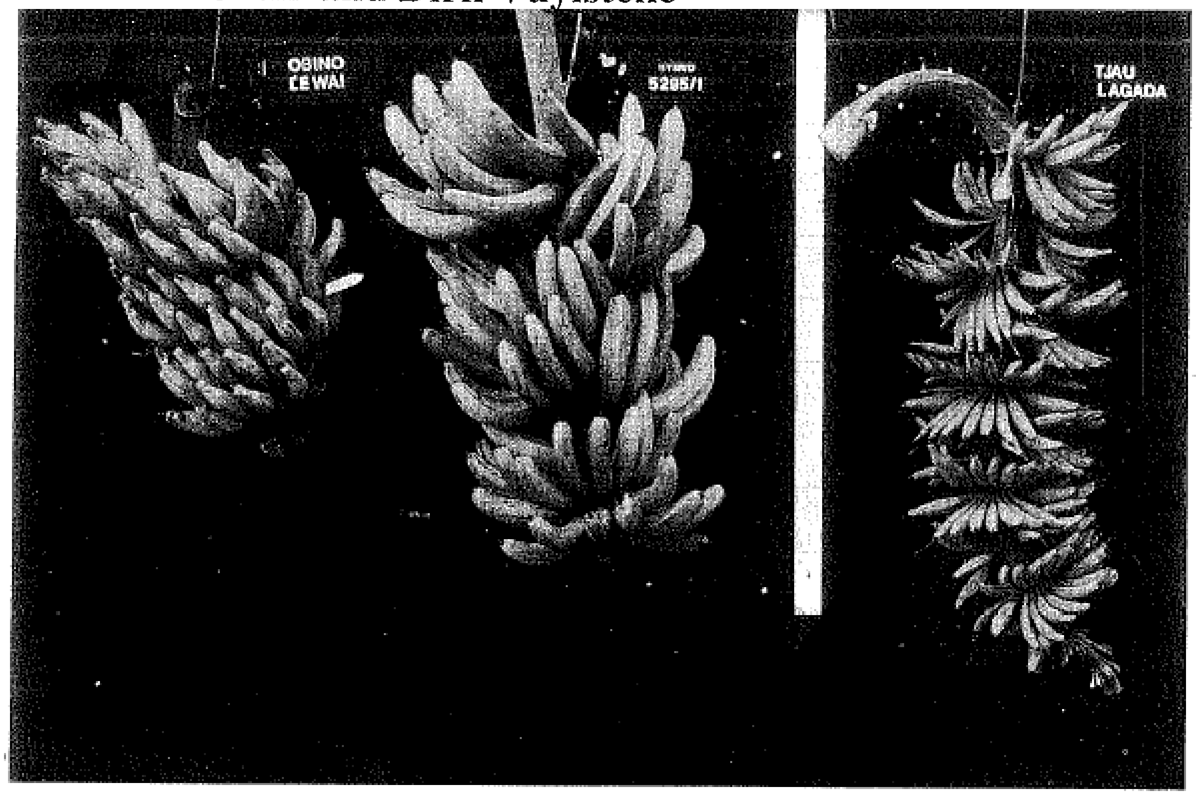
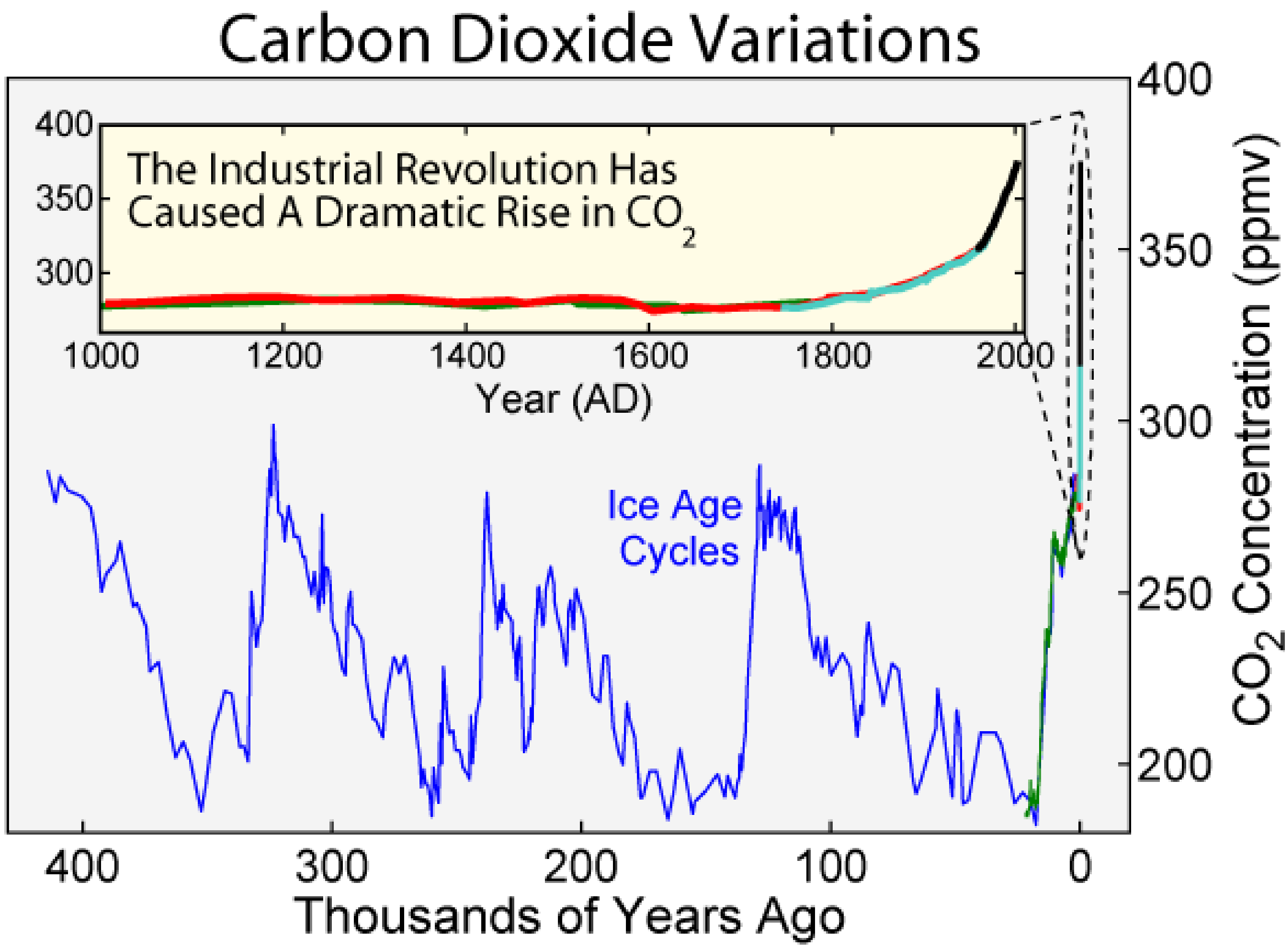


Fig. 1. Tetraploid banana hybrid 'BITA-3' (**center**), obtained from crossing the triploid starchy banana 'Laknau' with the diploid banana 'Tjau Lagada' (**right**). The bunch of 'BITA-3' (or TMBx 5295-1) weighed 18 kg, and had 8 hands of long fruit (27 cm). This bunch outyielded that of the medium French plantain landrace 'Obino l'Ewai' (**left**). 'Tjau Lagada' (**right**) shows a medium-size bunch (9 kg) bearing 10 hands with many small fruit (12 cm).

Improved hybrids act as "bio-pesticides" to enhance landrace performance and preserve diversity (50% substitution) in cultivar mixtures

Clone	Treatment	Bunch Weight (kg)	Index of Nonspotted Leaves (%)
		Nigeria	
Agbagba	Agbagba sole	4.9 ± 0.2	43.2 ± 3.1
Agbagba	Agbagba + BITA3	8.1 ± 0.6	55.7 ± 2.1
Agbagba	Agbagba + PITA14	7.1 ± 0.4	51.4 ± 3.6
Agbagba	Agbagba + PITA17	7.3 ± 0.3	52.8 ± 2.7
BITA3	Agbagba + BITA3	16.7 ± 1.1	73.8 ± 2.8
PITA14	Agbagba + PITA14	12.7 ± 0.6	89.7 ± 2.0
PITA17	Agbagba + PITA17	12.7 ± 0.7	75.4 ± 3.0
		Cameroon	
Essong	Essong sole	9.6 ± 1.9	24.3 ± 0.5
Essong	Essong + BITA3	9.1 ± 2.6	30.8 ± 3.7
Essong	Essong + PITA14	11.2 ± 0.8	37.7 ± 3.6
Essong	Essong + PITA21	10.6 ± 3.0	39.6 ± 7.5
BITA3	Essong + BITA3	11.5 ± 1.4	68.7 ± 1.2
PITA14	Essong + PITA14	9.0 ± 1.2	72.0 ± 0.6
PITA21	Essong + PITA21	6.6 ± 0.7	66.6 ± 1.8



Carbon Dioxide Variations
The Industrial Revolution Has
Caused A Dramatic Rise in CO2
400
350
300
1000
1200
1400
1600
1800
2000
Year (AD)
Ice Age
Cycles
400
350
300
250
200
CO2 Concentration (ppmv)
400
300
200
100
0
Thousands of Years Ago

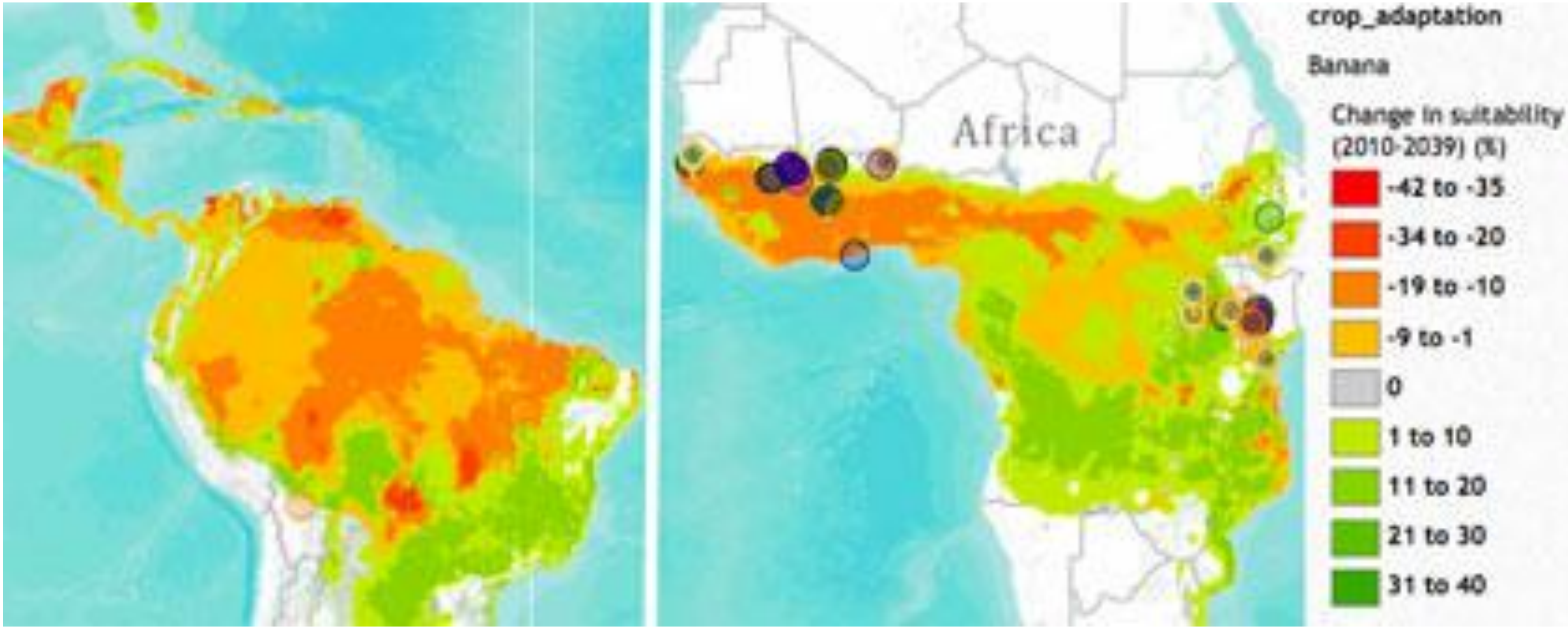
Potential impact of climate change in plantain and banana

- **Water needs for bananas and plantain are relatively high** and both are very susceptible **to dry soils**:
- **Cooking bananas (ABB)** are **most promising 3*x* cultivars for transient dry conditions** because of their high potential for restricting water use due to their **ability to close stomata** and **higher rate of conductance and transpiration in the afternoon.** They can also show **early root development**
- **B genome**: a valuable source of alleles for adapting cooking bananas to mild drought environments

Global warming and *Musa*

- **Temperature increase** will allow cultivation of banana and plantain at **higher altitudes** but it may be **associated with an increase of new pests and diseases**
- **Gradual increase of temperature, intense precipitation** followed by **dry periods and high foliar humidity**, favored **disease incidence and severity** of both black and yellow **Sigatokas**

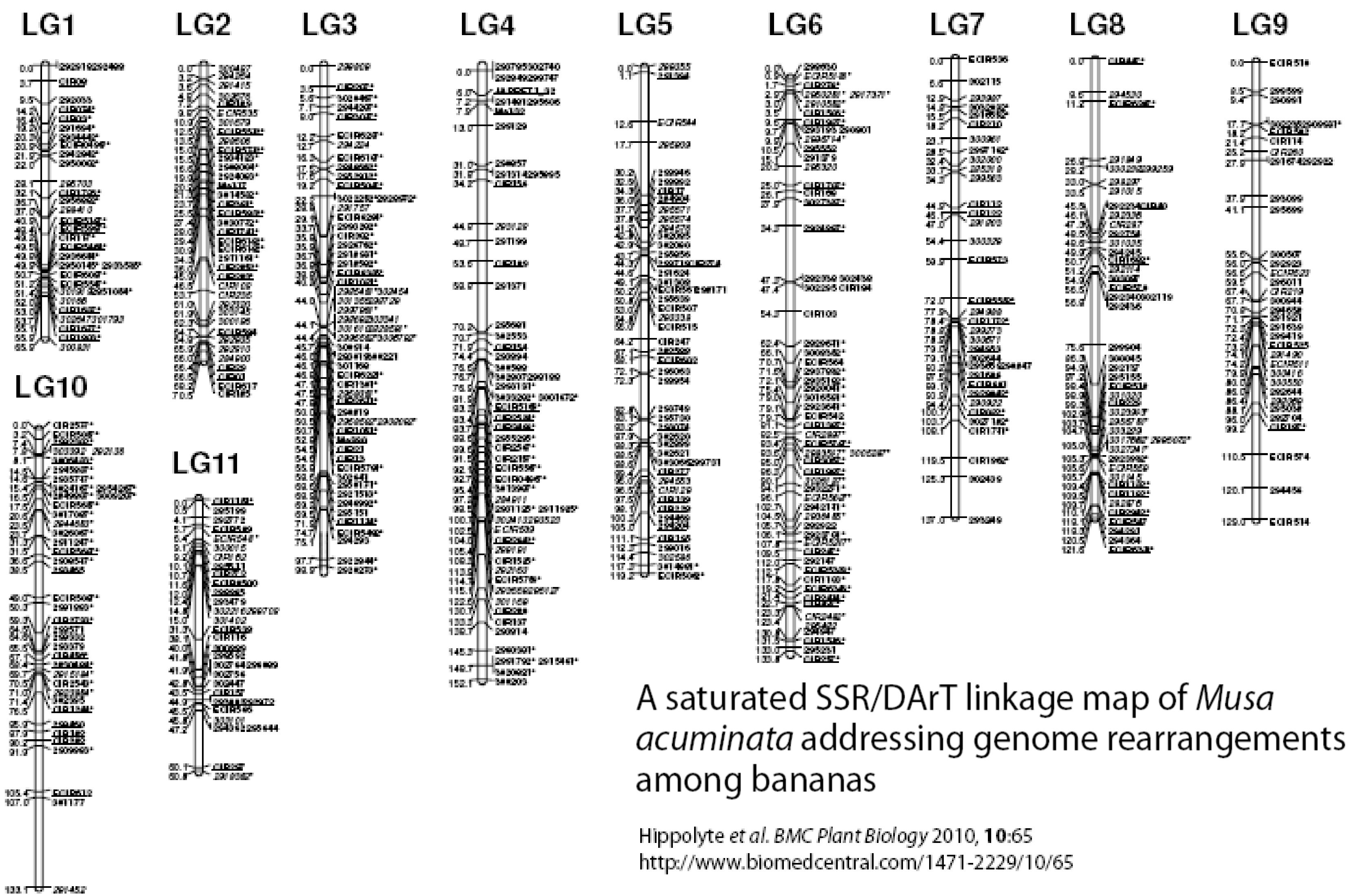
Banana suitability changes in Latin America and Africa



- Increased temperatures are expected to favor banana production in cool Eastern and Southern Africa
- Black Sigatoka pressure may decrease in Central America and the Atlantic coasts of Brazil, Colombia, and Venezuela

Source: http://ccafs.cgiar.org/blog/bananas-will-face-climate-stress

Reference *Musa acuminata* map (built from Pisang lili and Borneo)



A saturated SSR/DArT linkage map of *Musa acuminata* addressing genome rearrangements among bananas

Hippolyte *et al. BMC Plant Biology* 2010, **10**:65
http://www.biomedcentral.com/1471-2229/10/65

Breeding banana and plantain: from intractability to feasibility

“A broad-based, improved *Musa* germplasm with pest and disease resistance will be a major component to achieve sustainable production of this vegetatively propagated, perennial crop. Such germplasm can be produced through conventional cross-breeding, enhanced by the utilization of innovative methods for the introduction of additional genetic variation. Also, the increased use of molecular markers will accelerate the process of recurrent selection of improved *Musa* germplasm and, hence, facilitate the development of new hybrids. The prospects of banana and plantain breeding are unlimited and increased efforts will at once initiate a new phase of *Musa* evolution.”

Dirk R. Vuylsteke (1958-2000)

Innovation for development

- Health
- Life
- Dreams

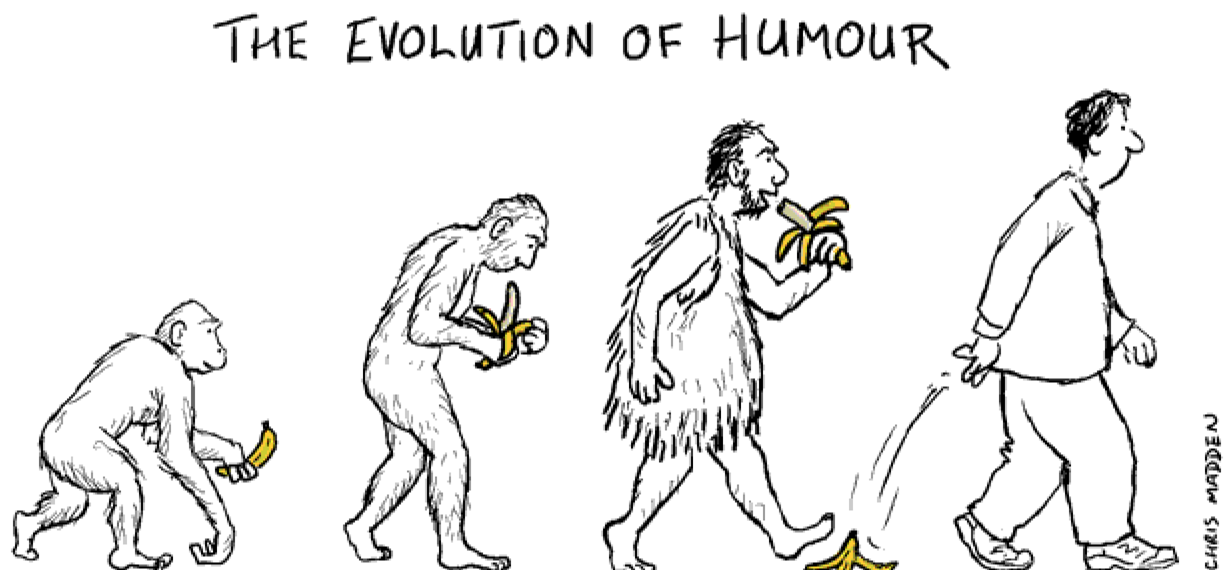








EVOLUTION
Still think we didn't evolve from apes?



THE EVOLUTION OF HUMOUR
CHRIS MADDEN