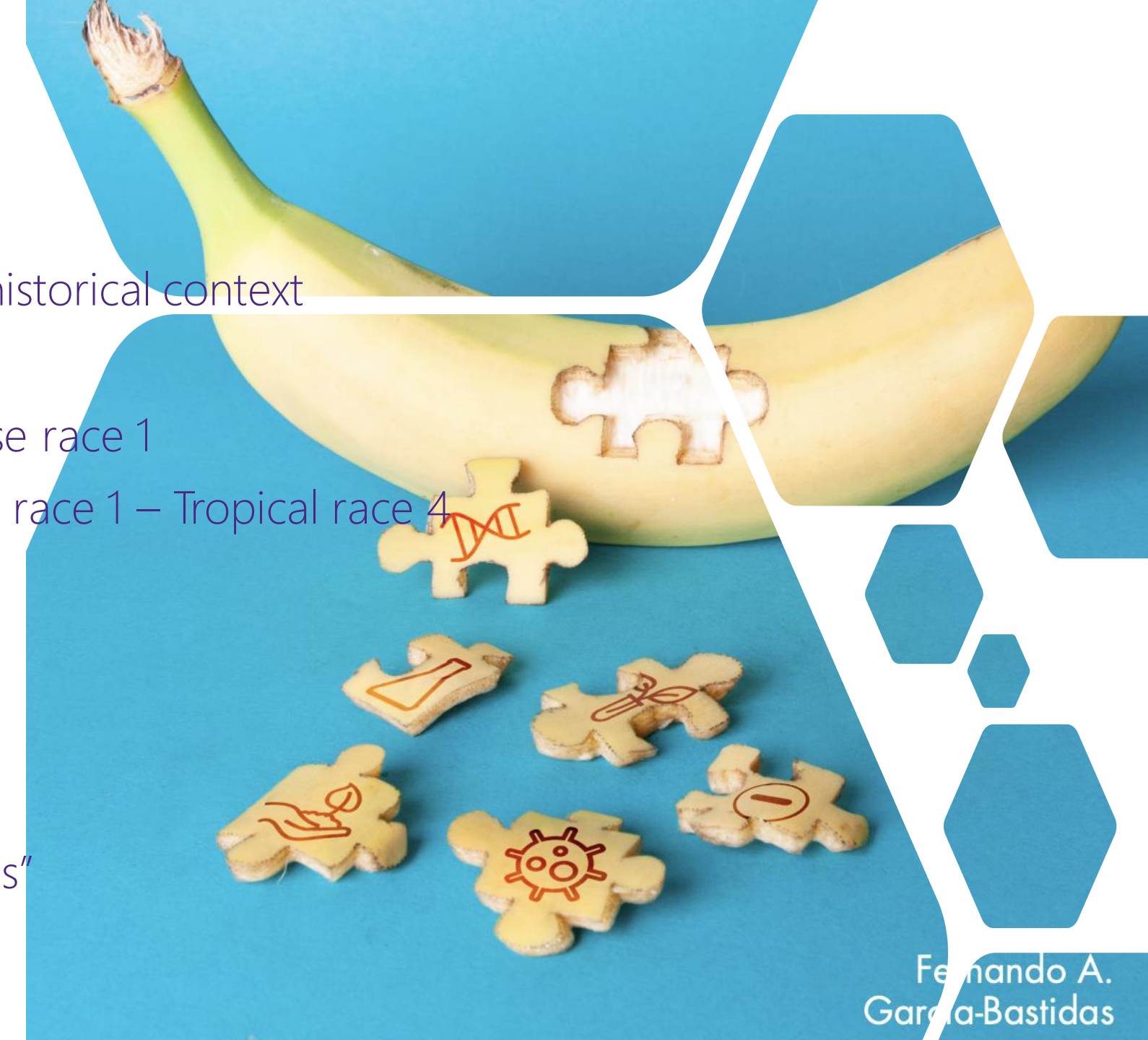
PANAMA DISEASE IN BANANA: PAST, PRESENT AND CHALLENGES FOR THE FUTURE

Fernando A. Garcia-Bastidas *Ph.D*

START PRESENTATION

CONTENT

- Bananas and panama disease historical context
  - Bananas
  - Gros Michel & Panama disease race 1
  - Cavendish & Panama disease race 1 – Tropical race 4
  - Spreading and diagnostics
- The pathogen
  - Symptoms
  - Genetic diversity
- ~~Control~~ Management "strategies"



BONITA

4229
TURBANA
COLOMBIA
BURRO

Chiquita

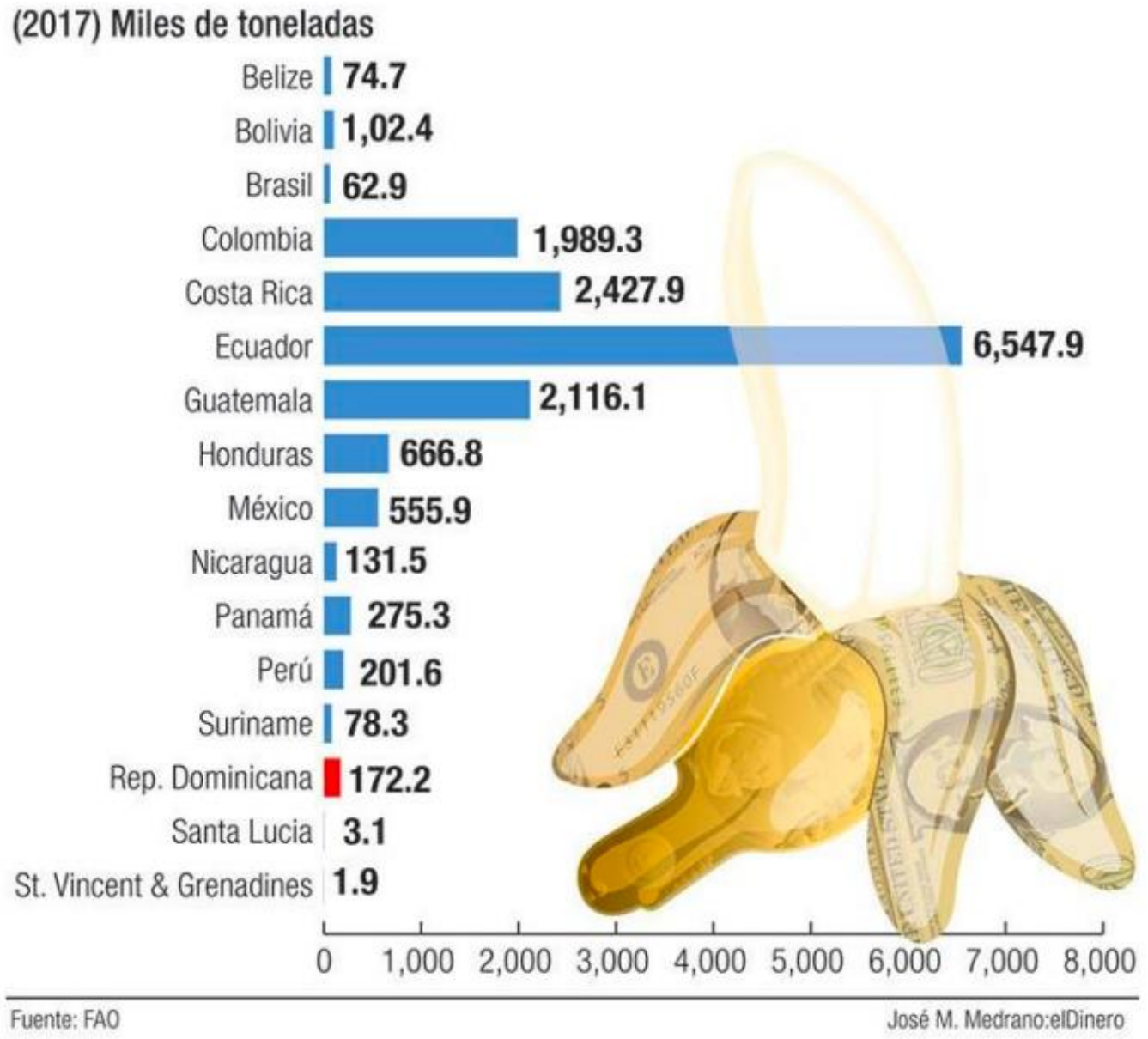
Dole

FAIRTRADE

Fyffes

Del Monte
Quality

PRODUCCIÓN GLOBAL BANANO

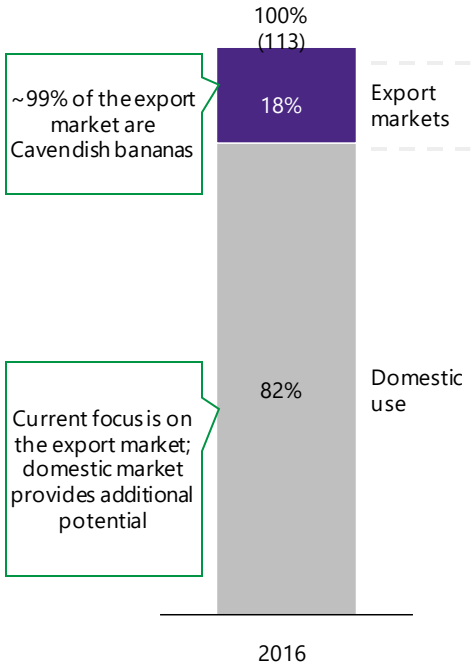


~ 70% OF THE EXPORT BANANAS ARE SUPPLIED BY ONLY 5 COUNTRIES;

50-50 PRODUCED BY MULTINATIONALS AND SME'S

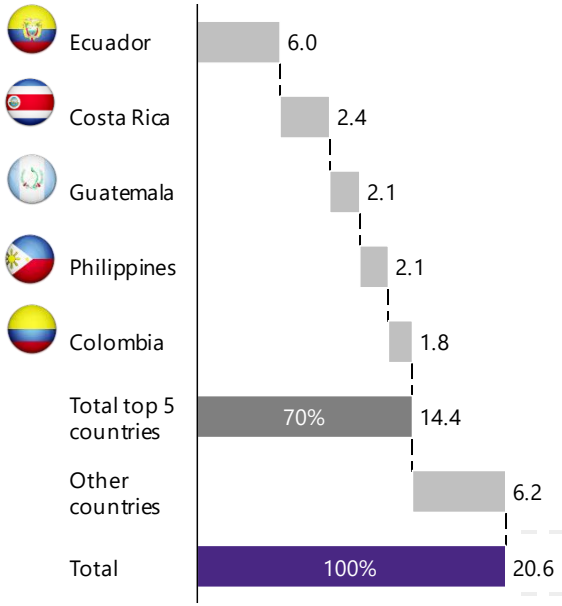
MAJORITY OF THE BANANAS IS PRODUCED FOR DOMESTIC USE AND ~17% IS EXPORTED

BANANA PRODUCTION VOLUMES, 2016 (113M TONNES)



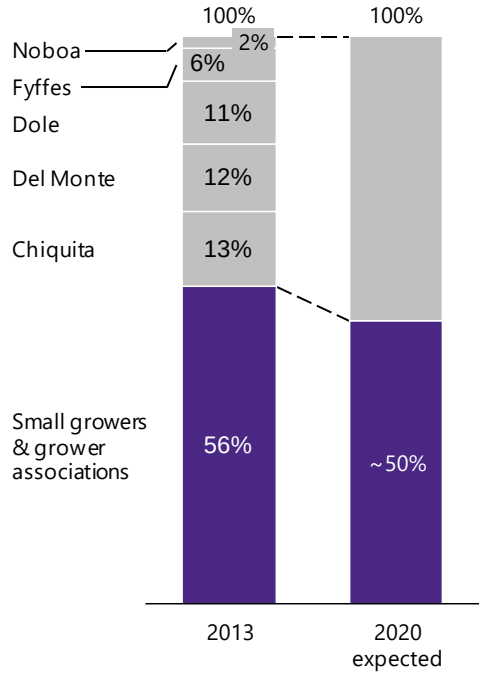
~70% OF THE BANANA EXPORT MARKET IS SUPPLIED BY ONLY 5 COUNTRIES

EXPORT MARKET VOLUMES, 2016 (M TONNES)



SME GROWERS ARE EXPECTED TO HAVE AN EXPORT MARKET SHARE OF ~50% IN 2020

MARKET SHARES IN GLOBAL BANANA EXPORTS, 2013-20E (%)



SOURCE: FAO, THECONVERSATION.COM

Bananas under attack. Major problems are associated to fungal diseases Black Sigatoka and Panama disease)

BANANA DIVERSITY

- More than 1.200 varieties
  - 650 triploid cultivars
  - 290 diploid cultivars
  - Hybrids
  - 180 wild accessions

Papua New Guinea

‘Seseve’

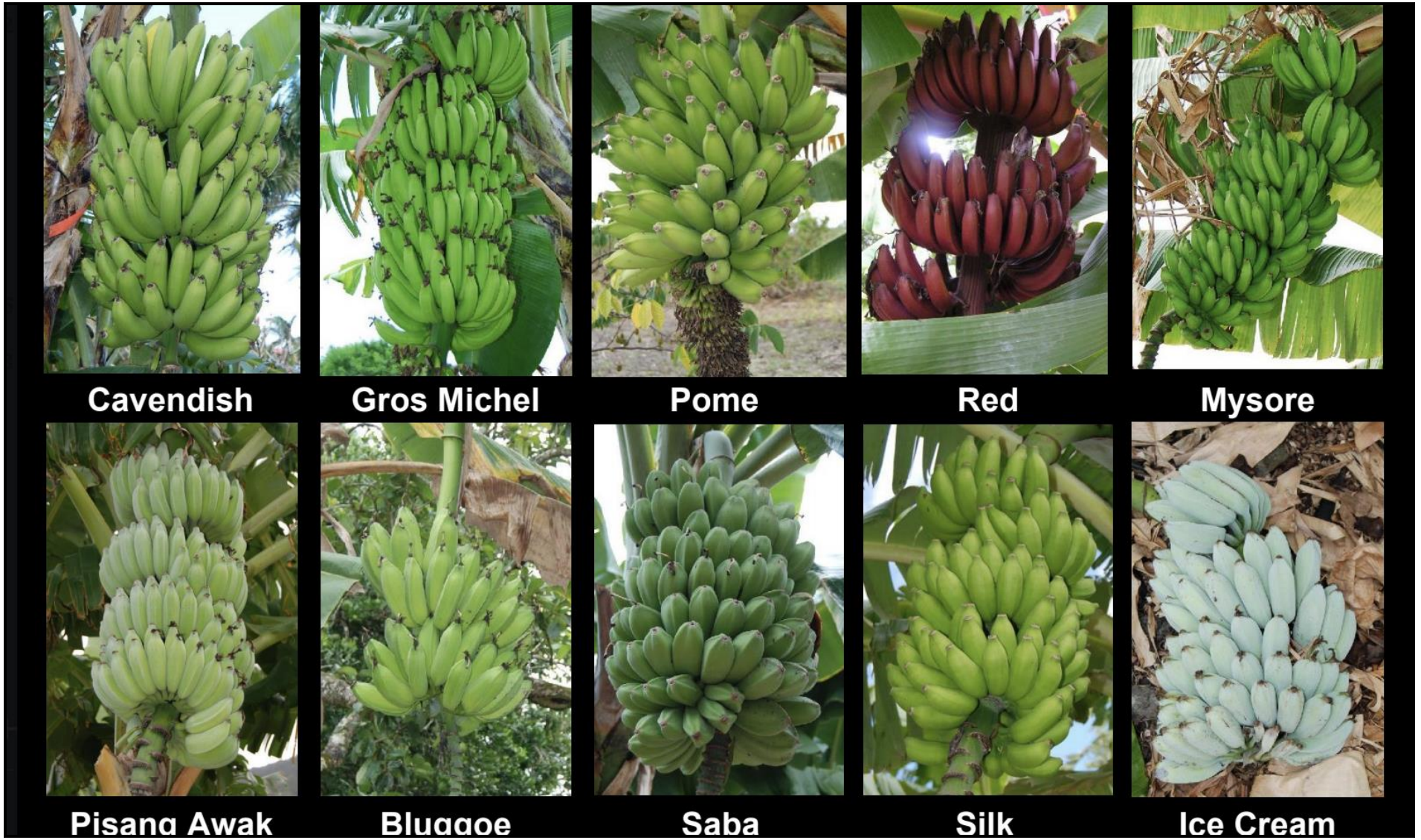
‘5-minute’

‘Talasea’

‘Ruhuvia Chichi’

DIPLOIDS

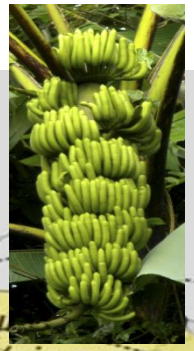
Photos by Smith GS



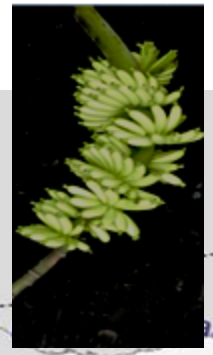
TRIPLOIDS

Photos by Smith GS

halabanensis



sumatrana



alasensis

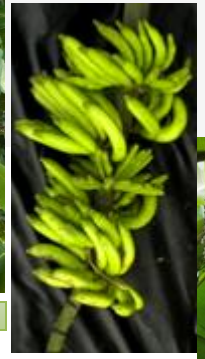
microcarpa

tomentosa

banksii

longipetiolata

malaccensis



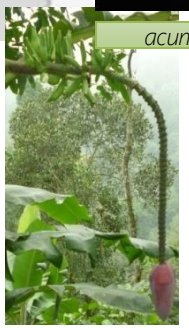
zebrina

breviformis

cerivera

bantamensis

nakaii



rutilifes

acuminata

Photos by Fajar Ahmad

Musa acuminata (AA)

X

Musa balbisiana (BB)

Pisang Mas (AA)

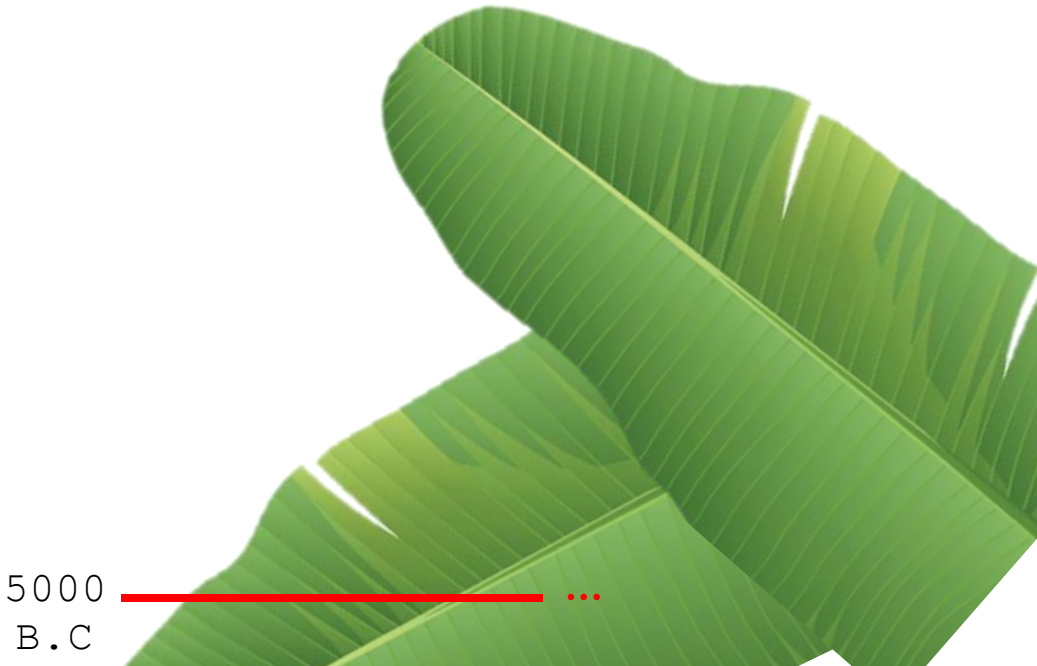
Cavendish (AAA)

Kepok (ABB)

AB, ABB, AAAA, ABBB….

BANANA DOMESTICATION

#TheHistoryOfTheBanana



5000 B.C ...

CAVENDISH: KING OF THE FRUITS

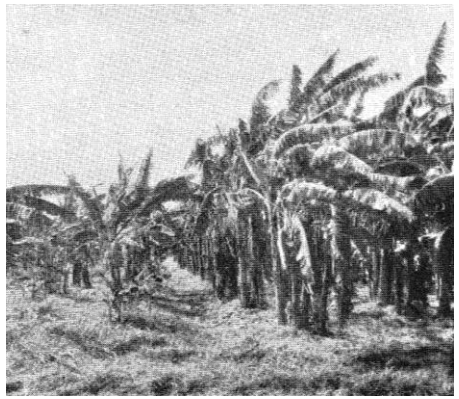
111 million

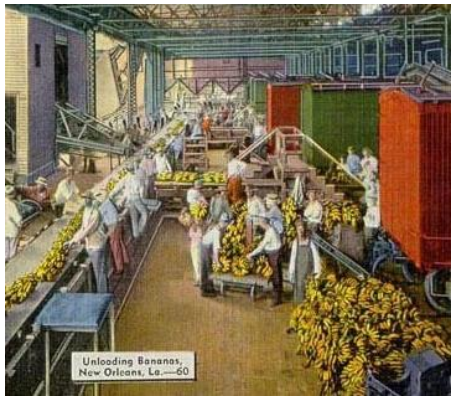
148 million

84 million

In million metric tons

THE GROS MICHEL ERA





1830 1890

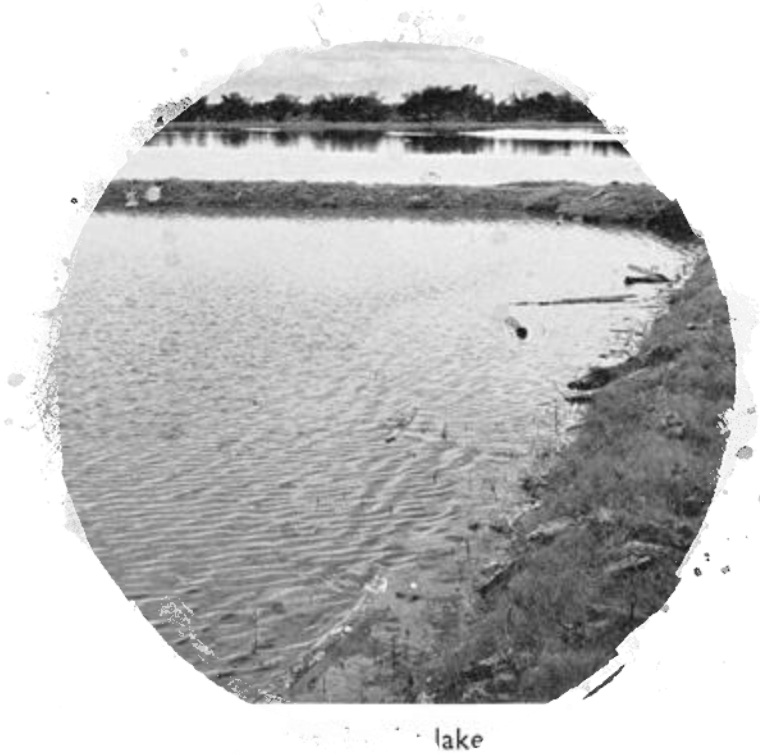
From Martinique through
the Caribbean and beyond

1890

First big losses

1890

Fusarium oxysporum f.sp. *cubense*
Race 1



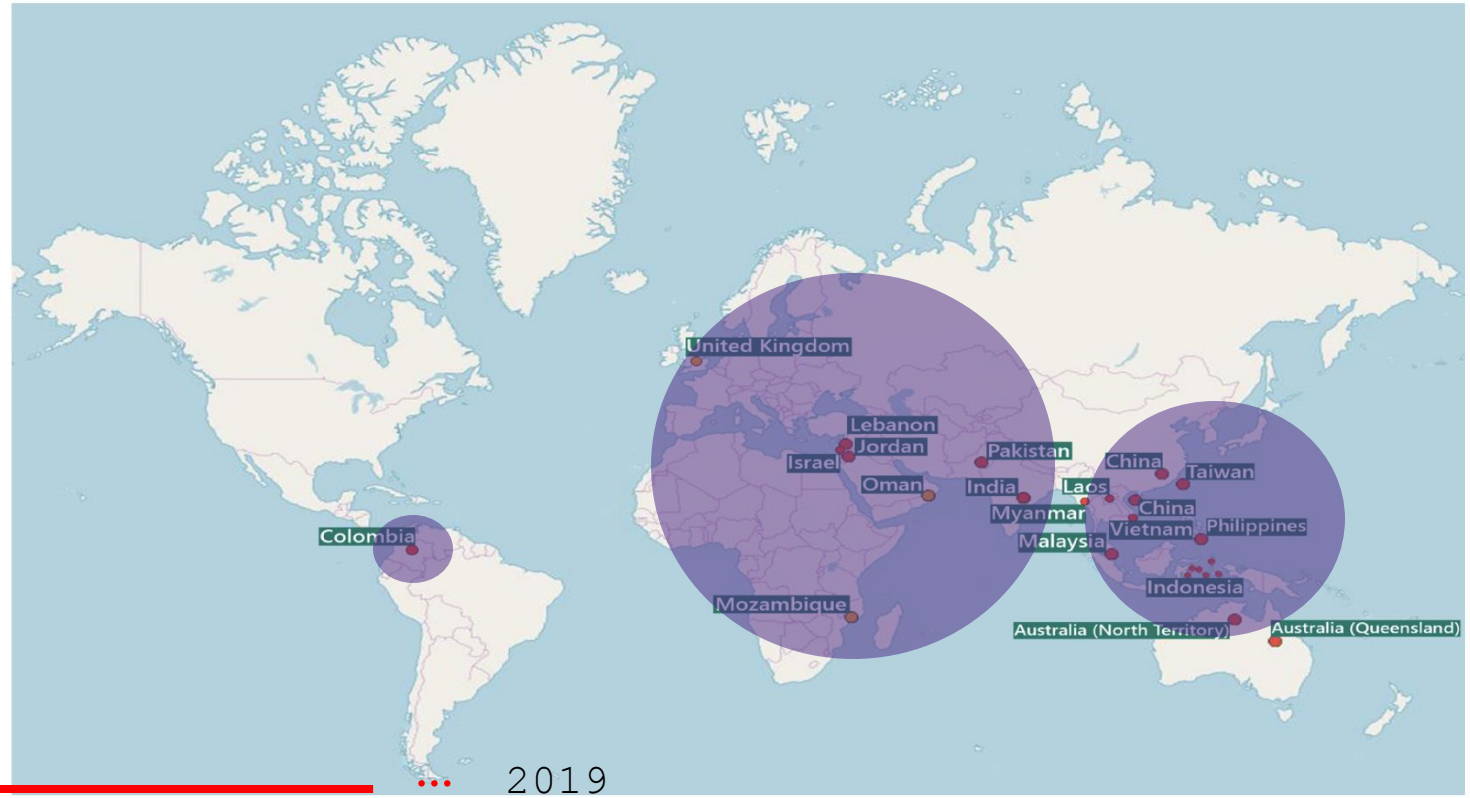
THE END OF THE GROS MICHEL ERA

1950 ...

CAVENDISH BANANAS SAVED THE BANANA INDUSTRY

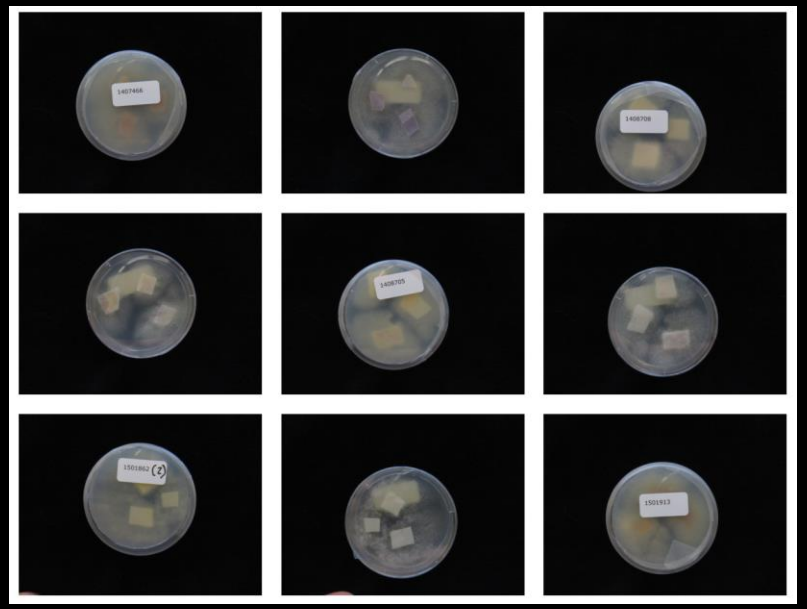
1950 ...

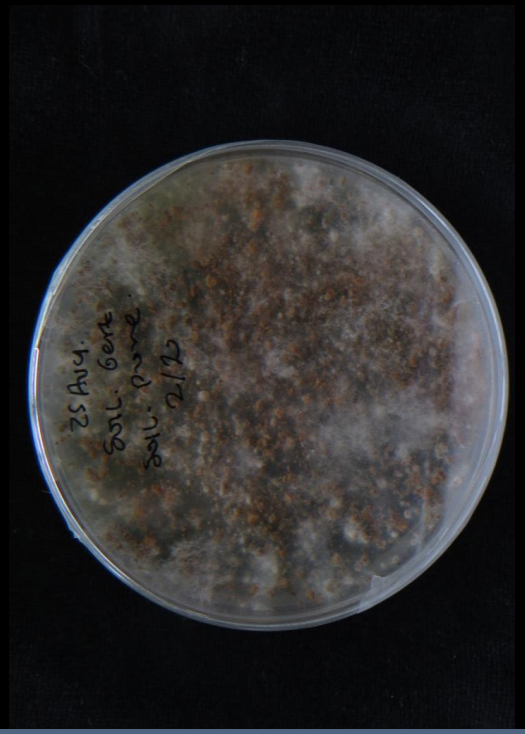
But not forever



1990 ••• 2019

© FA Garcia, Filipinas





DIAGNÓSTICO MOLECULAR APLICADO A DIFERENTES TIPOS DE MUESTRAS EN DIFERENTES REGIONES

- Jordania
- Libano
- Pakistan
- Indonesia
- Filipinas
- China
- Australia
- Colombia
- Mexico
- Surinam
- Costa Rica
- Thailandia
- Perú
- Ecuador

DIAGNÓSTICO LOS REPORTES INICIALES DE LAS NUEVAS INCURSIONES DE *FUSARIUM* RAZA 4 TROPICAL

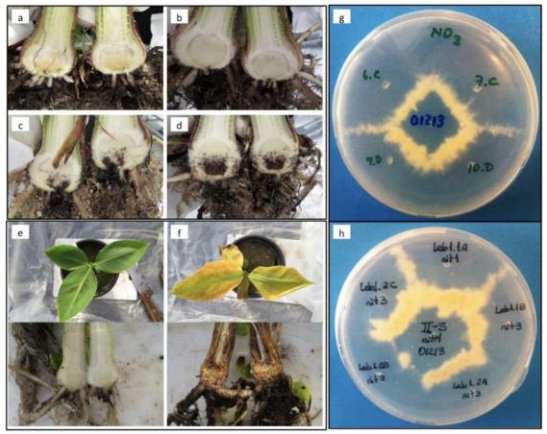
Disease Notes

First Report of *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 Associated with Panama Disease of Banana outside Southeast Asia

F. García-Bastidas, N. Ordóñez, J. Konkol, M. Al-Qasim, Z. Naser, M. Abdelwali, N. Salem, C. Waalwijk, R. C. Ploetz

2014

Jordania



DISEASE NOTES

OPEN

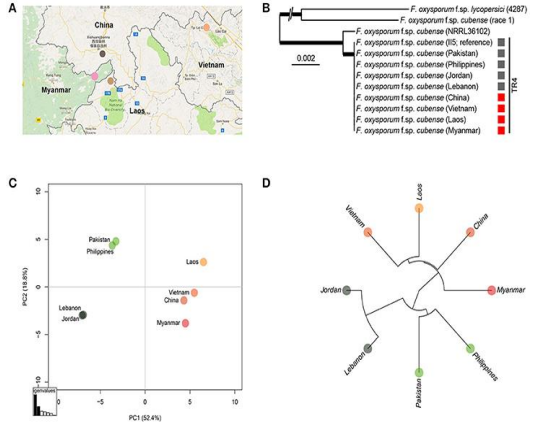
First Report of *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 Causing Panama Disease in Cavendish Bananas in Pakistan and Lebanon

N. Ordoñez, F. García-Bastidas, H. B. Laghari, M. Y. Akkary, E. N. Harfouche, B. N. al Awar, and G. H. J. Kema

Affiliations

2016

Líbano
Pakistán

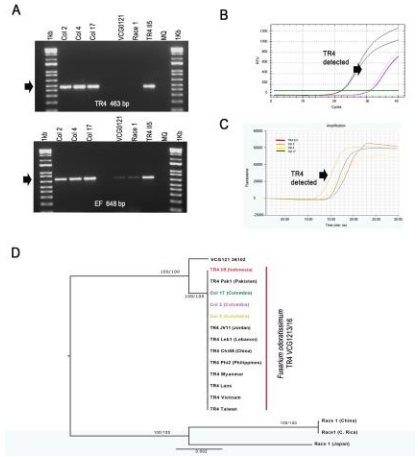


New Geographical Insights of the Latest Expansion of *Fusarium oxysporum* f.sp. *cubense* Tropical Race 4 Into the Greater Mekong Subregion

Si-Jun Zheng[1,2*†], Fernando A. García-Bastidas[3,4†], Xundong Li[1†], Li Zeng[1], Tingting Bai[1], Shengtao Xu[1], Kesuo Yin[1],

2018

Vietnam
Laos
Myanmar



First Report of Panama disease in Cavendish bananas caused by Tropical Race 4 in Colombia.

F.A. García-Bastidas[1†], J.C. Quintero-Vargas[2], M. Ayala-Vasquez[2], T. Schermer[3], M.F. Seidl[3], M. Santos-Paiva[4], A.M. Noguera[2], C. Aguilera-Galvez[5], A. Wittenberg[1], R. Hofstede[1] A. Sørensen[1], G.H.J. Kema[5†]

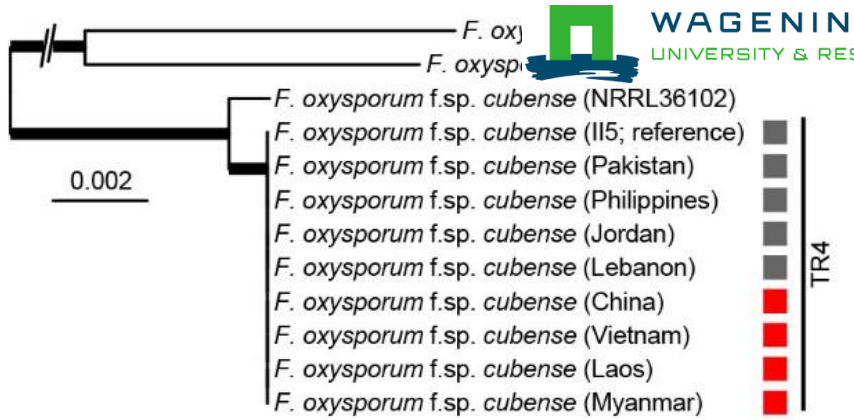
2019

Colombia

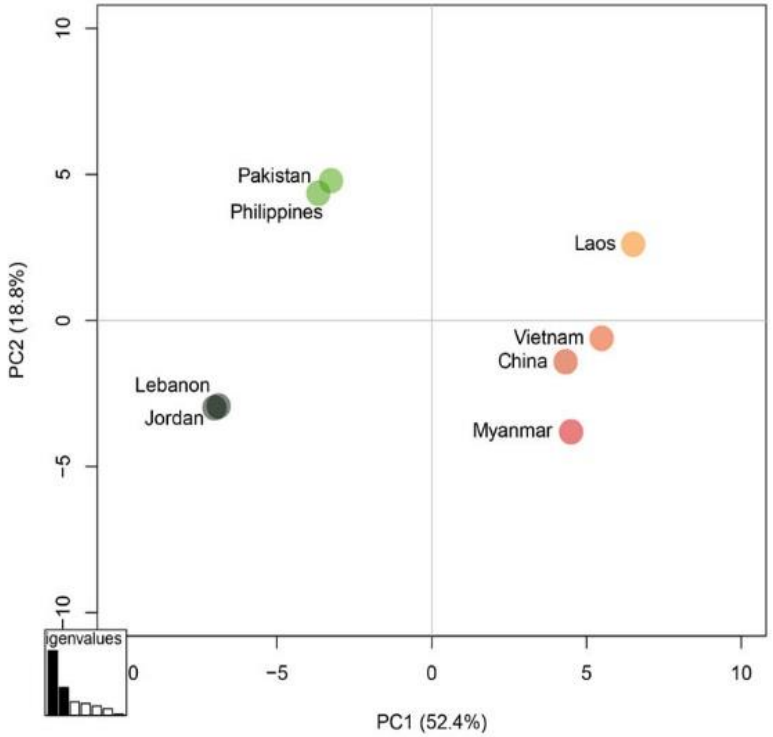
RAZA 4

A

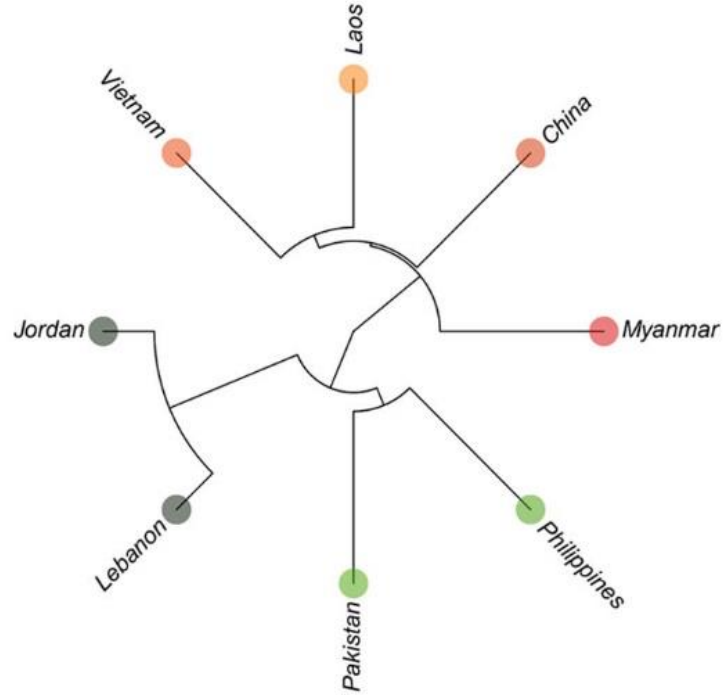
B



C



D



Zheng S, Garcia-Bastidas F., et al., 2018

TALLERES

- Reconocimiento de síntomas en campo y diagnóstico en laboratiorio
  - ICA Medellin - 2016
  - ICA Barranquilla - 2017
  - CIB, Cenibanano, Corpoica (Agrosavia)
- Proyecto diversidad del patógeno agente causal del mal de Panama en el territorio Colombiano (en preparación).

TALLER DE NIVELACIÓN DE CAPACIDADES EN DIAGNÓSTICO DE R4T.

2019

SENASAG
Servicio Nacional de Sanidad Agropecuaria e Inocuidad Alimentaria
BOLIVIA

AGROCALIDAD
AGENCIA DE REGULACIÓN Y CONTROL FITO Y ZOOSANITARIO

ica

SENASA
Servicio Nacional de Sanidad Agraria
PERÚ

COMUNIDAD ANDINA
SECRETARIA GENERAL

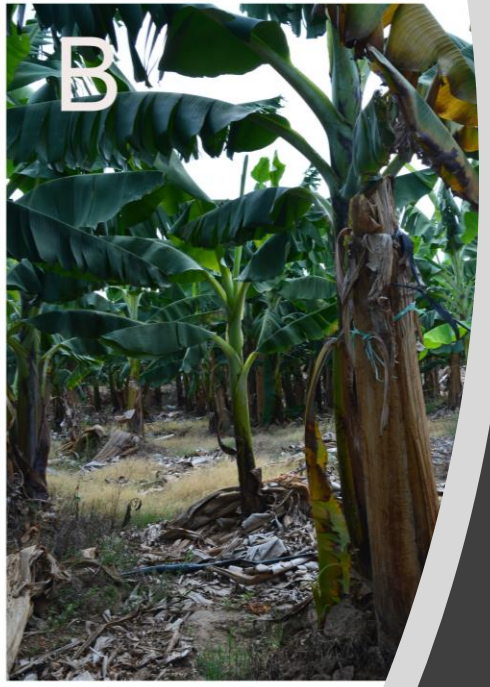
IMPACT

JORDAN (2013)

Garcia FA, Ordoñez N, et al., 2014

PAKISTAN Y LEBANON (2015)

Ordoñez N, Garcia FA, et al., 2016



GREATER MEKONG SUBREGION

"low awareness among banana growers and industry stakeholders has resulted in an almost unlimited movement of banana suckers, contaminated nursery soils, and farming equipment as well as the use of contaminated surface irrigation water."

Zheng S, García-Bastidas FA, et al., 2018

COLOMBIA 2019

Código SPV	Predio	Municipio	Latitud	Longitud	Área erradicada (Has)
A44001-288	Don Alí	Riohacha	11,2773	-73,134	11,51
B44090-188	Villa Belinda	Dibulla	11,275	-73,187	94,78
C44001-388	Eva Norte (1 y 2)	Riohacha	11,2599	-73,116	0,8
D44001-205	Don Marce	Riohacha	11,2775	-73,171	0,25
E44001-435	Don Pedro	Riohacha	11,2595	-73,077	5,2
F44001-058	Rosa Paulina	Riohacha	11,2774	-73,134	58,22
G44001-146	La Vela	Riohacha	11,2565	-73,06058	1,2

Fotos: ICA Twitter

Fusarium Raza 4 Tropical en Colombia, Garcia-Bastidas FA, Quintero C, *et al.*, *2019*

DISTRIBUCIÓN E IMPACTOS DE Foc R4T				
Continente/ región	País	Reporte oficial (año)	Área afectada (aHa)	Impacto (pérdidas)
Asia	Taiwán	1989	~ 160.000	Producción cayó 1999 – 2008 de 350 millones a 50 millones de cajas de 12kg
	Malasia	1990		nd
	Indonesia	1990		US$105 millones
	China	2001		> US$100 millones
	Filipinas	2005		~ US$20.687/ha/ año
	India	2016		nd
	Vietnam	2017		nd
	Laos	2017		nd
	Myanmar	2018		nd
África	Mozambique	2013	1.424	~ US$30 millones
Medio Oriente	Omán	2012	nd	nd
	Jordania	2013	nd	nd
	Líbano	2015	121	nd
	Pakistán	2015	2	nd
	Israel	2018	nd	nd
Australia	Darwin	1997	500	nd
	Queensland	2015	181	> US$22 millones
Total			161.702	~US$277 millones

El Impacto de R4T en Australia

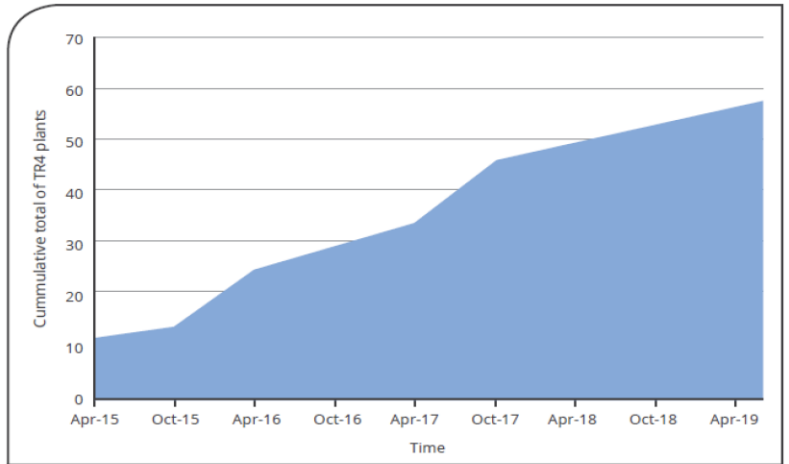
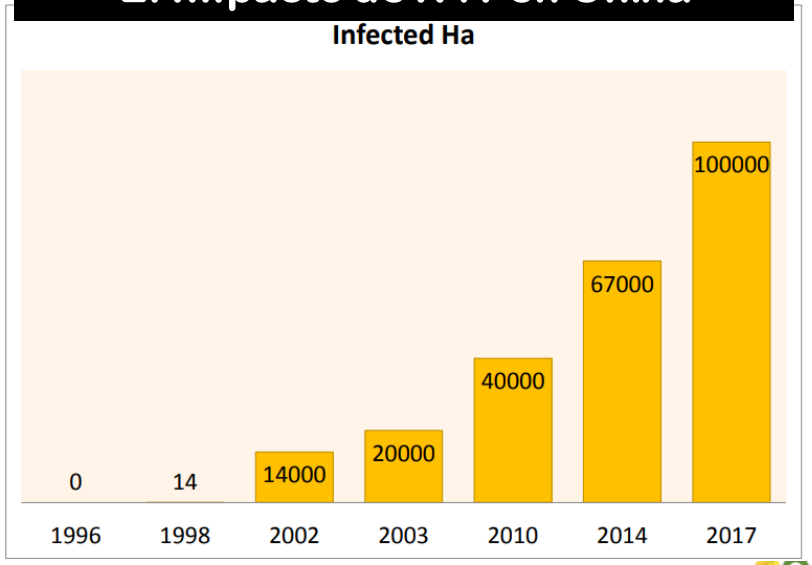


Figure 1: Increase in the cumulative total number of plants which have been confirmed positive with TR4 over time, aggregated 6 monthly.

El Impacto de R4T en China



SYMPTOMS IN BANANA

Foc R1- Banano Manzano

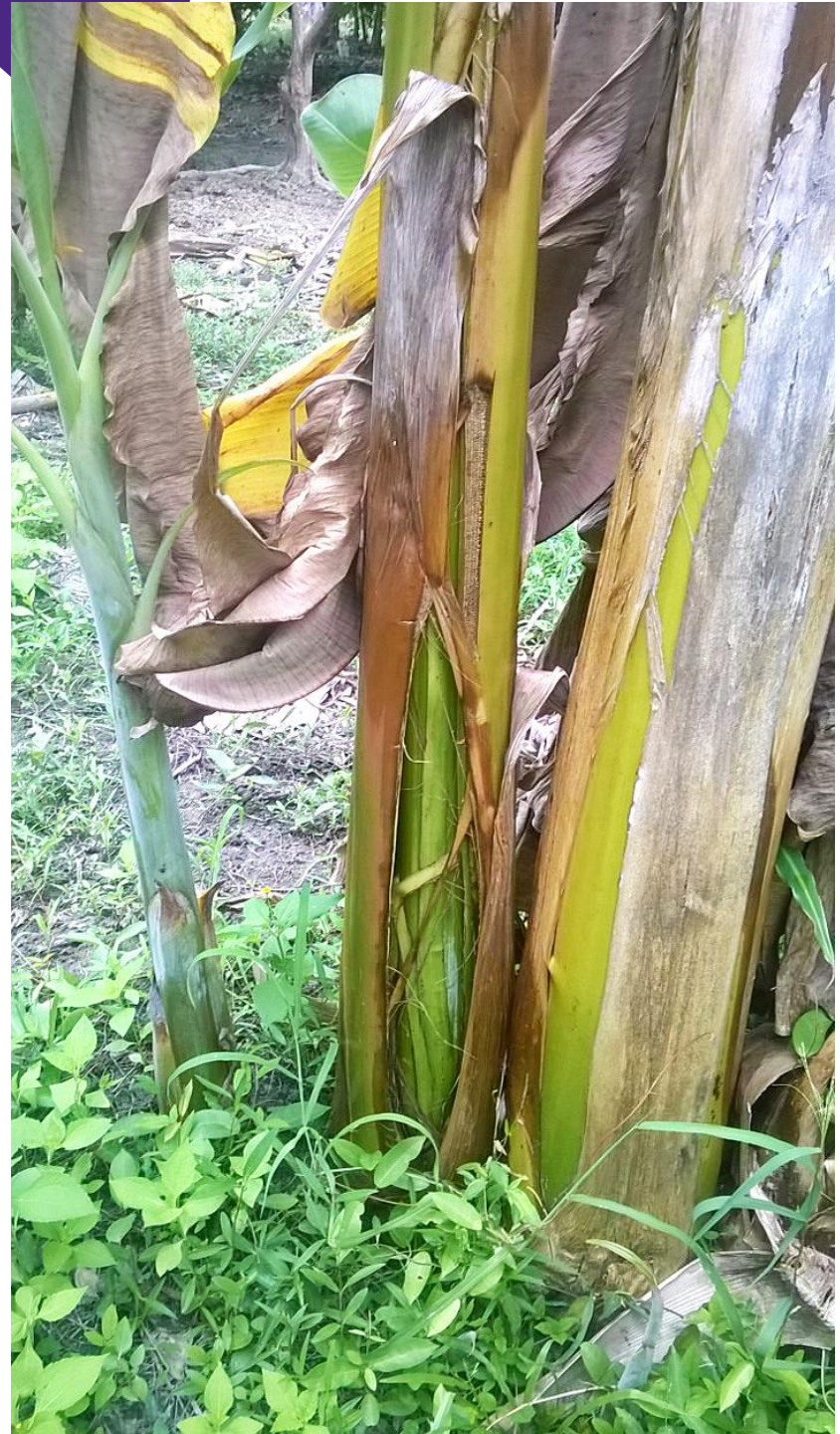
© J. Vargas, Urabá

Foc R2-plàtano "popocho"

© J. Vargas, Urabá

TR4-Cavedish

© FA Garcia, Filipinas

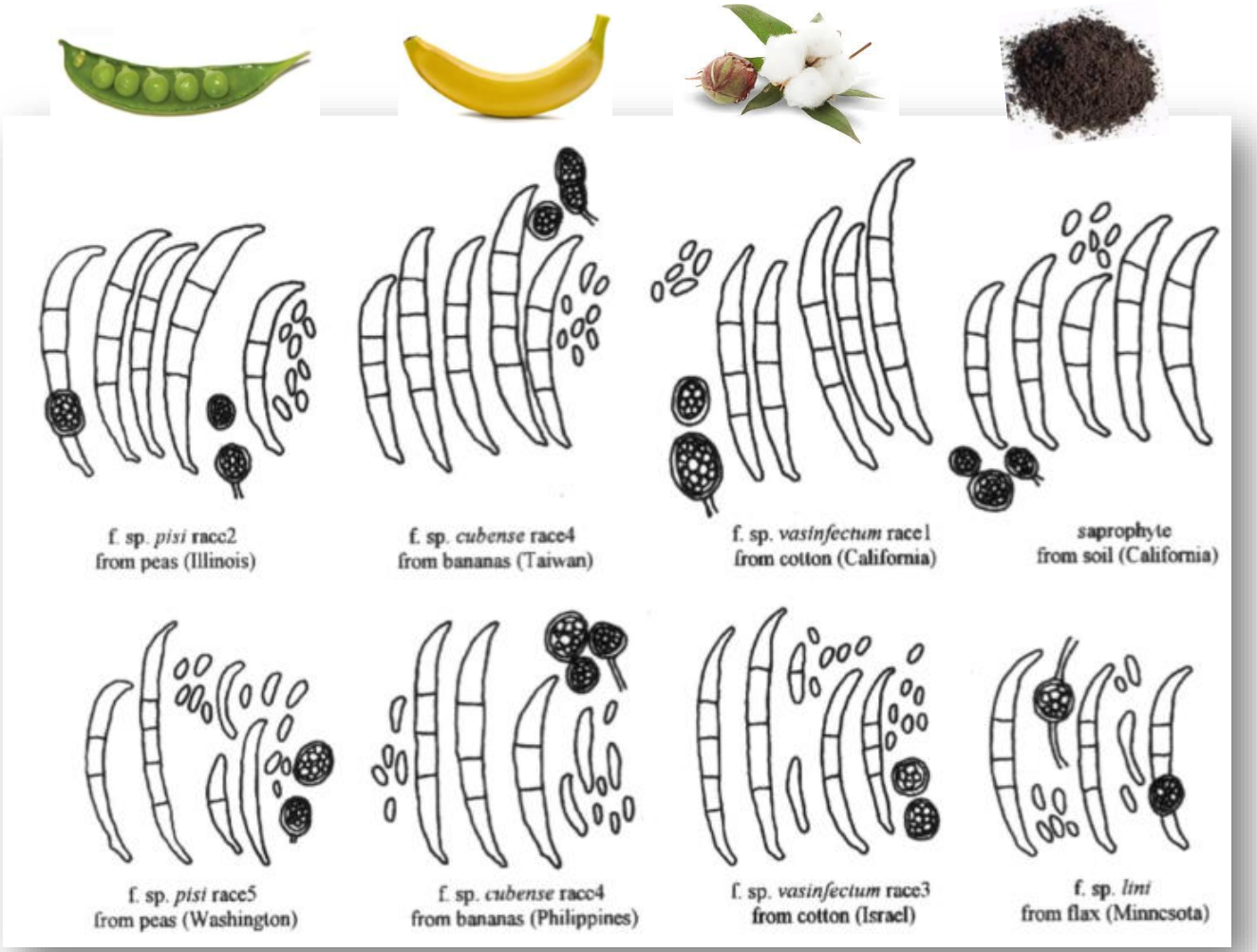


cenibanano
centro de investigaciones del banano
augura

INTERNAL SYMPTOMS

EL PATÓGENO

- Genero *Fusarium* spp.
- Habitantes del suelo
- Causantes de marchitamiento y enfermedades radicales en un amplio rango de hospedantes.
- Se divide en mas de 120 *formae speciales* (f.sp)
- Razas fisiológicas
- VCG (*Vegetative compatibility groups*)



EL FUSARIUM DEL BANANO

- Marchitamiento por Fusarium o Mal de Panamá
- *Fusarium oxysporum* f.sp. *cubense* (revised taxonomy Mariany *et al* 2018)
- Cuatro razas descritas y 24 VCGs
- Contamina suelos por decadas
- No existe un control
- Se disemina muy fácil (Suelo contaminado, hijuelos, partes de plantas infectadas, agua contaminada)

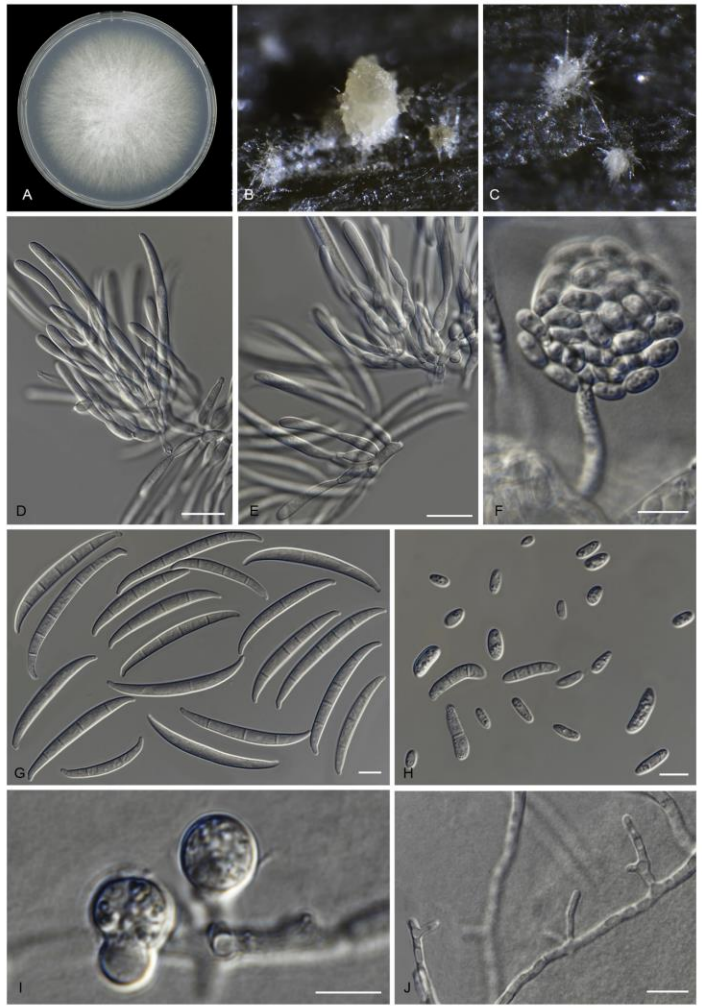
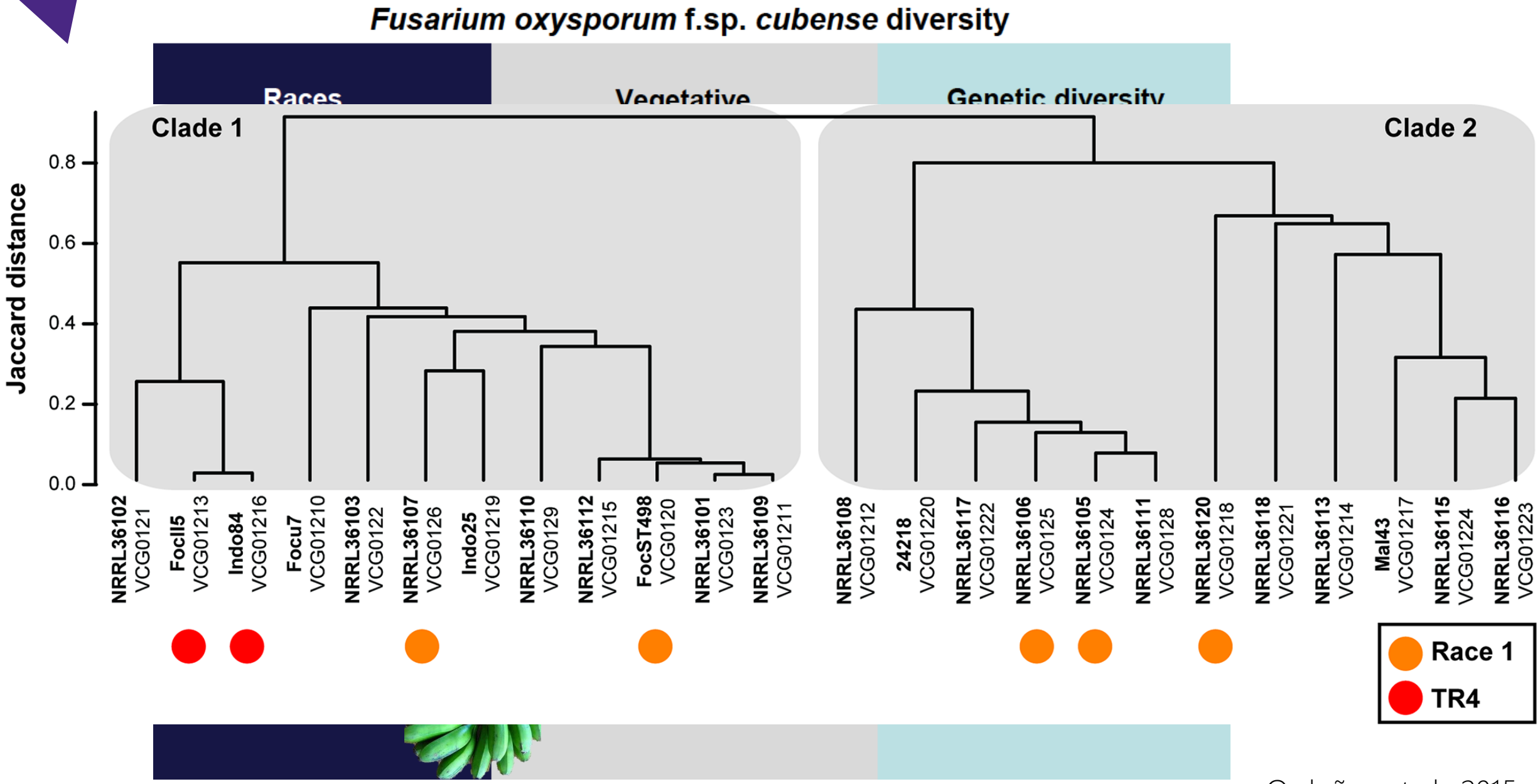


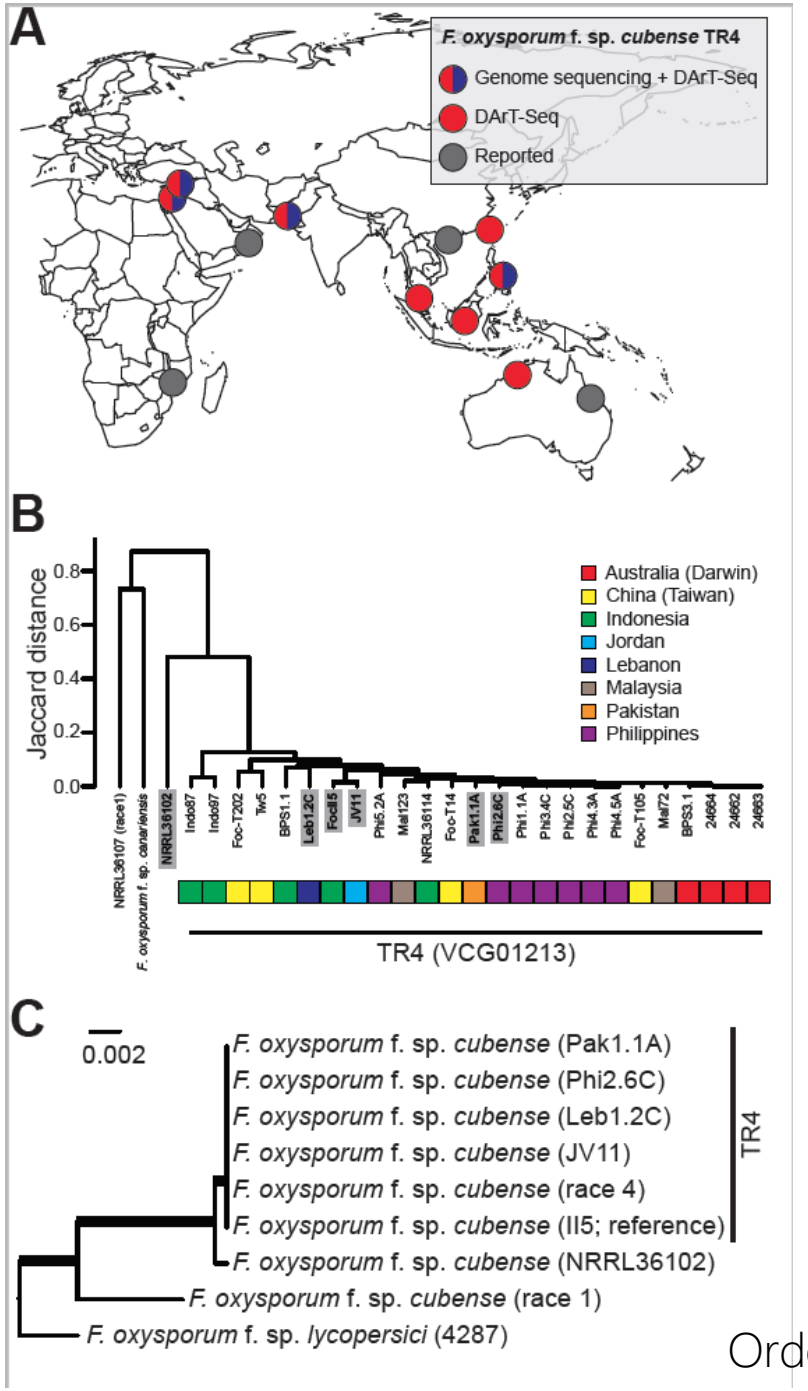
Fig. 7. *Fusarium odoratissimum* (InaCC F817). **A.** Culture grown on PDA. **B–C.** Sporodochia on carnation leaves. **D–E.** Sporodochial branched conidiophores with monophialides. **F.** False head. **G.** Falcate-shaped macroconidia. **H.** Microconidia. **I.** Chlamydospores. **J.** Polyphialides. Scale bars D–J = 10 µm.

PARA RESUMIR



Ordoñez et al., 2015

UNIFORMIDAD GENÉTICA

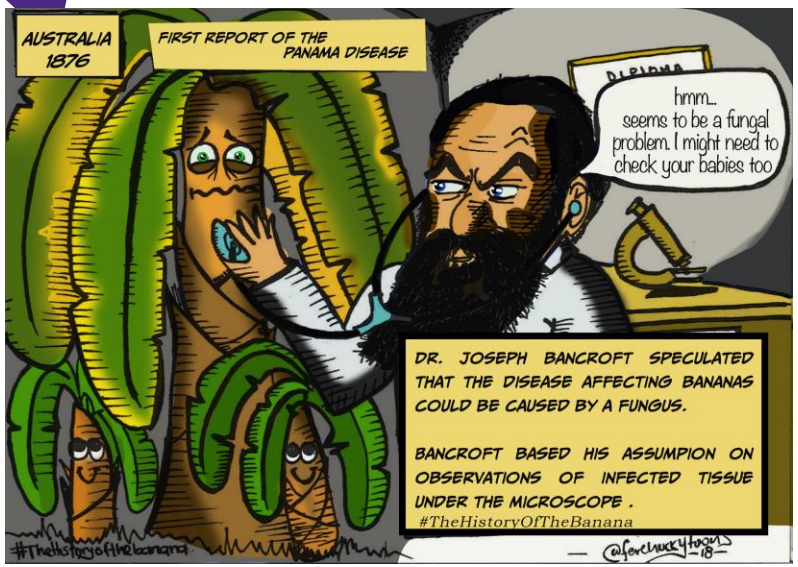


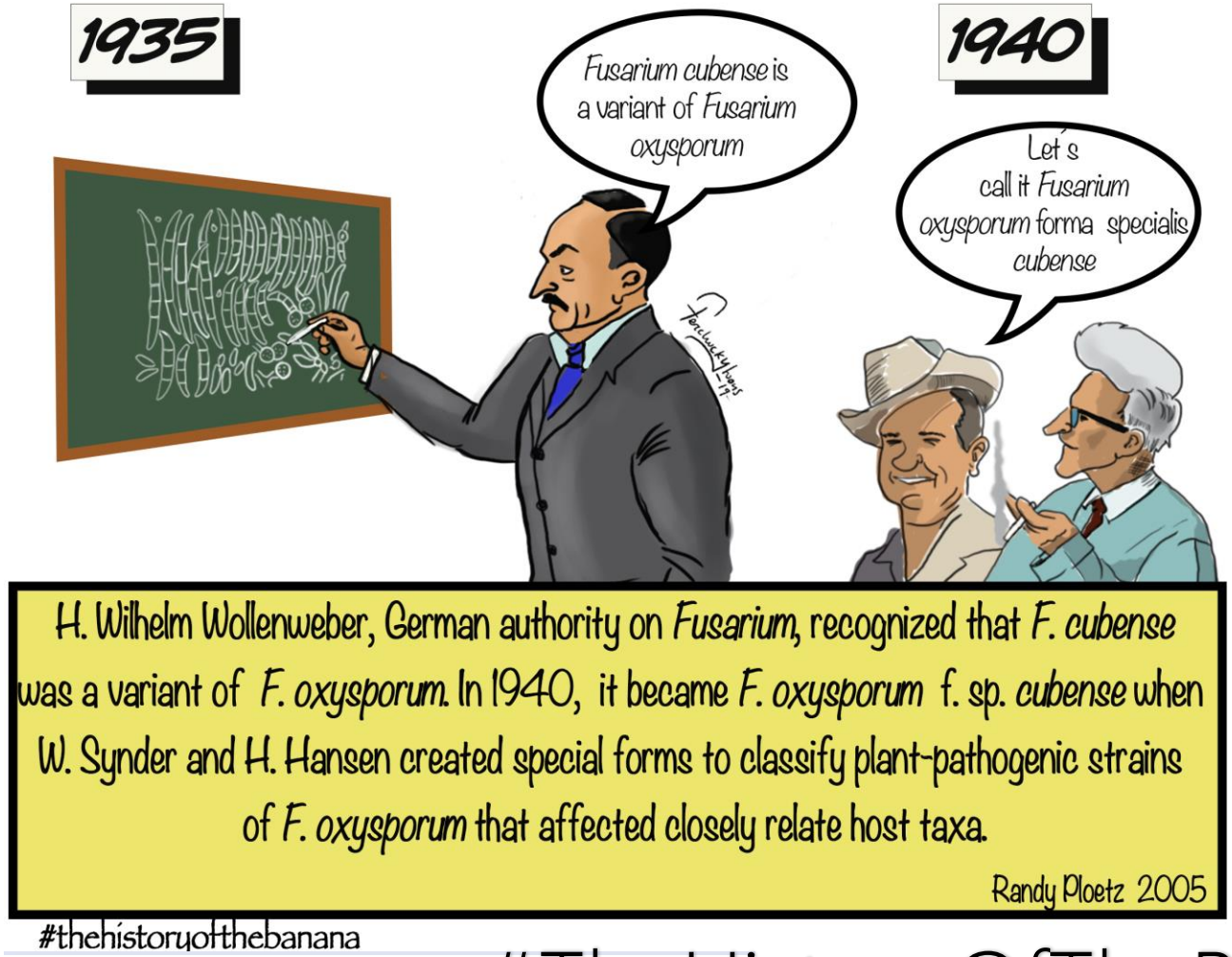
Ordoñez et al., 2015

- Riesgo de entrada
  - Material vegetal
    - Material de propagación
    - Artículos fabricaos con fibras naturales de Musáceas
  - Suelo
    - Animales (Insectos y mamíferos)
      - Vestimenta y calzado
    - Vehículos
    - Contenedores
  - Agua
    - Sistemas de riego provenientes de Fuentes en contacto con áreas de riesgo
    - Escorrentía

© FA Garcia, Colombia

Fusarium odoratissimum, a new name fo TR4 isolates

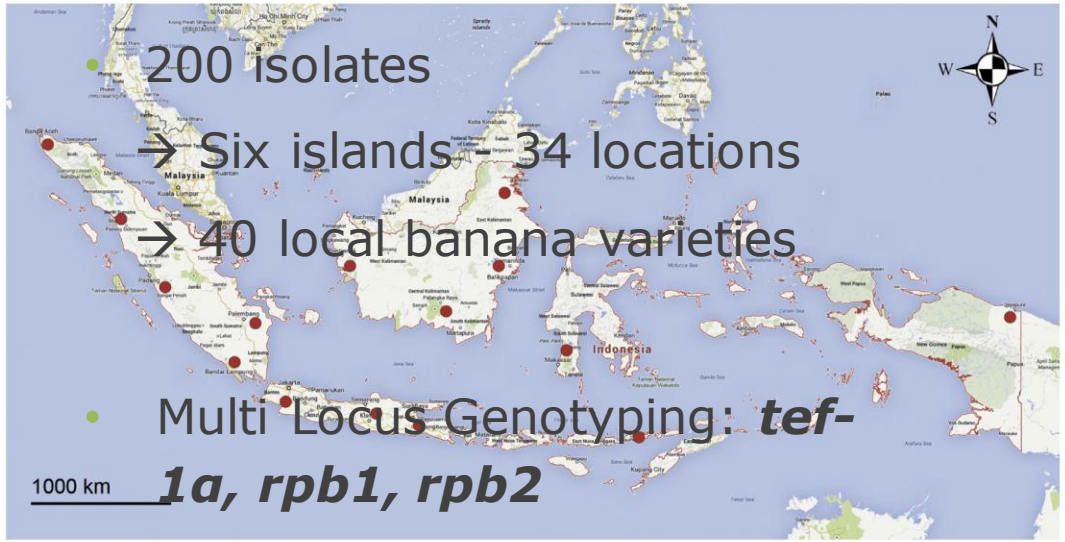




#TheHistoryOfTheBanana

Phylogeny and genetic diversity of the banana Fusarium wilt pathogen *Fusarium oxysporum* f. sp. *cubense* in the Indonesian centre of origin

N. Maryani[1,2,3*], L. Lombard[4], Y.S. Poerba[5], S. Subandiyah[6], P.W. Crous[2,4], and G.H.J. Kema[1,2*]



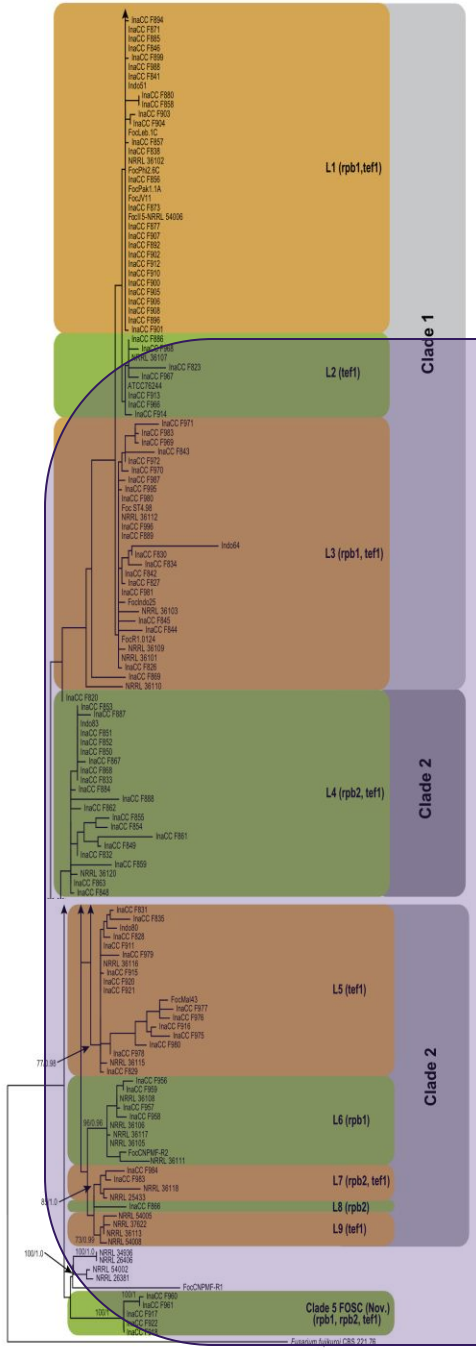
- 200 isolates
- → Six islands – 34 locations
- → 40 local banana varieties
- Multi Locus Genotyping: ***tef-1a, rpb1, rpb2***

Fig. 1. Map of sampling collection in 2014–2015 in the island of Java, Sumatra, Kalimantan, Sulawesi, Papua, and Flores.

Fig. 2. Symptoms of Fusarium wilt on banana. **A**. External wilting symptom on leaves in a monoculture plantation in Lampung, Sumatra. **B**. External wilting symptom in a backyard home plantation in Cianjur, West Java. **C**. Splitting of the pseudostem. **D**. Internal symptoms, discoloration of the pseudostem. **E**. Discoloration of the corm.

Phylogenetic Species Recognition revealed 9 novel taxa in the *Fusarium oxysporum* Species Complex (FOSC).

Maryani et al., 2018



Fusarium odoratissimum* = *Raza 4 Tropical

Fusarium purpurascens

Fusarium phialophorum

Fusarium grosmichelii

Fusarium duoseptatum

Fusarium tardichlamydosprorum

Fusarium cugenagense
Fusarium hexaseptatum
Fusarium tardicrescens

Fusarium kalimantanense

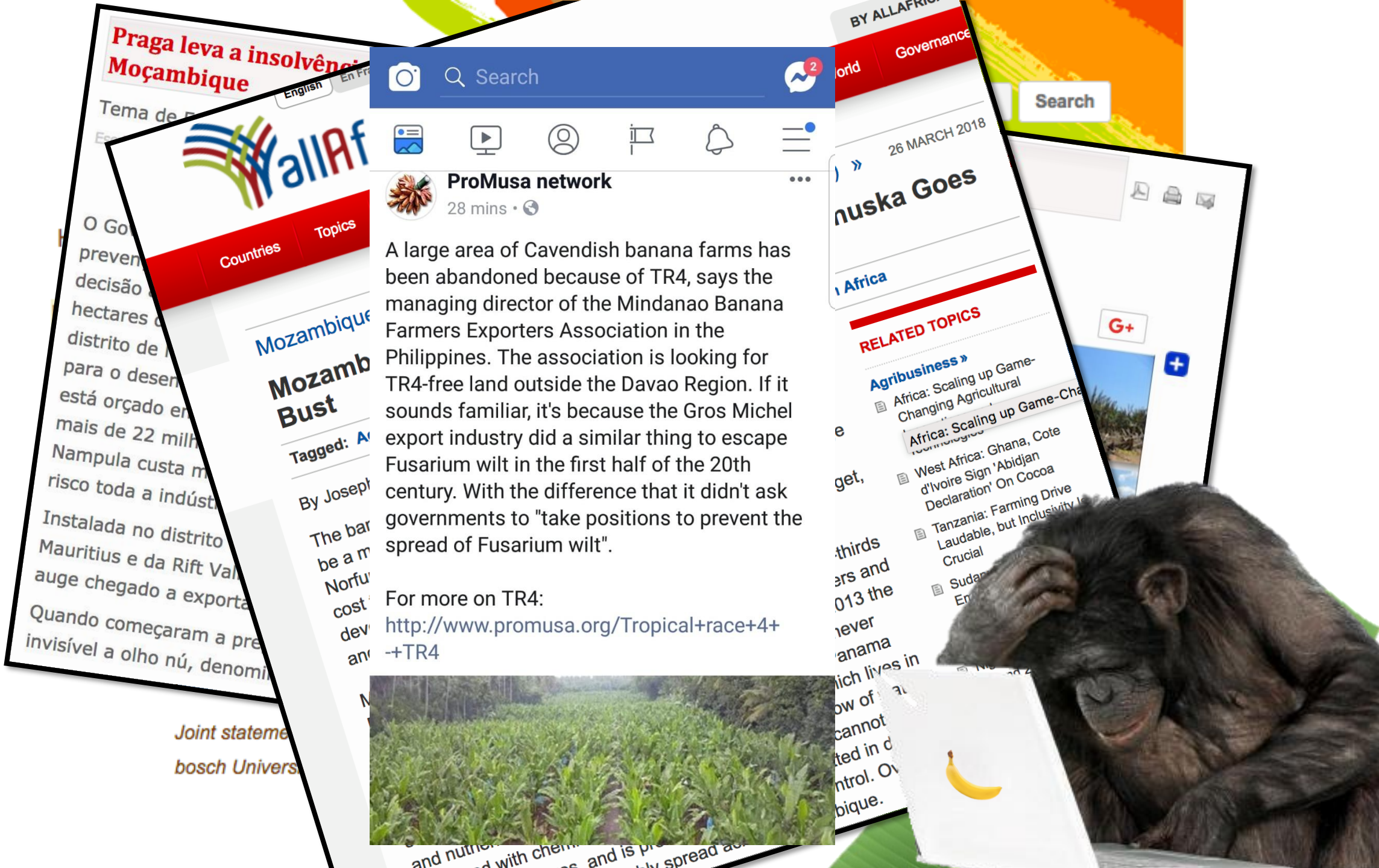
- History repeats itself
- No awareness
- Soil contaminated for decades
- Move somewhere else
- Change crop
- Loose income

- Not replacement available
- Not control available

© Fotos Wageningen university

DID WE LEARN SOMETHING FROM THE PAST?

Very little


Praga leva a insolvên
Moçambique
Search
ProMusa network
28 mins
A large area of Cavendish banana farms has been abandoned because of TR4, says the managing director of the Mindanao Banana Farmers Exporters Association in the Philippines. The association is looking for TR4-free land outside the Davao Region. If it sounds familiar, it's because the Gros Michel export industry did a similar thing to escape Fusarium wilt in the first half of the 20th century. With the difference that it didn't ask governments to "take positions to prevent the spread of Fusarium wilt".
For more on TR4:
http://www.promusa.org/Tropical+race+4+-+TR4
Countries
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Mozambique
Bust
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26 MARCH 2018
Africa
RELATED TOPICS
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Africa: Scaling up Game-Changing Agricultural
Africa: Scaling up Game-Cha
West Africa: Ghana, Cote d'Ivoire Sign 'Abidjan Declaration' On Cocoa
Tanzania: Farming Drive Laudable, but Inclusivity
Crucial
G+

WHAT TO DO?

Escenario 1

"La enfermedad NO está presente en el país"

Escenario 2

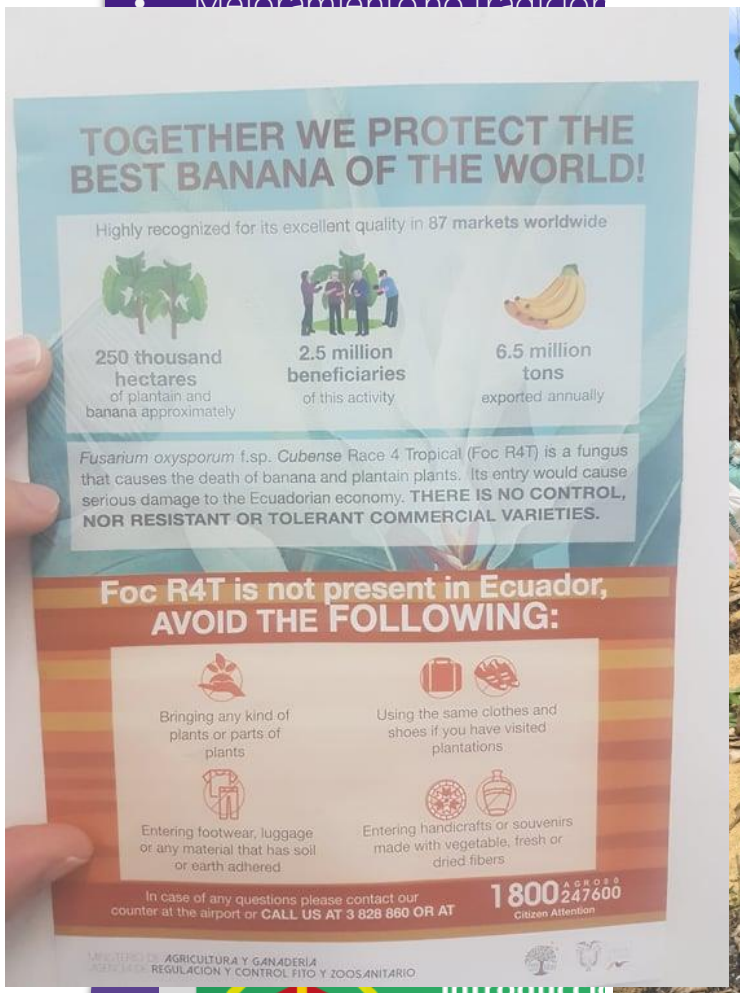
"La enfermedad YÁ está presente en el país"

- Medidas de Supresión
- Medidas Erradicación

- Genotipos Pre-existentes
- Mejoramiento tradicional
- Mejoramiento no tradicional

Cuarentena

Conciencia y programas de contingencia

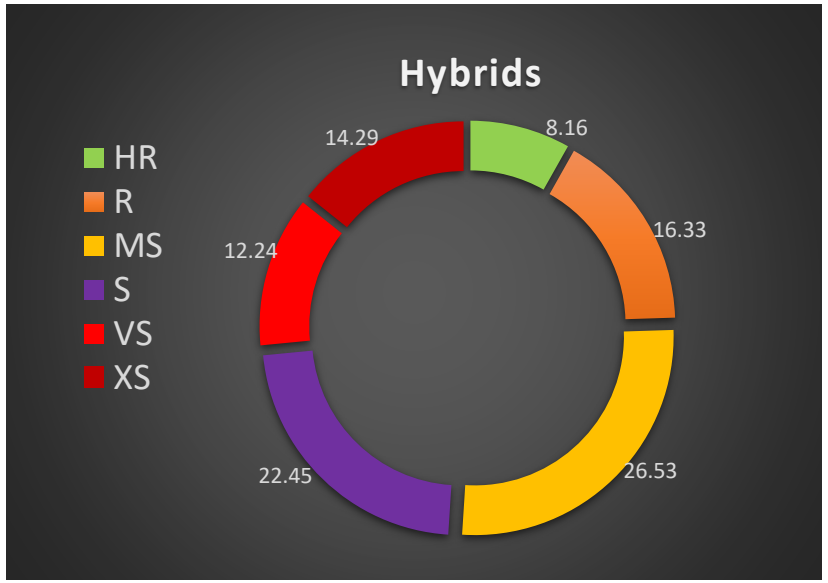


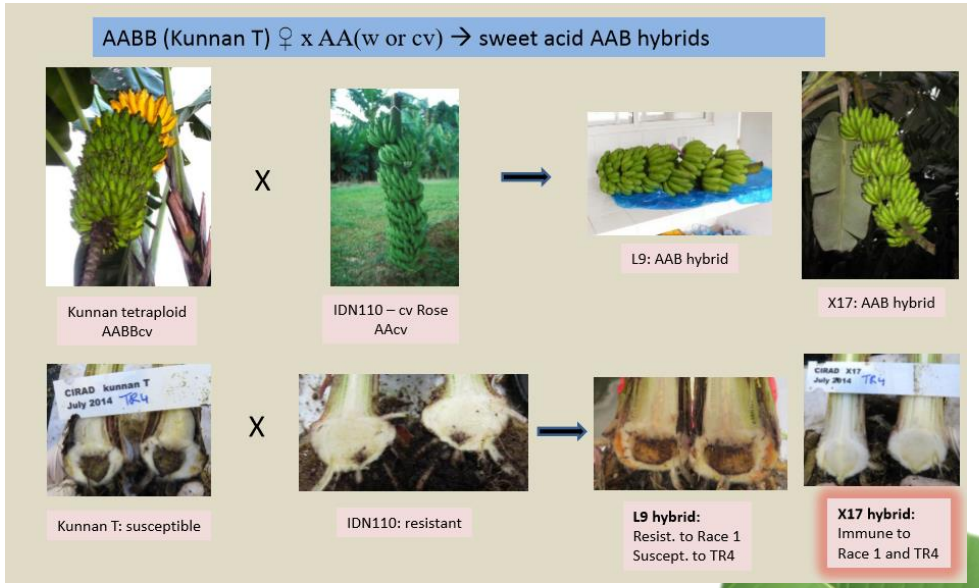
...vegetal de origen conocido y con garantía fitosanitaria.

CONVENTIONAL BREEDING

HYBRIDS

Response to TR4 (DI%)



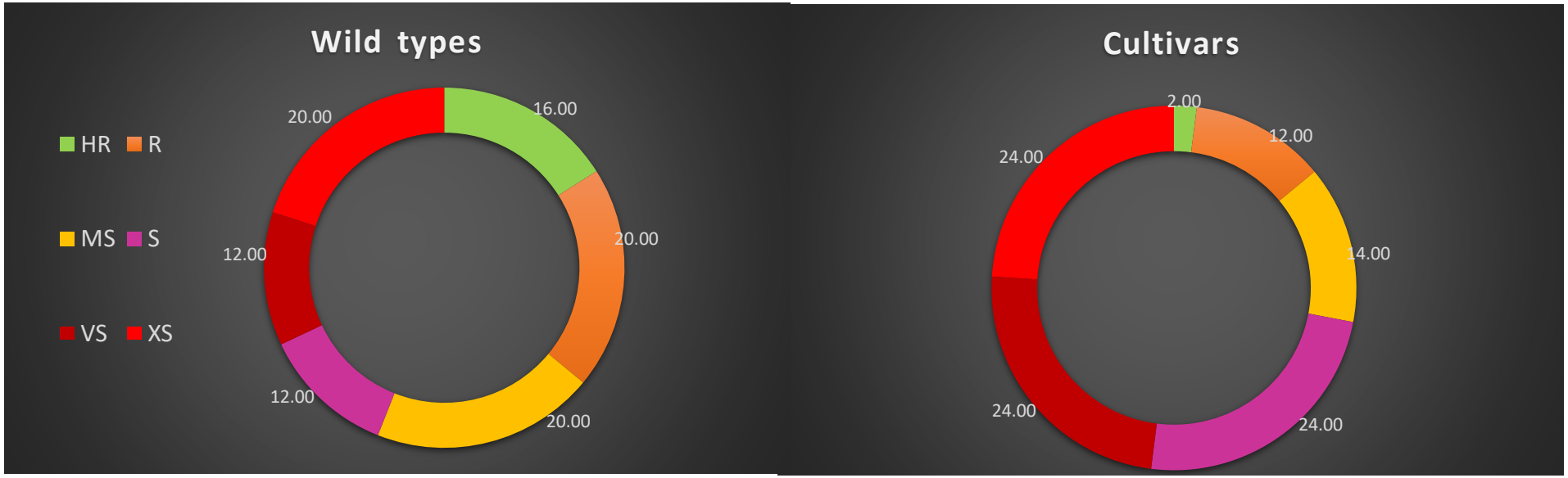


11 Resistant
13 M. susceptible

García-Bastidas F, Bakry F & Kema K., 2019 (*in prep*)

DIPLOIDS AND WILDTYPES

Response to TR4 (%)



9 Resistant
5 M. susceptible

M. ornata

Pahang

cv Rose

L. Tavoy

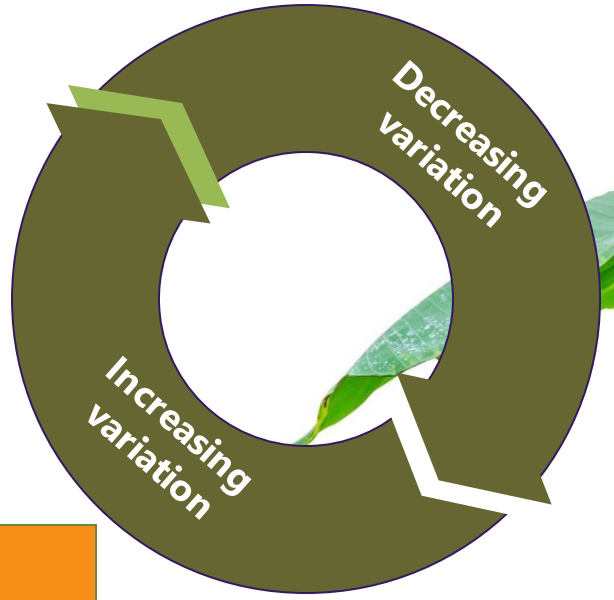
7 Resistant
7 M. susceptible

García-Bastidas F, Bakry F, Irish B, & Kema G., *in prep*

MOLECULAR PLANT BREEDING – Increase genetic diversity

MAKING CROSSES
Develop *Musa* breeding tools
Breeding by design

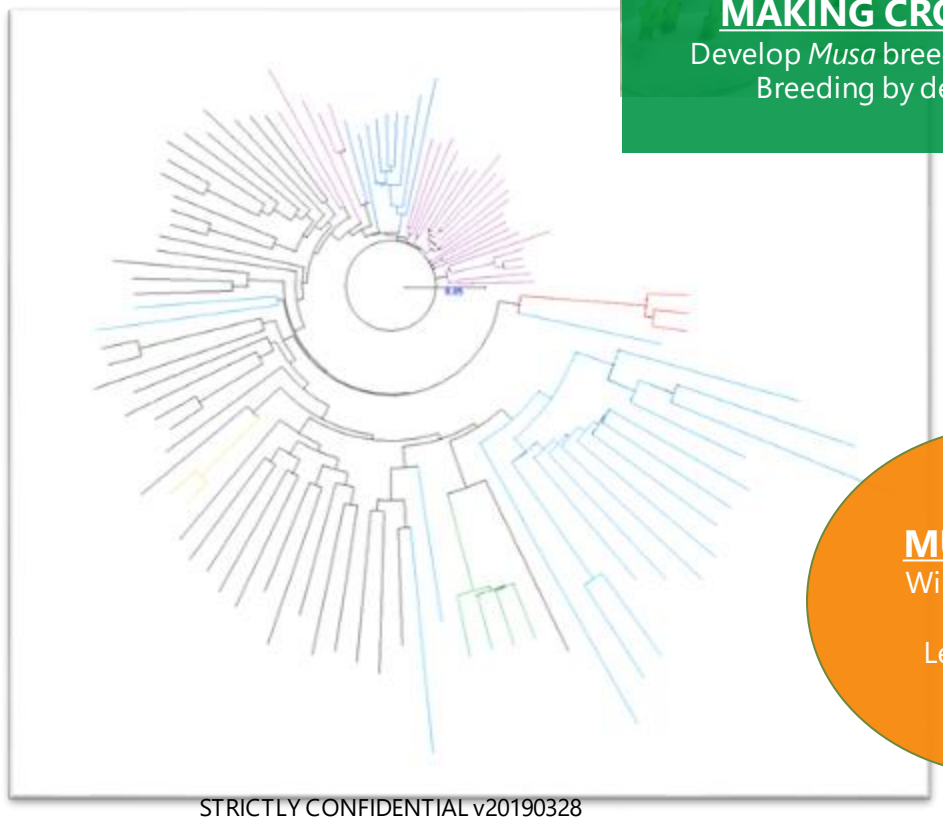
SELECTION
Using molecular markers
Novel traits



VARIETY TESTING
In-vitro
Greenhouse
Multi-location field

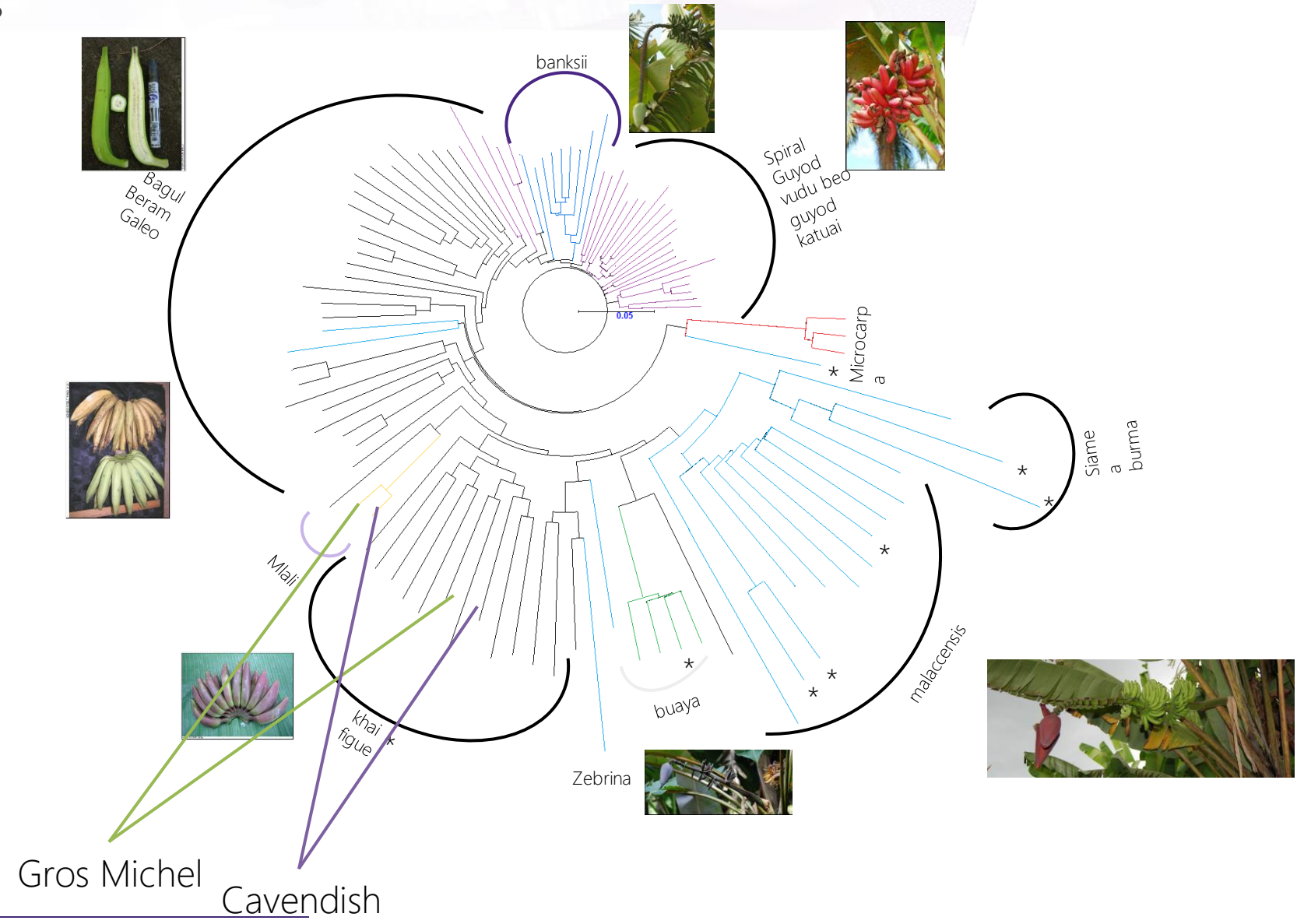
RELEASE OF NEW VARIETIES
Disease resistant
Color and taste
Agronomy improved

MUSAPEDIA
Wild germplasm
Public data
Lead genes ID



RE-SEQUENCING DATA

105 diploids



NON-CONVENTIONAL BREEDING

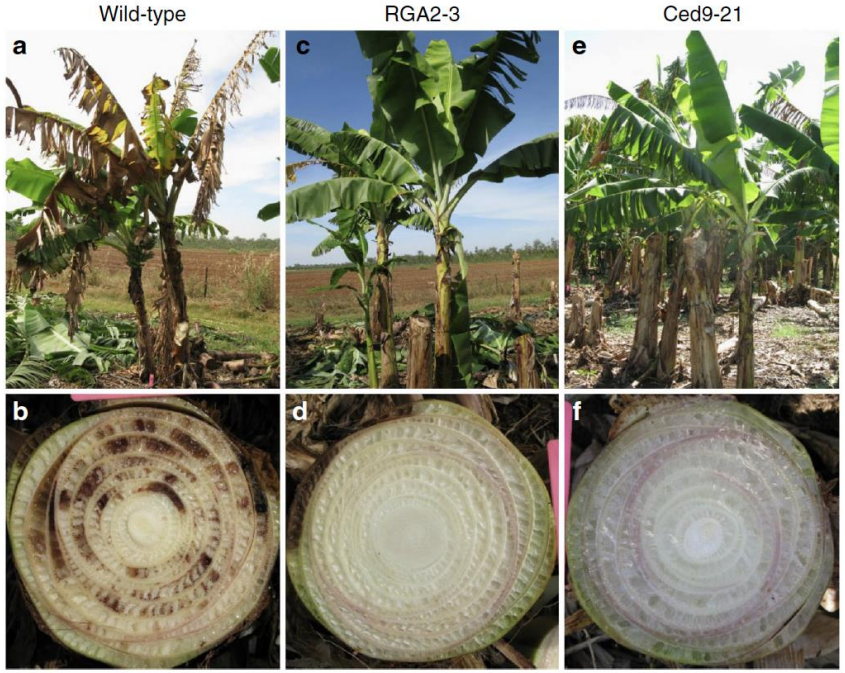
MUTANTS & GMS

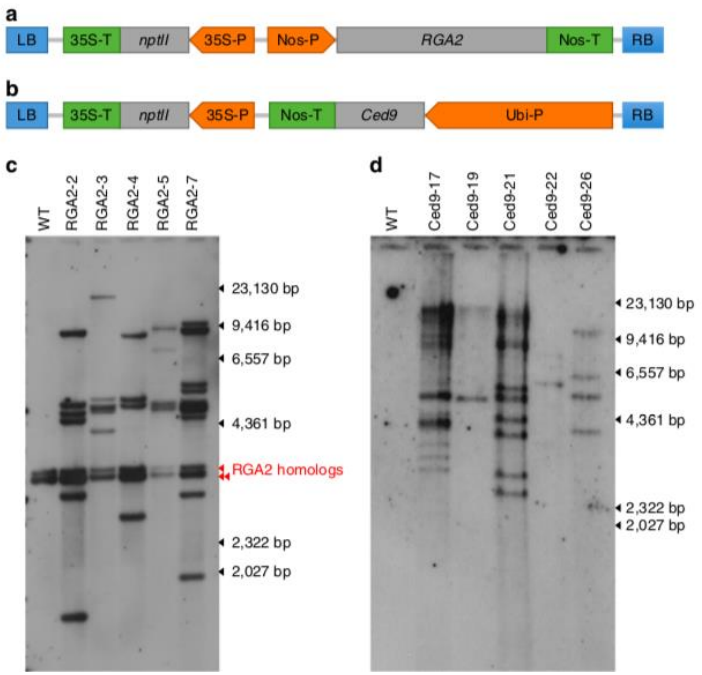
ARTICLE

DOI: 10.1038/s41467-017-01670-6 OPEN

Transgenic Cavendish bananas with resistance to Fusarium wilt tropical race 4

James Dale[1], Anthony James[1], Jean-Yves Paul[1], Harjeet Khanna[1,5], Mark Smith[2], Santy Peraza-Echeverria[1,6], Fernando Garcia-Bastidas[3], Gert Kema[3], Peter Waterhouse[1], Kerrie Mengersen[4] & Robert Harding[1]





Evaluation of Mutants (12K)

200 plants resistant/moderately susceptible

plants susceptible

RAAN MERISTEM
A BREED APART

WAGENINGEN
UNIVERSITY & RESEARCH

Diversity is the future

TAKE HOME MESSAGES

- Current pandemic is caused by a single clone
- Globally accepted standardized protocols for phenotyping are required.
- Resistance in banana germplasm exist!
- Efficacy of control measures is poor. Foc will continue its spreading.
- Compared to other pathosystems, bananas research is in its infancy.
- Endogenous populations in SE Asia contain other devastating strains.

Thanks
for your
attention
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@ ferchuckygarcia