A raça 4 tropical de Fusarium oxysporum f sp. cubense: situação atual na Ásia, avanços em pesquisa e iniciativas para mitigar seu impacto na América Latina e Caribe

Miguel Ángel Dita Rodríguez

*email: m.dita@cgiar.org

Bioversity International
Commodity Systems & Genetic Resources Programme
Coordinador Regional para América Latina e Caribe


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A. Molina

A. Molina

Mal de Panamá

Sintomas externos

Mal de Panamá

Síntomas externos

Mal de Panamá

Síntomas externos


Local: Peña Blanca, Honduras
Variedad: Gros Michel
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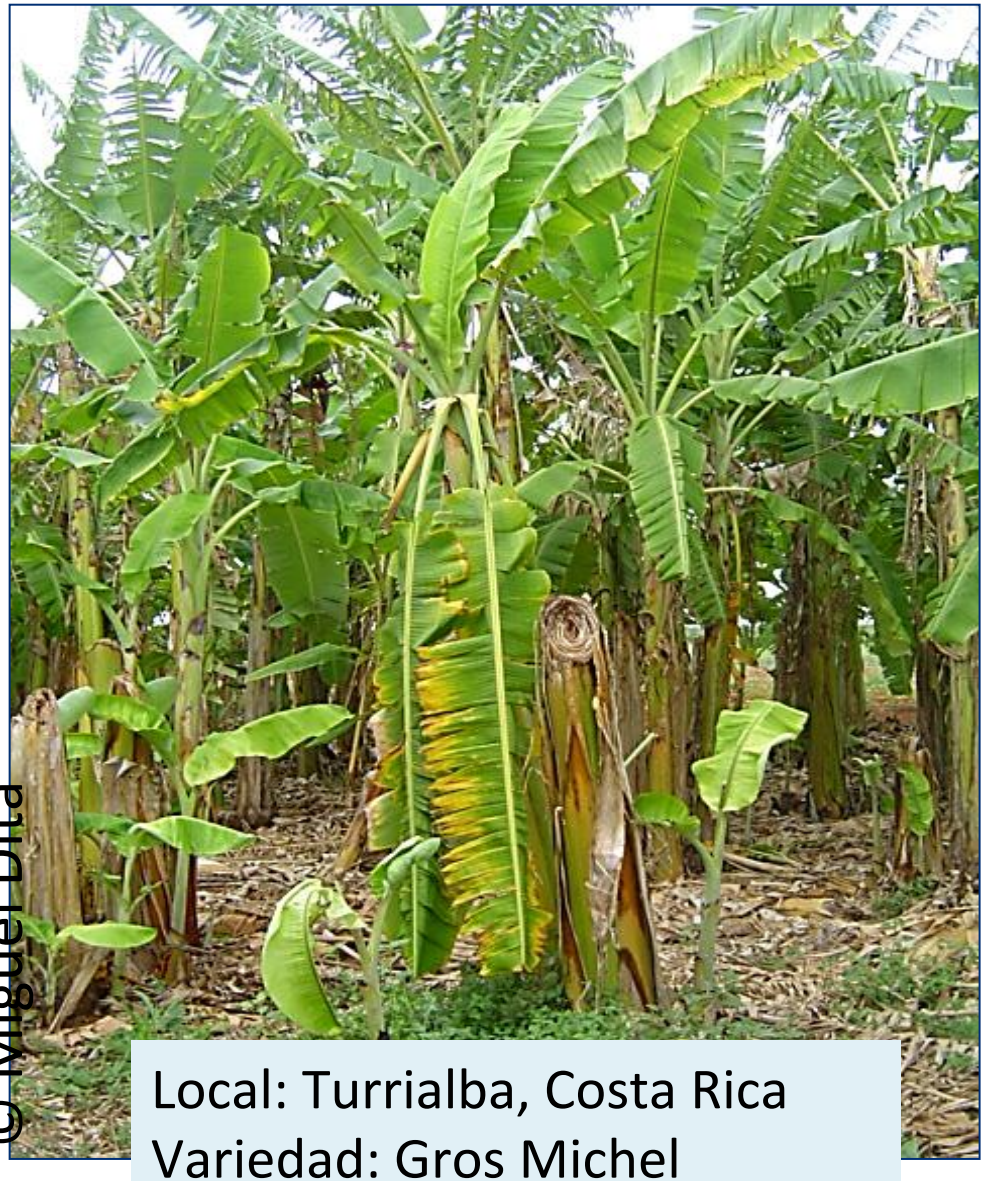
Mal de Panamá

Local: Alto piura, Perú
Variedad: Gros Michel

Mal de Panamá Síntomas externos



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Local: Turrialba, Costa Rica
Variedad: Gros Michel

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"Sindrome verde"

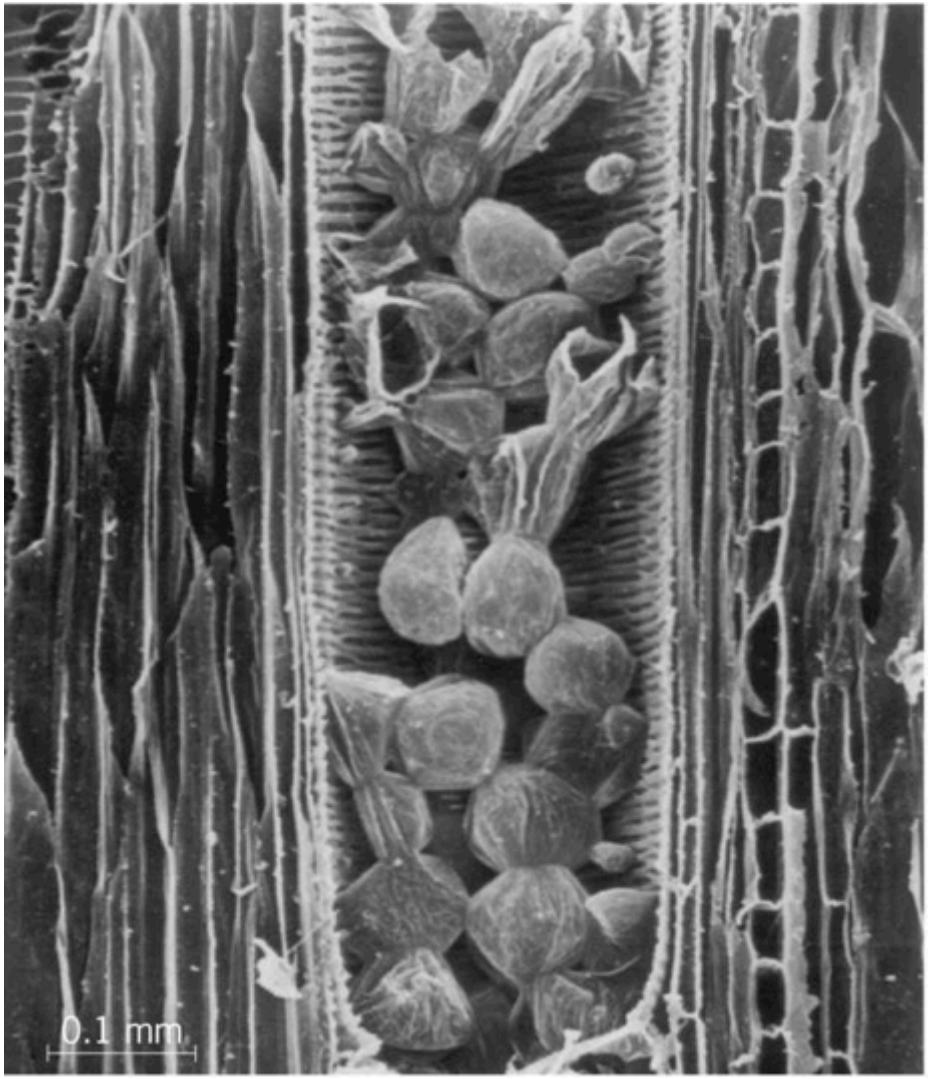
Mal de Panamá: Sintomas internos

Mal de Panamá
Sintomas internos

Marchitez por Fusarium en Musáceas

Formación de tilosas en los vasos del xilema de banana infectada por Marchitez por Fusarium.

(G. E. VanderMolen, University of Rhode Island)



http://www.accessscience.com/popup.aspx?figID=524000FG0060&id=524000&name=figure

Mal de Panamá - algunos aspectos históricos

- **Origen:** Asia Sur Este
- **1876 primer reporte** : Queensland. 1874, en banano Manzano (Bancroft, 1876)
- **1880- :** Se diseminó a la mayoria las regiones productoras en el mundo
- **1950-:** Pocas regiones permanecieron libres de la enfermedad
- **1900-1960:** Había destruido > 100 000 ha in América Central
- **1950-:** Las comañias bananeras fueron obligadas a cambiar Gros Michel por variedades del su grupo Cavendish ("resistentes")

…Cavendish de horizonte a horizonte

Nuestro problema está resuelto!

(tomado de Ploetz, 2000)

Valle Ulua, Honduras, 1994

Mundanzas na Produção

Era Gros Michel

Era Cavendish

Mundanzas na Produção

Era Gros Michel

Era Cavendish

Mal de Panamá - algunos aspectos históricos

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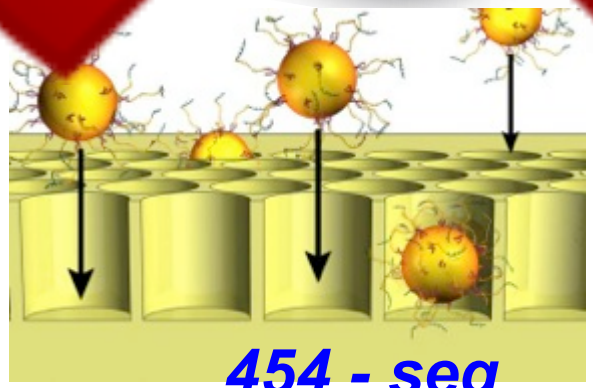
- **1950-:** Las comañias bananeras fueron obligadas a cambiar Gros Michel por variedades del su grupo Cavendish ("resistentes")

- **1970- :** Se reportan daños en Cavendish en el subtrópico (raza 4 subtropical)
- **1990- :** Se reportan daños en Cavendish en el trópico (raza 4 tropical)
- **Actualmente- : la enfermedad está en la mayoria de las áreas productoras, pero la raza 4 tropical está todavía restricta a Asia & Australia, pero**...

Panama disease vs. Commercial banana

RT4?



454 - seq

~ 60 años atrás

**Los síntomas provocados por raza 4 Tropical son similares a los de la raza 1 y 2

Raza 4 tropical – Cavendish, Australi

Raza 1 – Gros Michel, Costa Ric

Cortesía: Wayne O'Neil - Australia

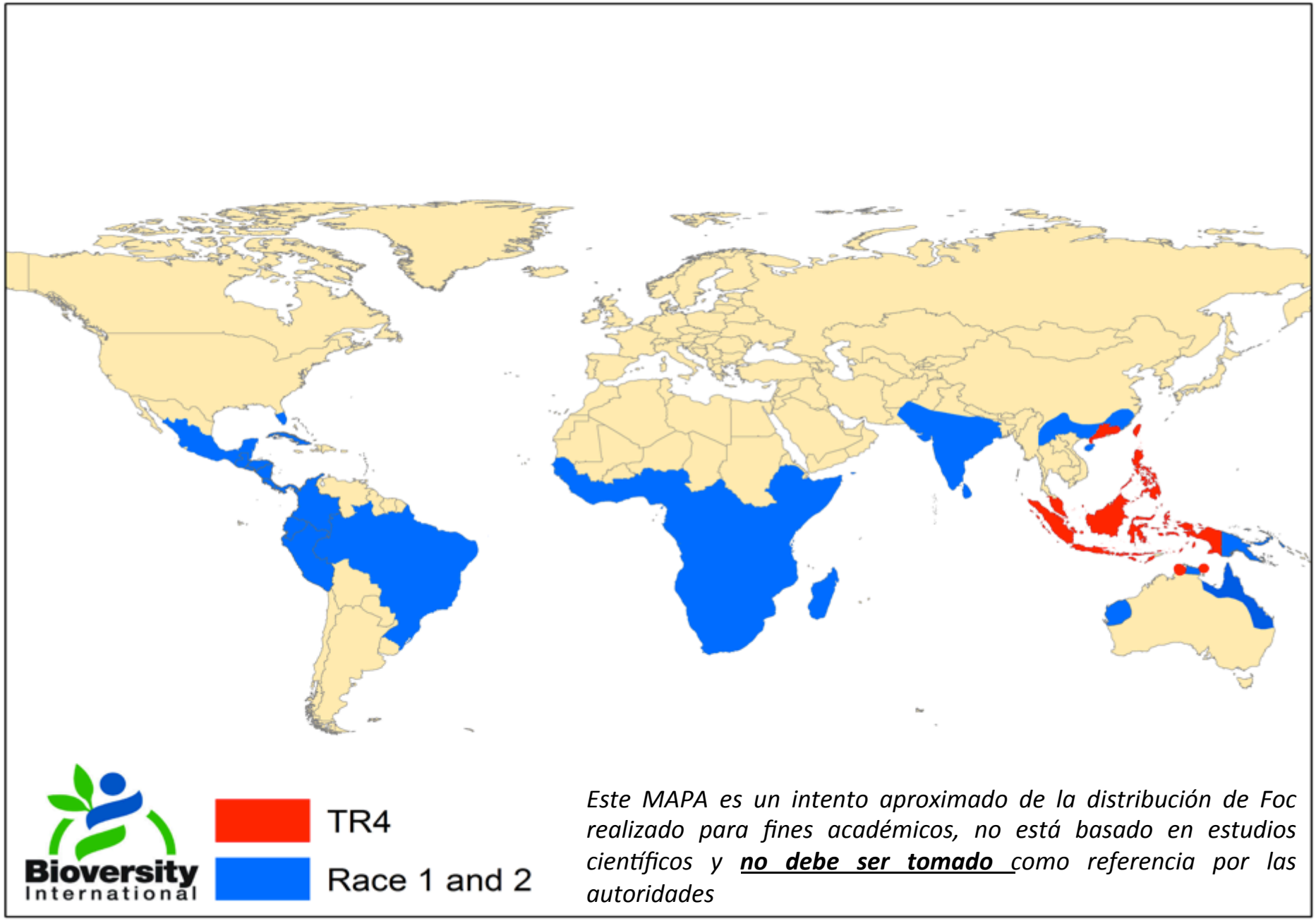
**Los síntomas provocados por raza 4 Tropical son similares a los de la raza 1 y 2

Raza 4 tropical – Cavendish, Australia

Cortesía Wayne O'Neil - Australia

Raza 2 – Monthan (ABB), Brasil

Marchitez por Fusarium : distribución mundial



Este MAPA es un intento aproximado de la distribución de Foc realizado para fines académicos, no está basado en estudios científicos y ***no debe ser tomado*** *como referencia por las autoridades*

Distribución de la Raza 4 tropical de Foc

La pregunta HOY no es si va a llegar o no a LAC o cómo?
La pregunta es cuando? – prevención – capacitación – preparación – desarrollar capacidades
“guerra avisada no mata soldado"?

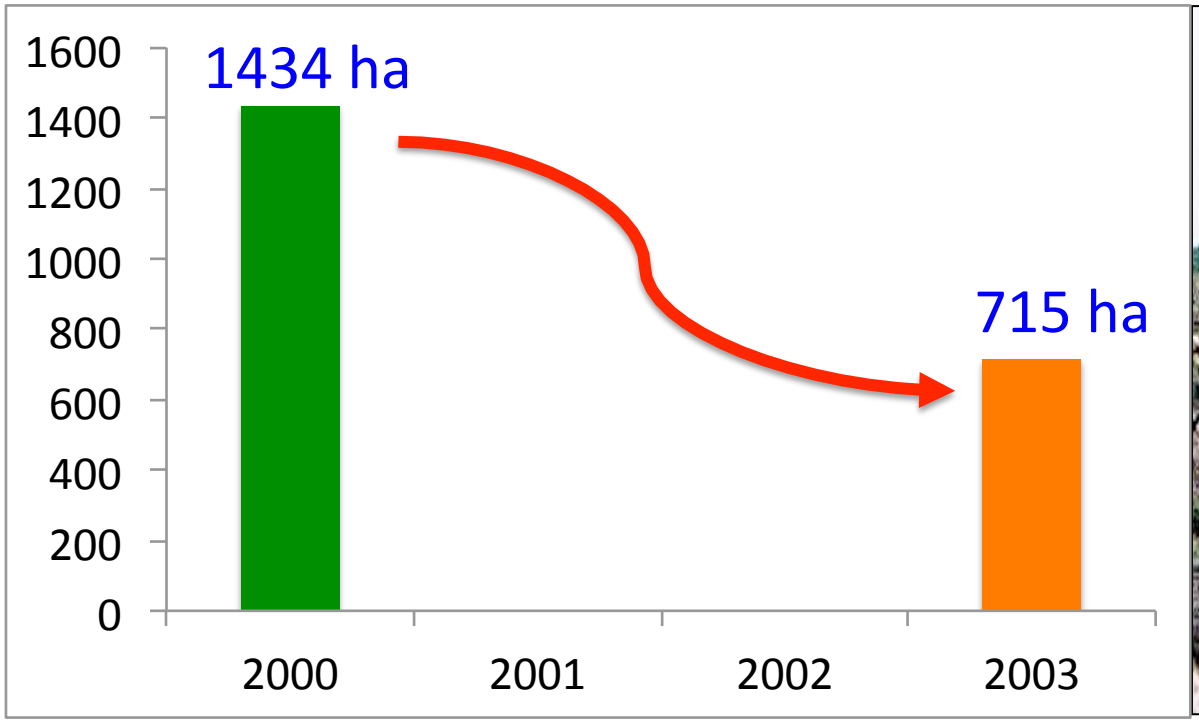
Este MAPA es un intento aproximado de la distribución de Foc realizado para fines académicos, no está basado en estudios científicos y **no debe ser tomado** como referencia por las autoridades

Impact of Foc TR4 in Asia

Indonesia

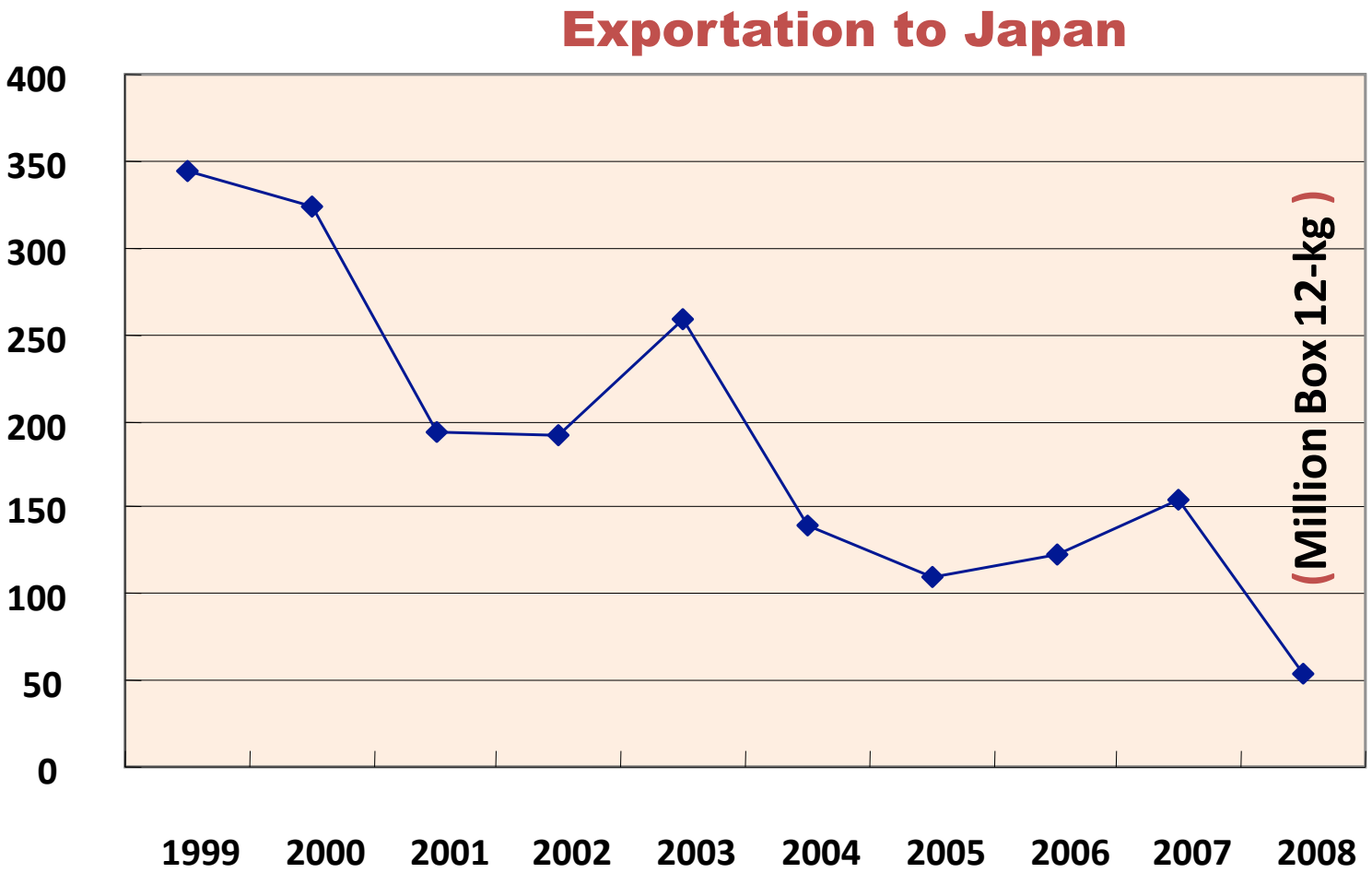
West Sumatra

(Horticulture Processing and Marketing Department, 2005)



Impact of Foc TR4 in Asia

TAIWAN



Dr. Molina, Bioversity

Chao(2008) BAPNET meeting

TR4 in China

[A. Molina – Bioversity International]

- **1996 – First infection on Cavendish**
  - Panyu district, Guandong, along the Pearl River.
- **Spread through planting materials and river water (irrigation)**
- **2001 – positive for VCG 01213-16 (TR4)**
- **2002 Infection spread to other districts**
- **2006 – about 6,700 hectares are affected in Guandong alone.**
- **2010 – Reported spread to Hainan, Guangxi, Yunnan and Fujian provinces**

Irrigation by river water

Foc TR4 in China

- **CHINA – 285 000 ha**
- **~ 65,000 ha affected by *Foc TR4***
- **Serious Problem on Cavendish**

Millions of banana plants have died and unfortunately **we have found No Cure** for the disease," said Liu Shaoqin, a researcher with Guangzhou's Academy of

Green Pass for Banana

Local administrations in Haikou have opened green passes at ports to facilitate banana business and avoid more losses after ghastly news on the "banana cancer" swept most parts of China.

As the rumor of the "Panama Disease" outbreak in banana plantations gradually quiets down, the local government has decided to give a 300-yuan subsidy ($37.5) for each banana truckload in attempts to boost the fruit sale and reduce losses suffered by local banana planters.

Trucks loading bananas can enjoy priority services at the ports.

Experts Refute Rumors of Banana-Cancer Link

An agricultural expert says rumors saying "bananas cause cancer," which have spread widely on the Internet, are groundless.

http://english.cri.cn/3126/2007/04/05/272@212949.htm.

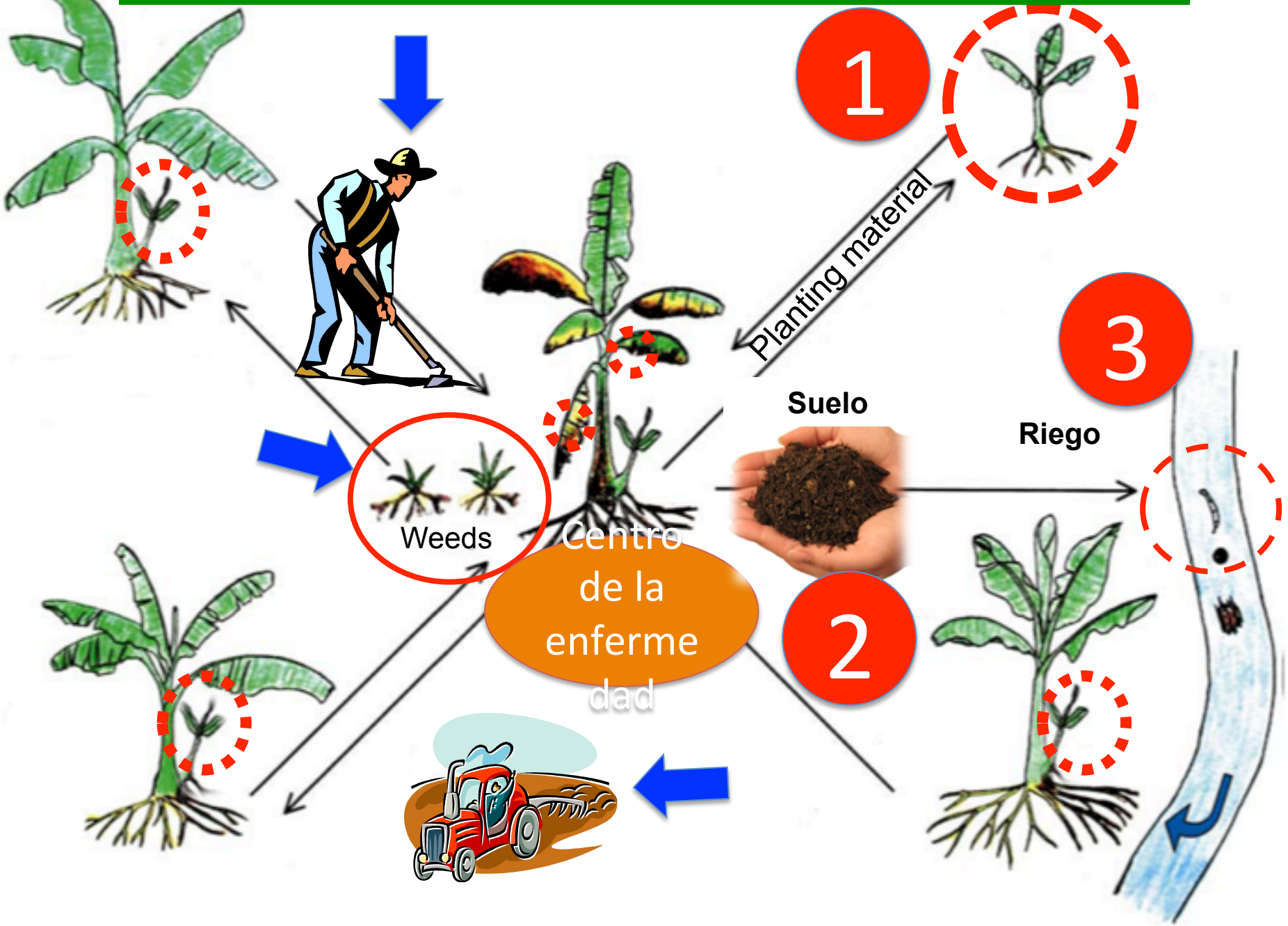

A. Molina


According to Horticulture Plant Protection Department (2007) reported that epidemic rates of Foc race 4 in Sumatra and other province reach 100 km/year
A. Molina

Cavendish plantation in Philippines devastated by Foc TR4

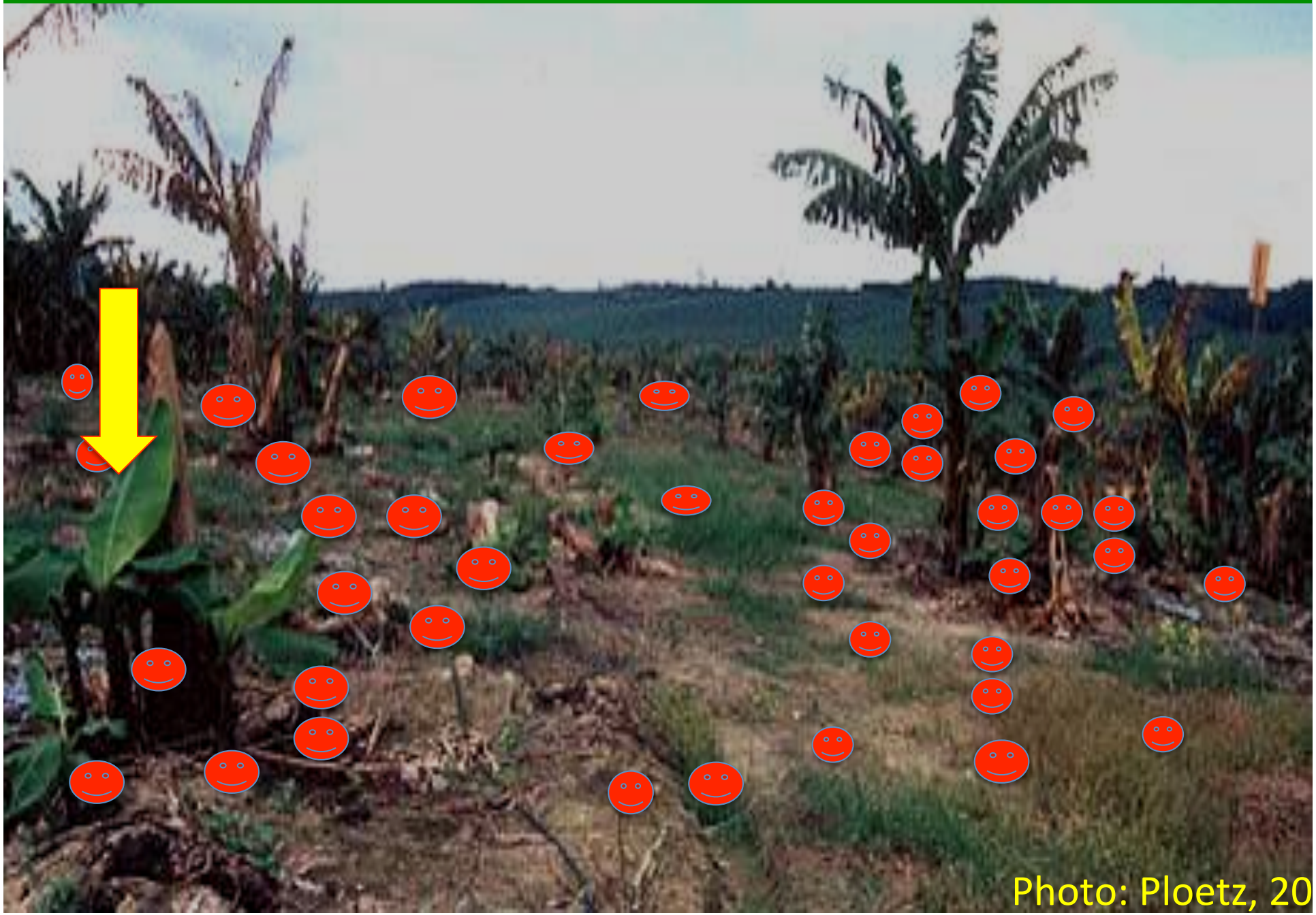
Gert Kema, 2012

Epidemiología de la marchitez por Fusarium en bananos



Fusarium oxysporum f. sp. *cubense* *vs. Typhoon*

Diseminación por hijos asintomáticos, pero infectados



Diseminación por hijos asintomáticos, pero infectados

© Miguel Dita

- Planta sana ?
- Los productores la usan como matetial de siembra?

- Planta enferma, los productores pueden no saber que los hijos están infectados y los deajn, incluso venden

Diseminación de F.o. sp cubense por el agua

Plantación de bananos en China. © Miguel Dita. 2009

Raza 4 Tropical en China

Banana plantation, Costa Rica, Miguel Dita 2011

Epidemiología de la marchitez por Fusarium en bananos

Factores a considerar:

1. Hongo del suelo
2. Penetra por raíces secundarias
3. Produce estructuras resistencia : Clamidospora que pueden permanecer en el suelo por más de 30 \ãnos en la ausencia de variedades susceptibles
4. Se disemina por
   - **a) Material de siembra visiblemente sano, pero que ya está infectado**
   - **b) Suelo [maquinaria, implementos, zapatos]**
   - **c) Água**
   - **d) Lluvia + viento**
   - **e) Aire?**

Factores de riesgo de la entrada de *Foc* R4T

- ✓ Síntomas similares a los de las demás razas
- ✓ Largo período de latencia
- ✓ La evidencia de su presencia puede ocurrir después de muchos años de su introducción
- ✓ Alta dependencia de la producción en un número reducido de clones (Cavendish, plátanos AAB, tipos Bluggoe y Pisang awak, ABB).
- ✓ Falta de acceso de los productores a semilla limpia certificada, lo que determina que usen su propio material infectado.
- ✓ Limitadas opciones de manejo químico y biológico
- ✓ Fácil diseminación por diferentes vías para ser introducido
- ✓ Pobre conocimiento y conciencia entre los productores del impacto de la enfermedad, su ciclo infectivo y las tácticas de manejo

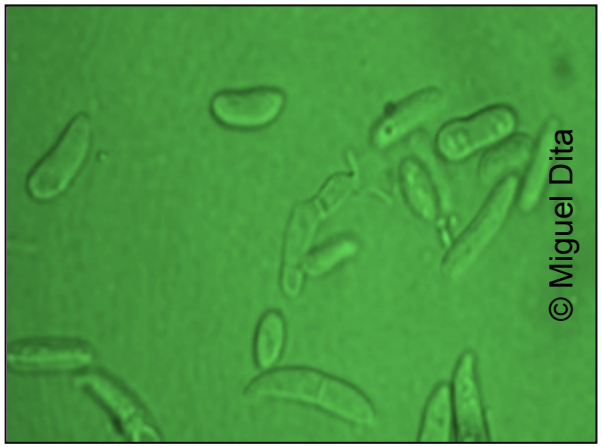
Research Targets on Foc Tropical Race 4

1. Prevention - early detection
2. Use of resistant varieties
3. Disease management

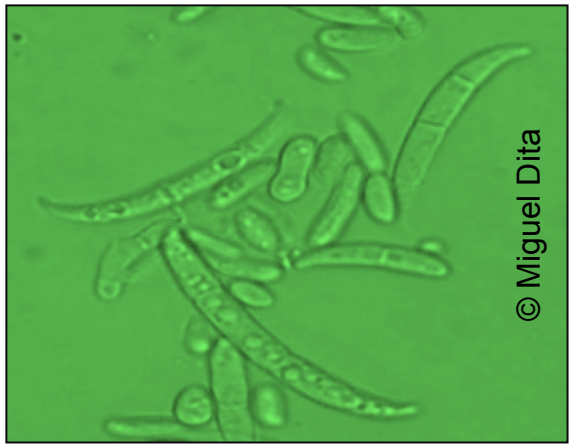
a. Diagnostic tools for Foc TR4 and other important races/strains of Foc;
b. Fast and reliable bioassays for high throughput phenotyping
c. Characterize genotypes of Musa for TR4 resistance/ Identify Resistant sources
d. Understand Foc- banana interaction at genetic, cytological and molecular level;
e. Epidemiology for integrated management strategies - Eradication

A diagnostic tool for Foc TR4

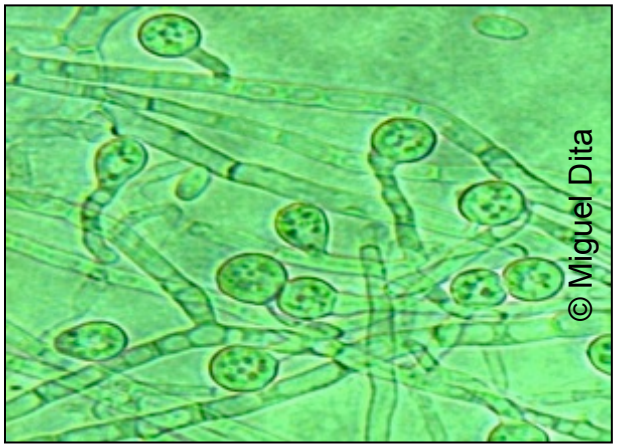
Structures of *F. o* f. sp. *cubense*



Microconidia are 5 - 16 x 2.4 - 3.5 µm, one- or two-celled, oval- to kidney-shaped, and are borne in false heads



Macroconidia: are 27 - 55 x 3.3 - 5.5 µm, four- to eight-celled and sickle-shaped with foot-shaped basal cell



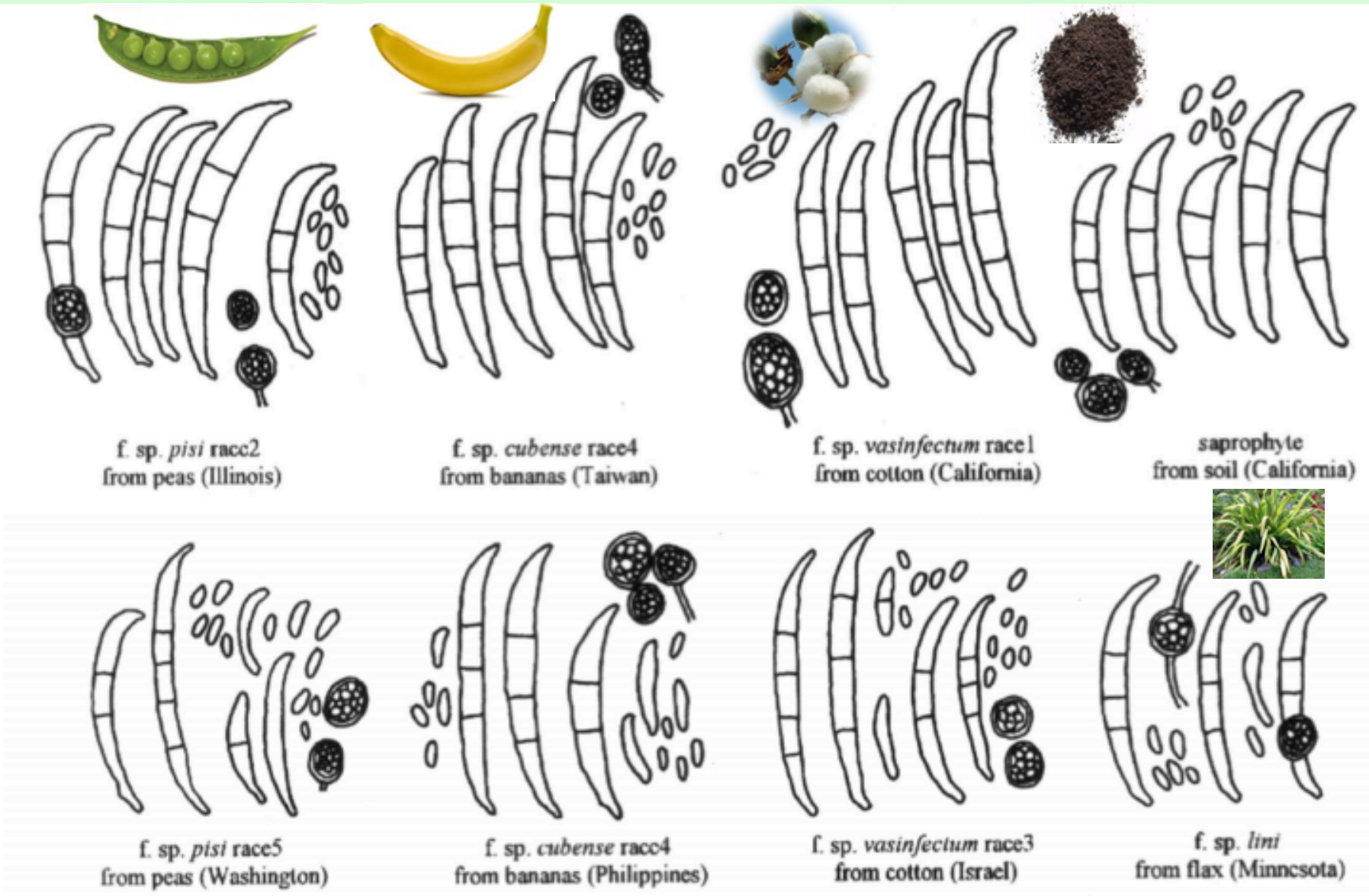
Chlamydospores: Terminal and intercalary are 7 - 11 µm in diameter, usually globose and are formed singly or in pairs in hyphae or conidia

- Fox: ~ 100 *formae speciales* cause wilting in plants

It contains pathogenic and saprophytic strains that cannot be distinguished morphologically

Source: Ploetz (2000)

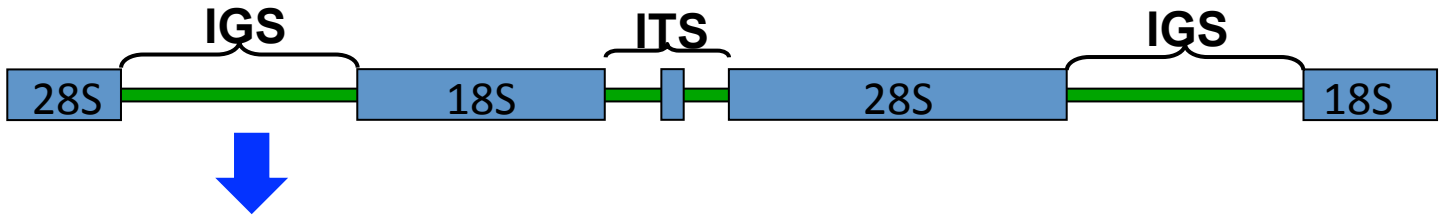
Foc cannot be distinguished morphologically from other Foxys



Source: Smith (2007)

Genetic diversity of *Foc* based on:

Elongation factor 1-α (*Tefa*-1a) and Intergenic spacer region- IGS



Plant Pathology (2010) **59**, 348–357 Doi: 10.1111/j.1365-3059.2009.02221.x

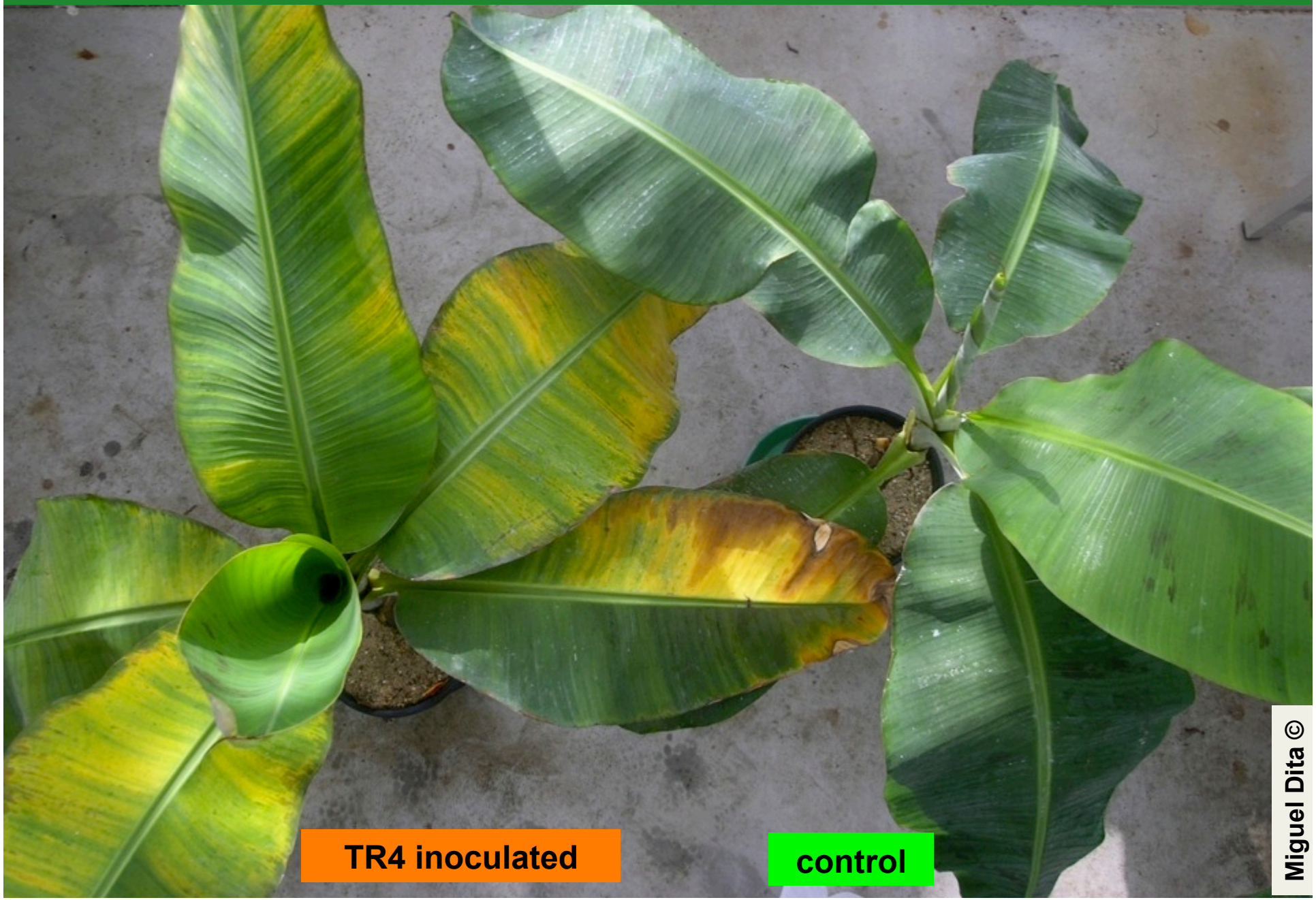
BSPP

A molecular diagnostic for tropical race 4 of the banana fusarium wilt pathogen

M. A. Dita[a,b], C. Waalwijk[b], I. W. Buddenhagen[c], M. T. Souza Jr[b,d] and G. H. J. Kema[b*]

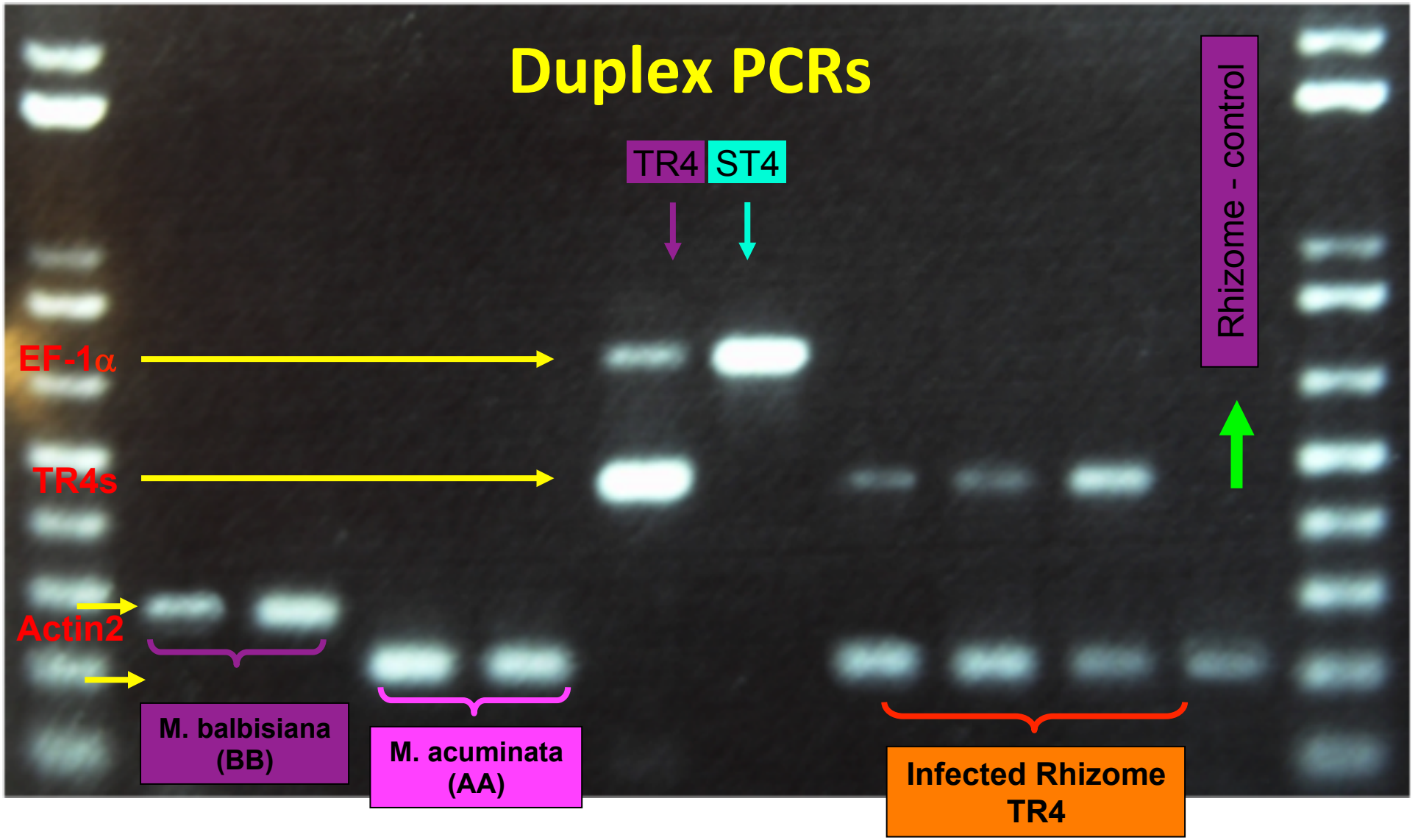
[a]*Embrapa Cassava & Tropical Fruits, Cruz das Almas, 44380-000, Bahia, Brazil;* [b]*Plant Research International B.V., PO Box 16, 6700 AA Wageningen, the Netherlands;* [c]*1012 Plum Lane, Davis, California, USA; and* [d]*Embrapa LABEX Europe, PO Box 16, 6700 AA Wageningen, the Netherlands*

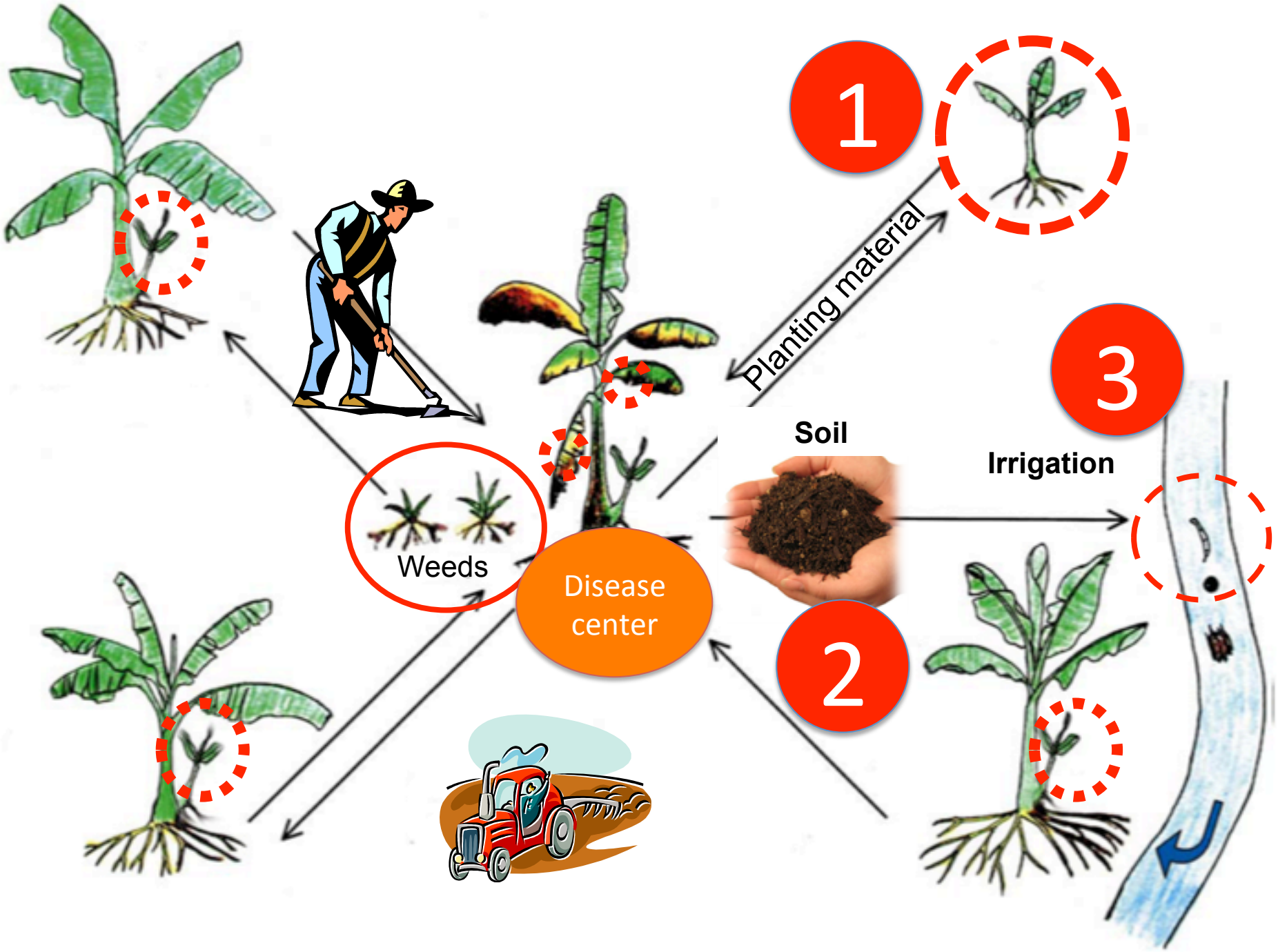
Foc TR4 - *in planta* detection



Foc TR4 - *in planta* detection

EF +FocTR4 // Actin2 + FocTR4

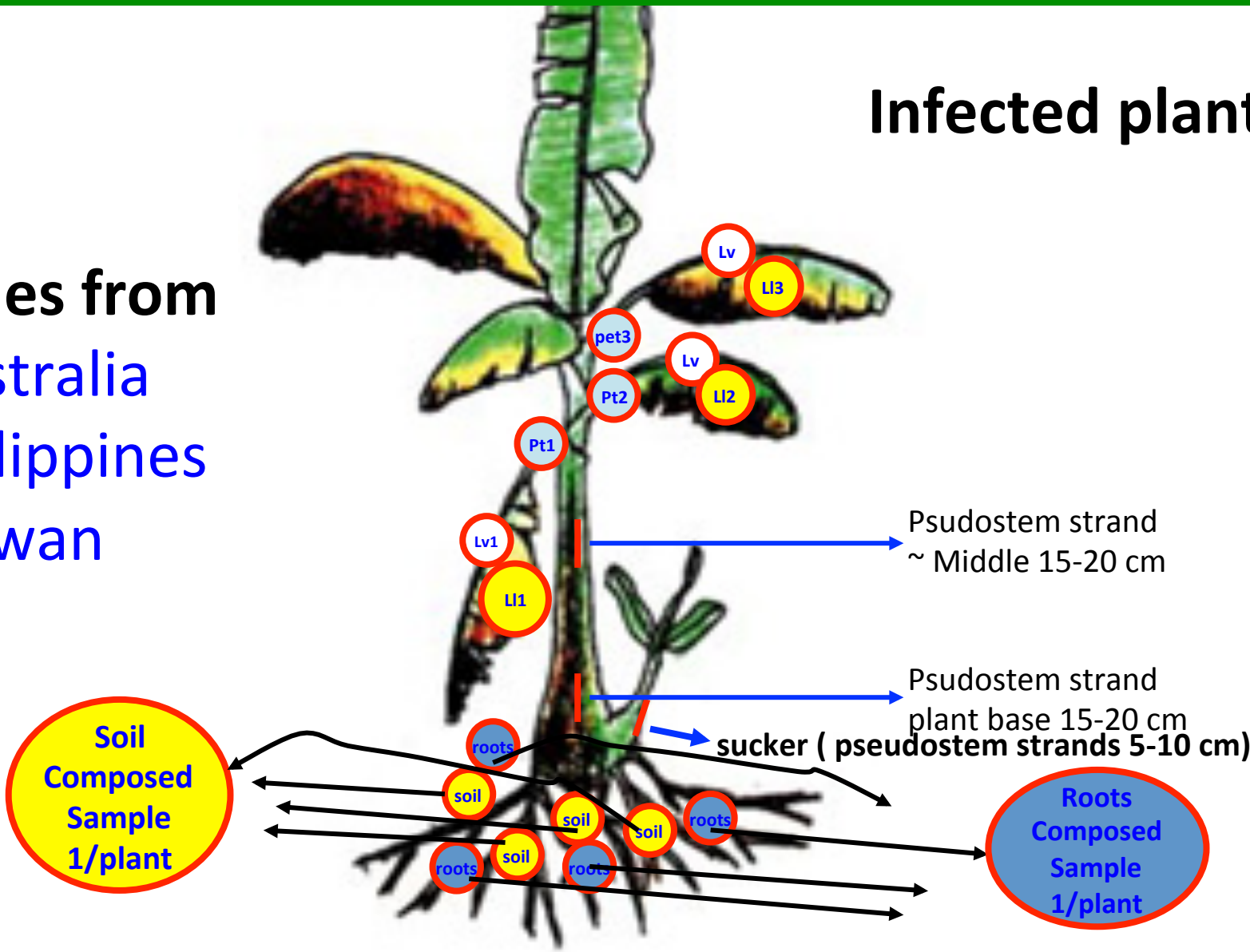



1
Planting material
3
Soil
Irrigation
Weeds
Disease center
2

Detecting *Fusarium oxysporum* f. sp. *cubense* tropical race 4 in soil and symptomless banana tissues

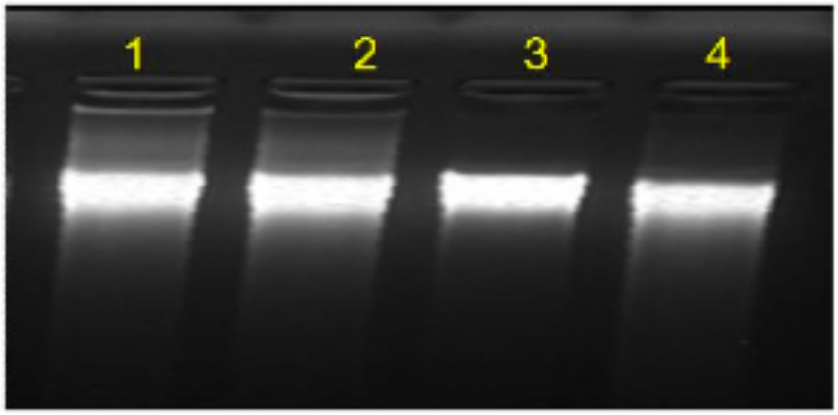
Samples from

- Australia
- Philippines
- Taiwan



Detecting Foc TR4 in soil

DNA extraction



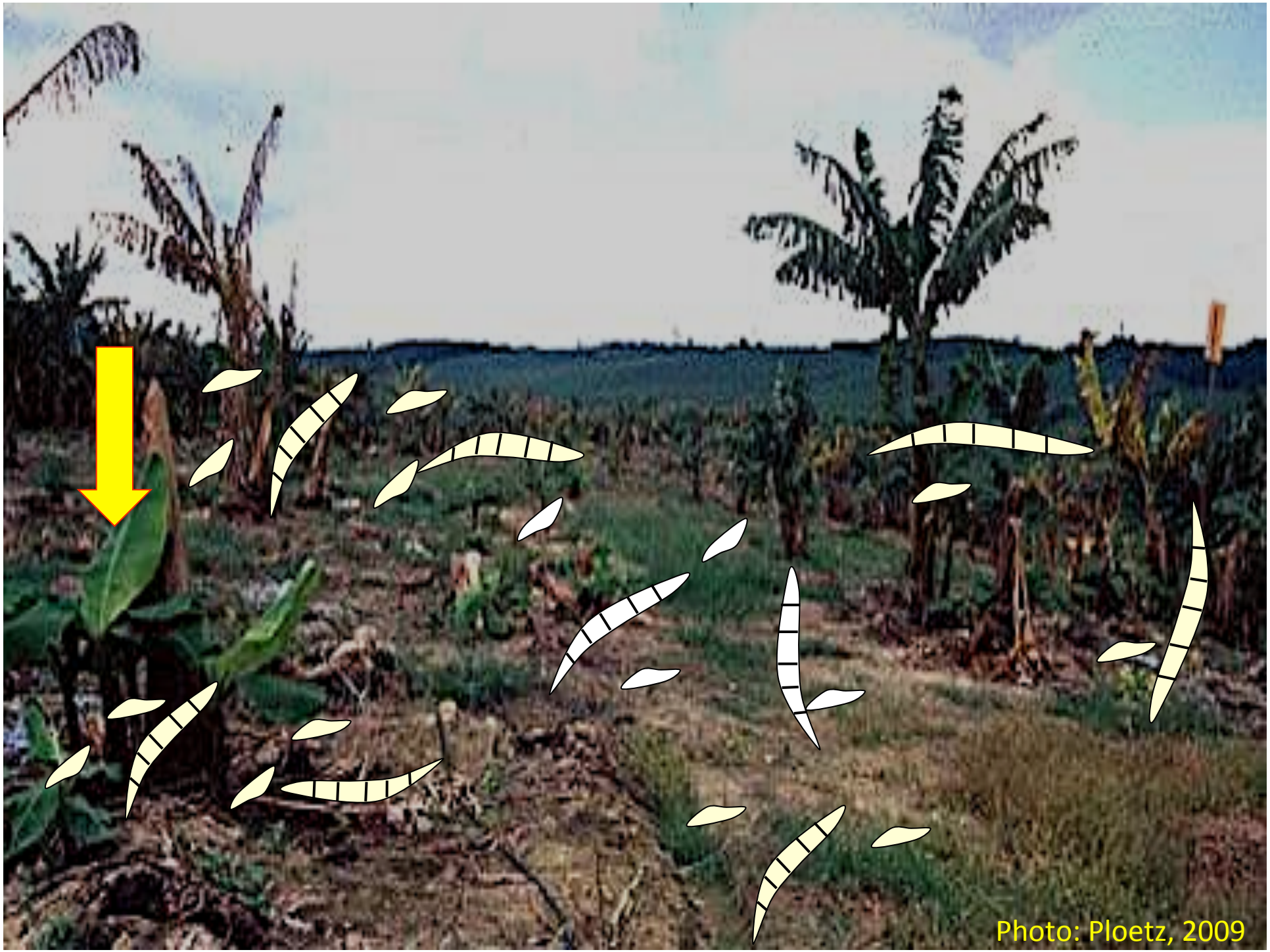


Photo: Ploetz, 2009

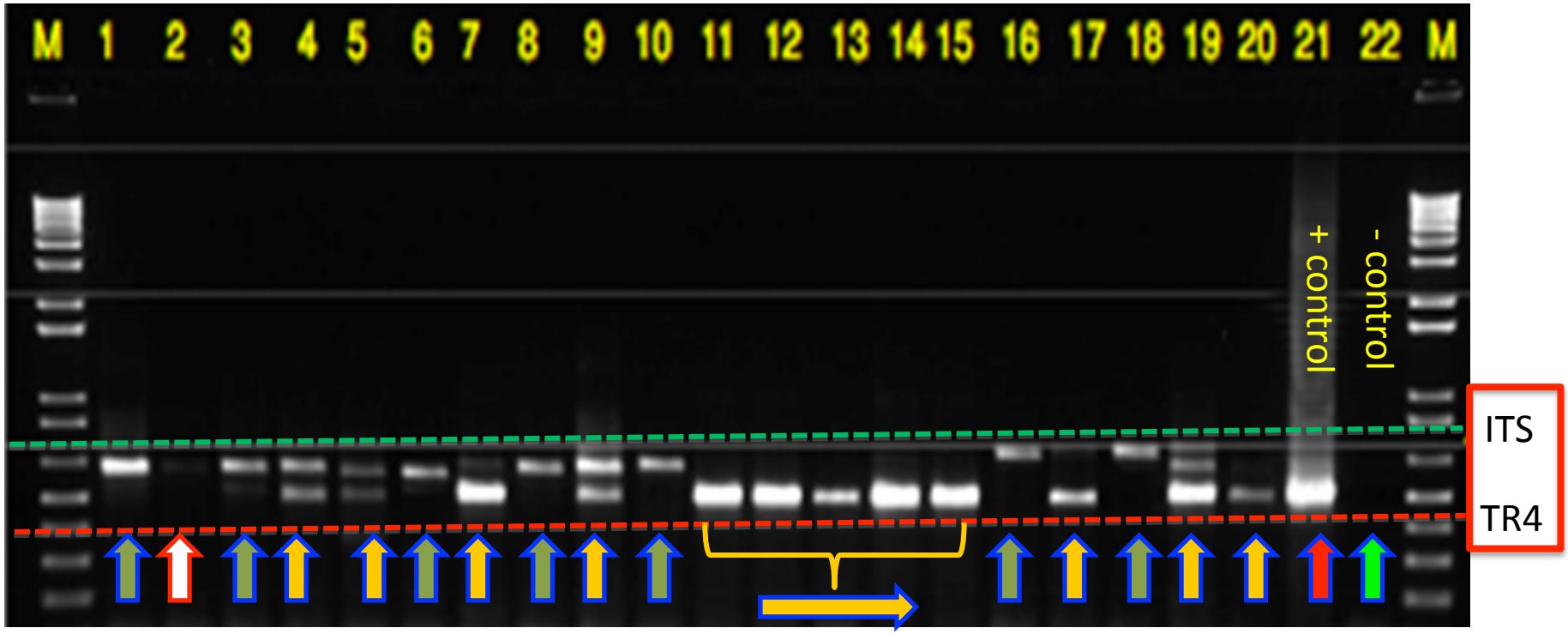
Water is an efficient way for FOC dissemination….

- Can we detect Foc TR4 easily in water samples?
- What would be the app/implications?

Sample ID	Cultivar [a]	Plant stage	Location	Source	Sample processed	Single PCR	Nested PCR
AuD1	Cavendish	Symptomatic	Darwin	Australia	Plant	+	nd
AuH1	Cavendish	Symptomless	Darwin	Australia	Plant	+	nd
TS1	Cavendish	Symptomless	Chaojhou	Taiwan	Soil	-	+
					Plant	+	nd
TS3	Cavendish	Symptomatic	Chaojhou	Taiwan	Soil	+	+
					Plant	+	nd
TS6	Cavendish	Symptomless	Wandan	Taiwan	Soil	-	-
					Plant	+	nd
TS7	Cavendish	Symptomatic	Jiuru	Taiwan	Soil	+	+
					Plant	+	nd
TS8	Cavendish	Symptomless	Jiuru	Taiwan	Soil	-	+
					Plant	+	
TS9	Cavendish	Symptomatic	Luye	Taiwan	Soil	+	+
					Plant	+	nd
Phi126C	Gran Naine	Symptomatic	Kapalong	Philippines	Plant	+	nd
Phi39B	Tall William	Symptomatic	Kapalong	Philippines	Plant	-	nd
Phi2SV	Latundan	Symptomatic	Kapalong	Philippines	Plant	-	nd
ChlamyD2	n.a.	n.a.	n.a.	n.a.	Foc-colonized Substrate	+	+

DNA samples from soil of Ecuador & Costa Rica -consistently negative

Detecting Foc TR4 in soil

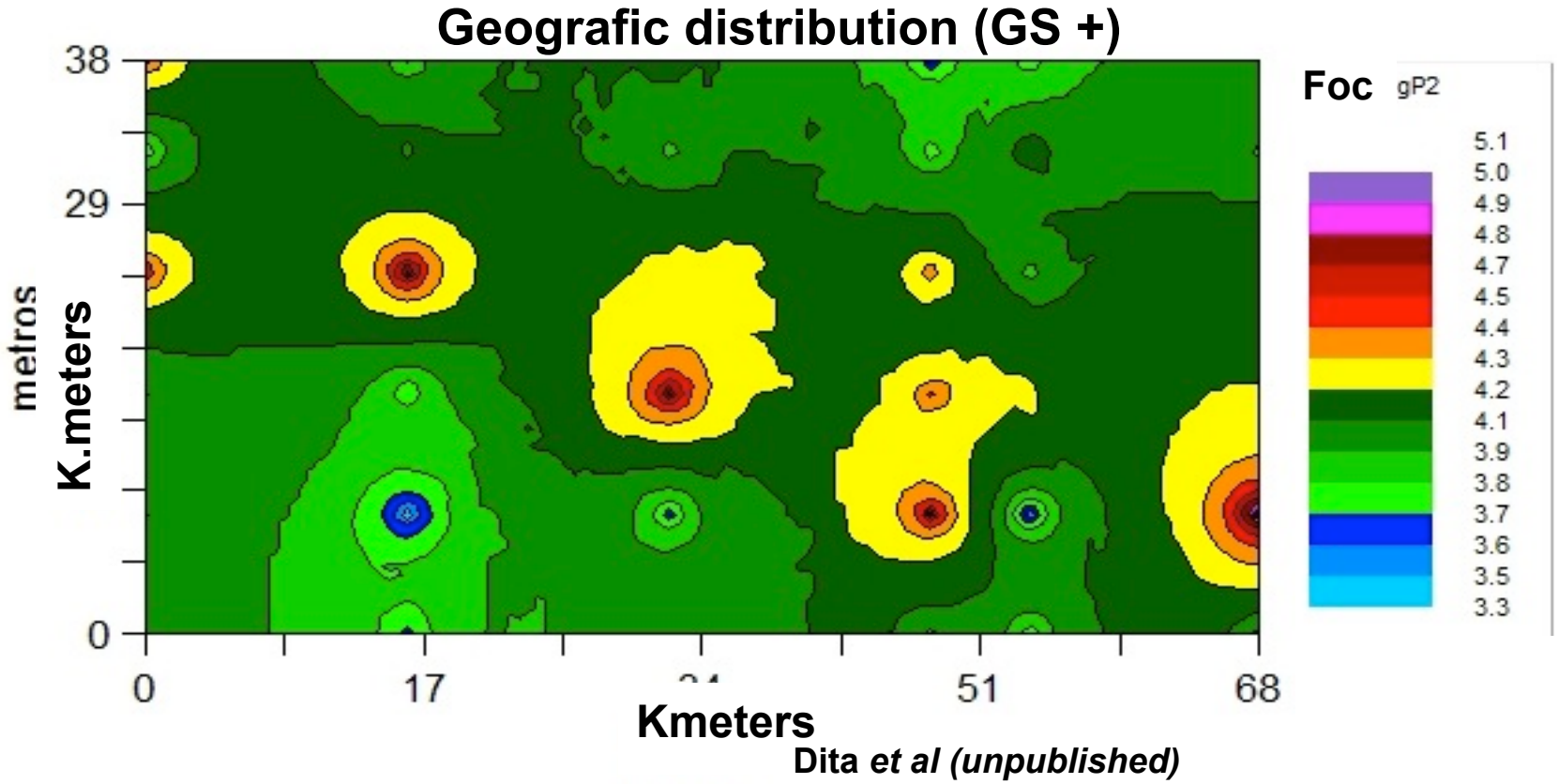


? – DNA quality*
– Sample
+ sample

Diagnostic tool applications

1. Quarantine support
2. Support eradication practices
3. Planting material certification
4. Risk analysis

Next- improved the method and turn into qPRC / high throughput tech – Data?



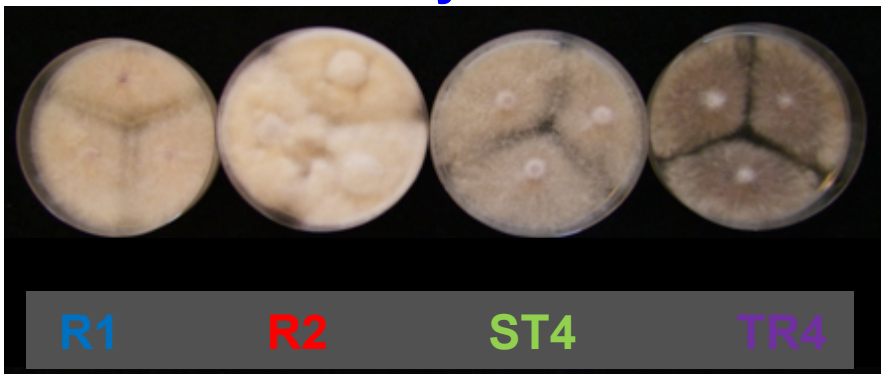
Dita *et al (unpublished)*

Generating genome and transcriptome information from Foc : enabling tools for diagnostics and Foc-banana interactions

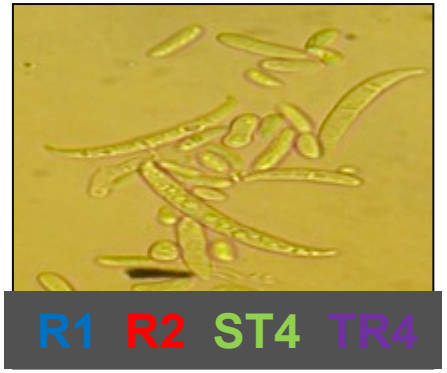
Isolate	Race	VCG	Host	Source
Foc_R1	1	Unknown*	Silk ()	Brazil
Foc_R2	2	124	Monthan	Brazil
FocST498	ST4	120	Dwarf /Cavendish	Spain
II-5	TR4	1213	Cavendish	Indonesia

Comparative analysis of ESTs (Expressed Sequenced Tags) from different races of Foc [R1, R2, ST4 & TR4]

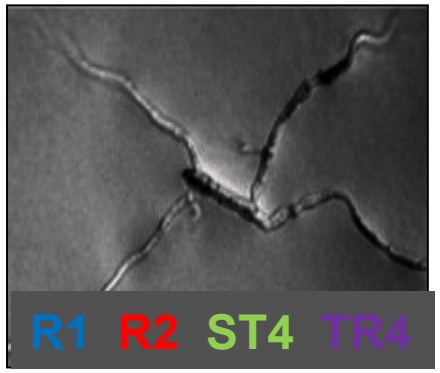
Mycelia



Conidia



Germinated conidia



RNA extraction

RNA pooling (mycelium + conidia + germinating conidia)

mRNA Isolation

cDNA from R1, R2, ST4, TR4 and 454 sequencing

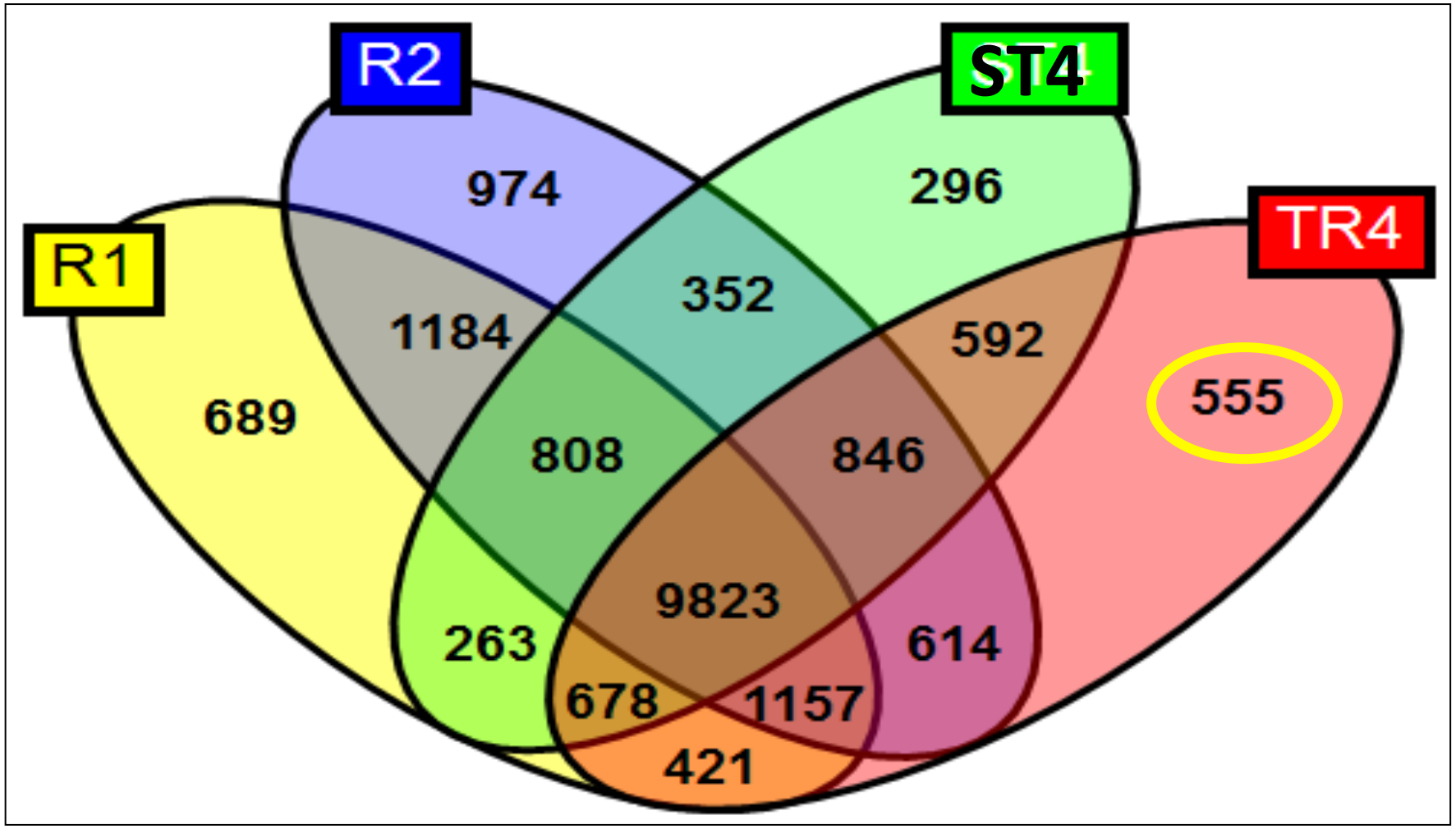
Comparative EST analyses

Comparative analysis of ESTs (Expressed Sequenced Tags) from different races of Foc [R1, R2, ST4 & TR4]

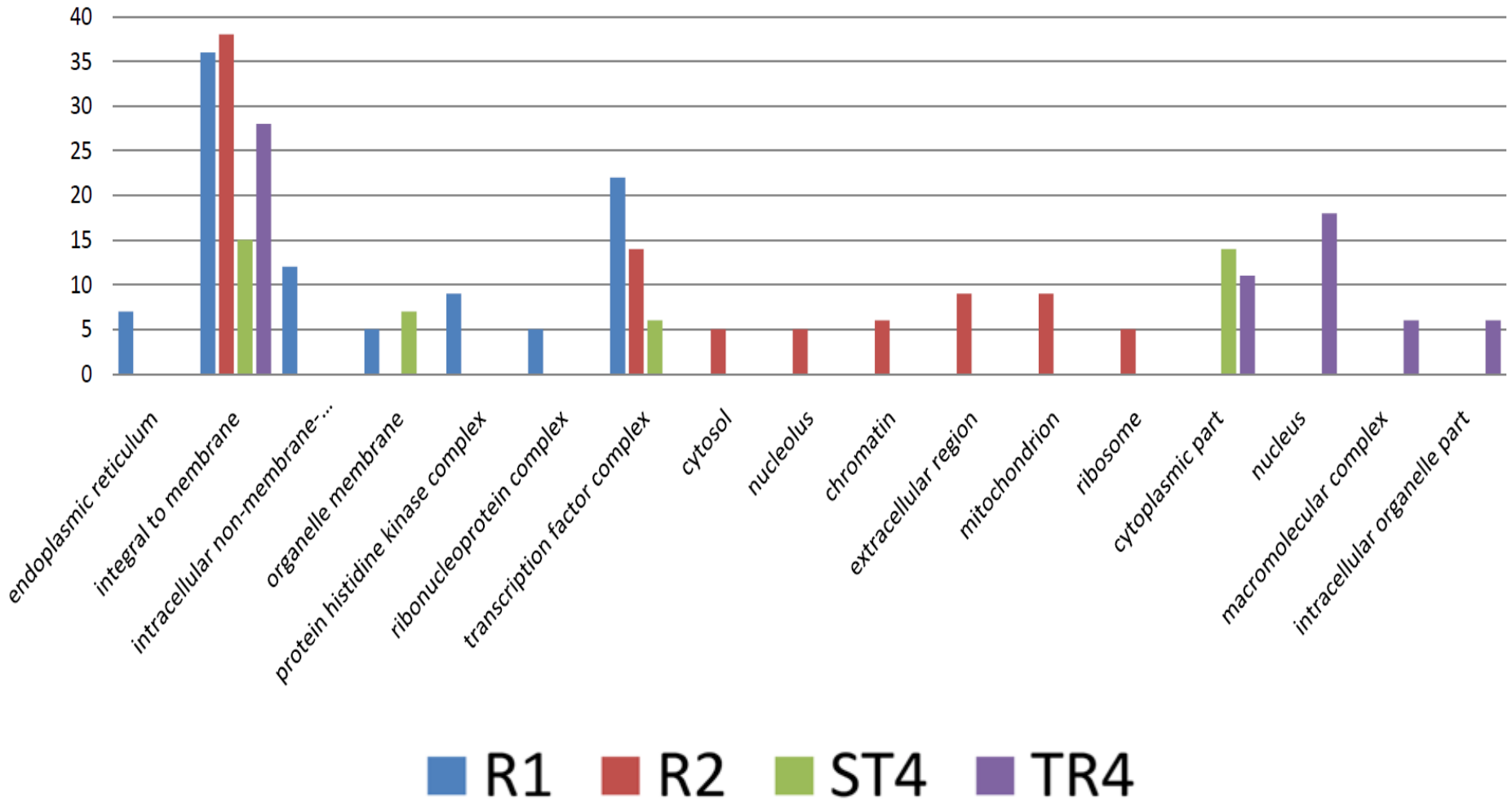
Library statistics

	R1	R2	ST4	TR4	All Libraries
Raw reads	644.444	661.201	633.453	606.533	2.545.631
rDNA	2.988	3.255	1.811	2.746	10.800
Passed reads	637.670	653.748	629.498	601.136	2.522.052
aver. length	396	392	364	371	381
% Singlets	6.2 %	6.3 %	5.5 %	7.2 %	5.3 %
Assembled reads	541.632	558.903	554.771	557.094	2.151.030
# isogroups	8.302	9.059	7.610	8.193	11.058
# isotigs >50nt	9.674	11.114	8.500	10.216	21.445
mean isotig length	1345.8	1440.5	1293.8	1406.3	2161.9
Longest Isotig	8.293	9.732	7.276	7.752	11.432

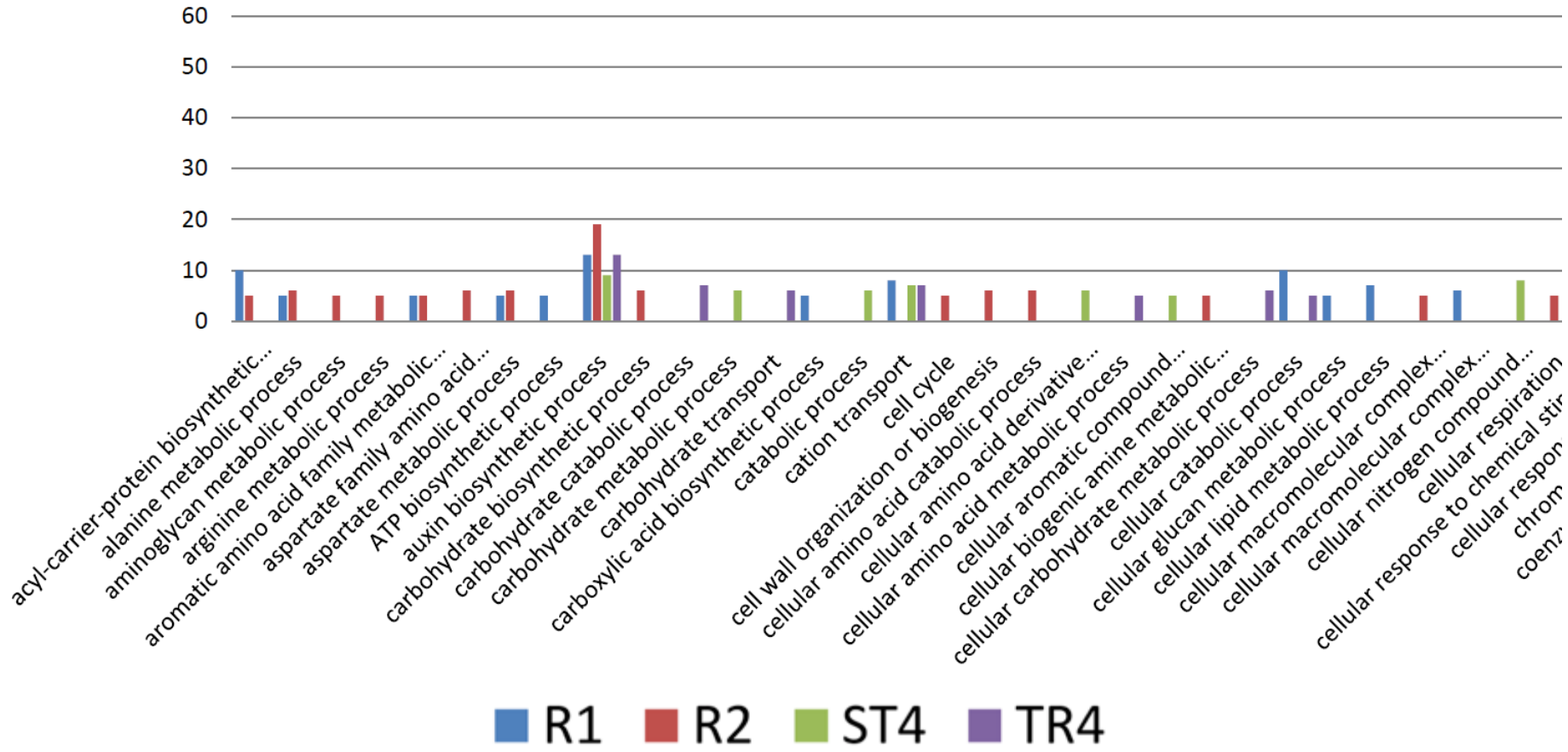
Gene distribution across Foc races



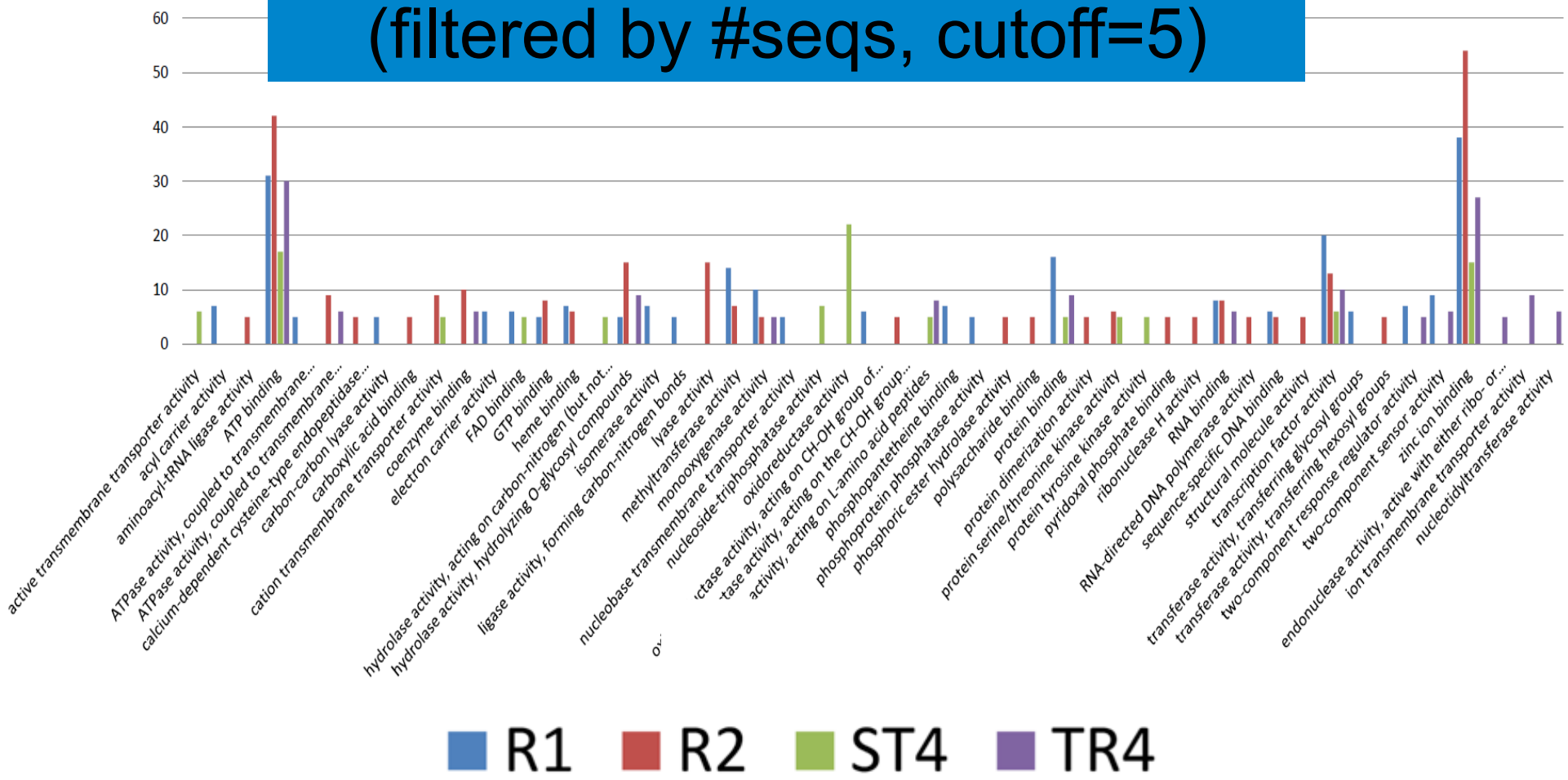
Cellular localization
(filtered by #seqs, cutoff=5)



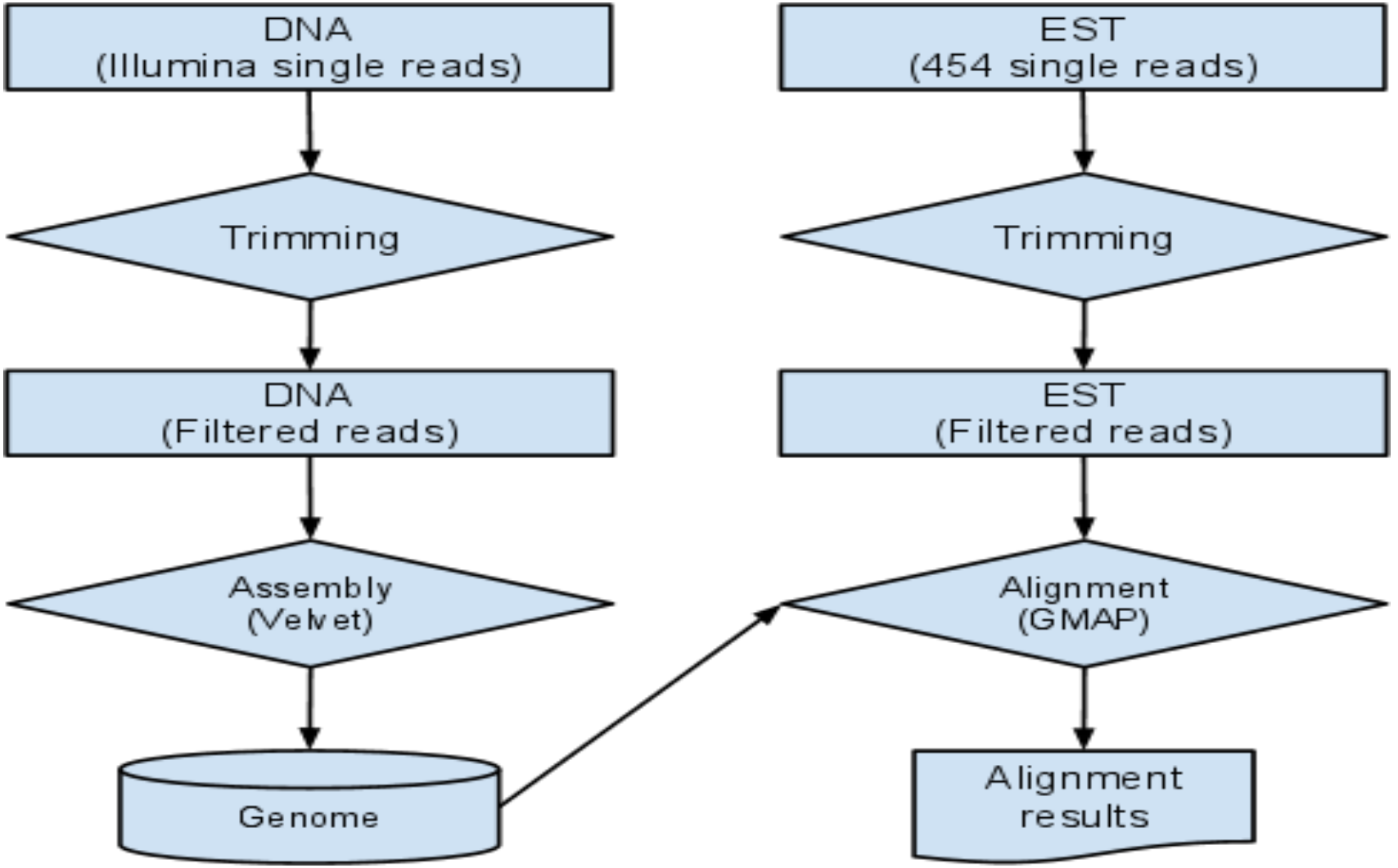
Biologal processes
(filtered by #seqs, cutoff=5)



Molecular function
(filtered by #seqs, cutoff=5)



Genome and transcriptome assembly and annotation



Alignment of ESTs in Foc genome

EST data was aligned against assembled genome

Strain	Filtered reads	Mapped reads	Unmapped reads
R1	252.589	244.242 (96.69 %)	8.347 (3.31 %)
R2	273.731	263.986 (96.43 %)	9.745 (3.57 %)
ST4	217.735	213.214 (97.92 %)	4.521 (2.08 %)
TR4	209.653	204.818 (97.69 %)	4.835 (2.31 %)
Total	953.708	926.260 (97.18 %)	**27.448 (2.82 %)**

Foc TR4 estimated genome size: 49 Mb (Dita et al. 2011)

51 Mb (Berg et al. 2012)

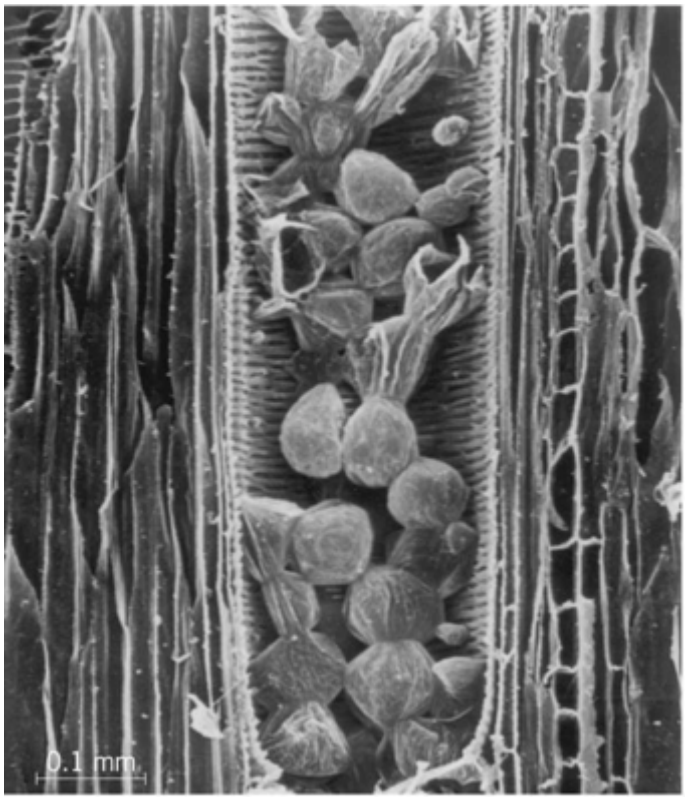
- including ~4.3Mb lineage specific sequences that are highly repetitive

Australasian Plant Pathol.
DOI 10.1007/s13313-012-0122-x

Presence of putative pathogenicity genes in isolates of *Fusarium oxysporum* f. sp. *cubense* from Australia

R. A. Meldrum · S. Fraser-Smith ·
L. T. T. Tran-Nguyen · A. M. Daly · E. A. B. Aitken

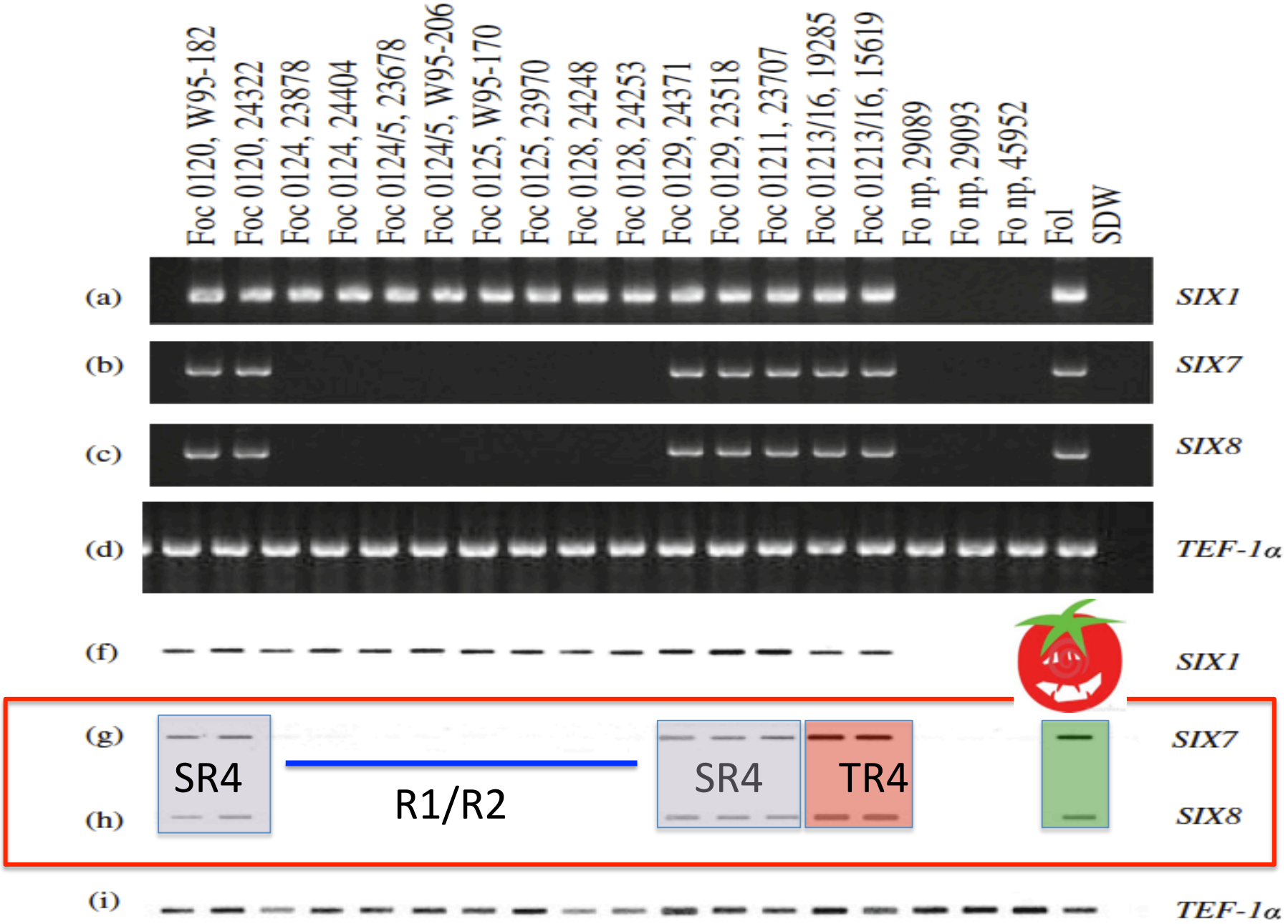
Secreted in Xylem Genes – SIX



(G. E. VanderMolen, University of Rhode Island)

http://www.accessscience.com/popup.aspx?figID=524000FG0060&id=524000&name=figure

Presence of putative pathogenicity genes



Comparative analysis of ESTs (Expressed Sequenced Tags) from different races of Foc [R1, R2, ST4 & TR4]

Applications

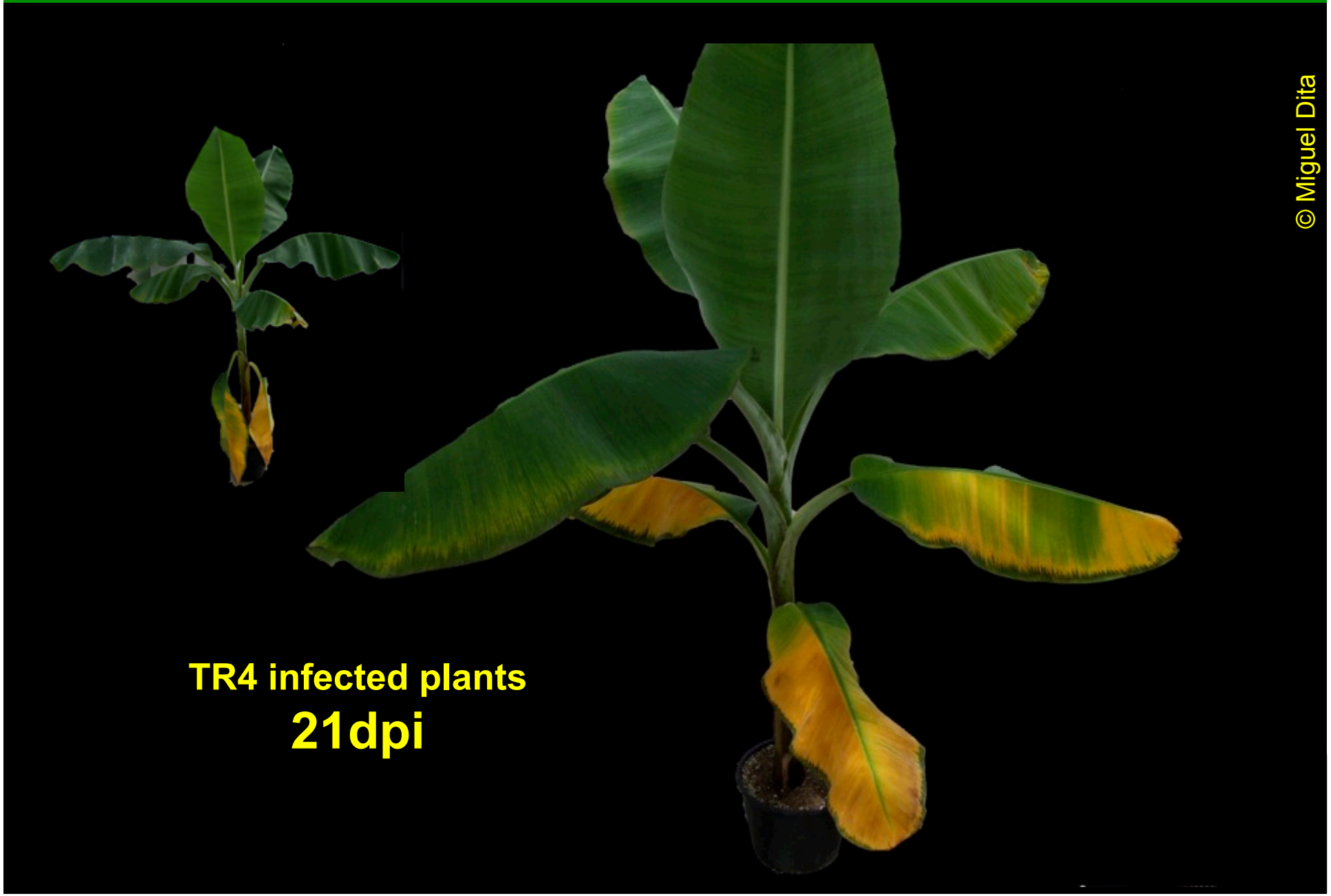
- Understanding the genetic diversity of Foc and it interaction with *Musa* spp., environments (SR4!)
- Diagnostics tools specifics for other races/VCGs more robust and sensitive.
- Identifying genes involved in pathogenicity/virulence - What genes hold TR4 that enables Cavendish infection?
- Identify genes involved on survival, aggressiveness, chlamydospores formation…
- Design management strategies more efficient …

Resistance for Tropical race 4?

1st – a rapid and reliable bioassay for Foc-banana interaction

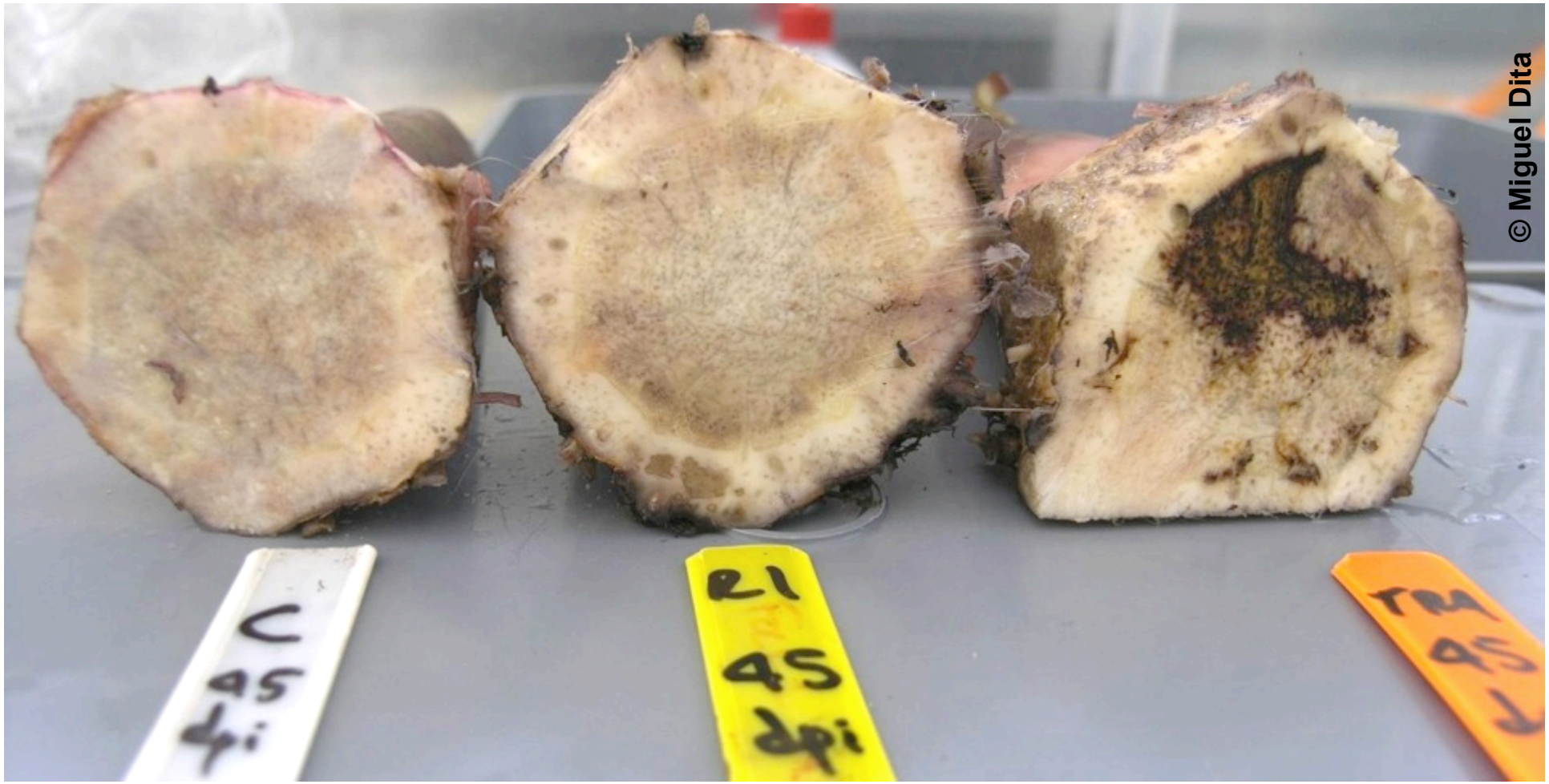
Bioassay for Cavendish – Foc TR4

Bioassay for Cavendish – Foc TR4



Bioassay for Cavendish – Foc TR4

Cavendish - R1 vs. RT4 incompatible vs. compatible



Musa phenotyping for Foc TR4 resistance: Greenhouse

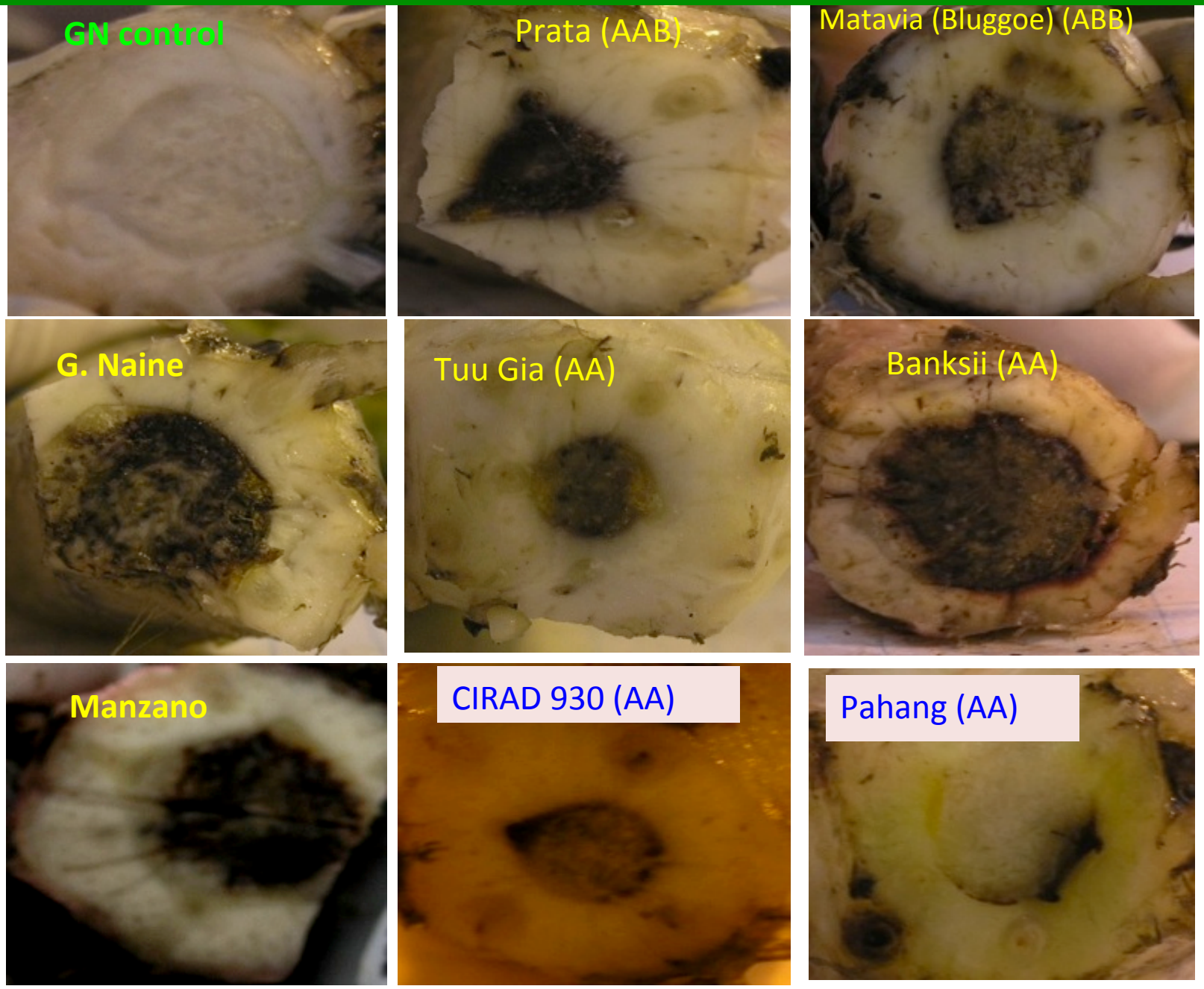
09 Genotypes vs. Foc TR4

1. Grande Naine (AAA)
2. Maçã (Silk) – AAB
3. Prata (AAB)
4. Pahang (AA)
5. CIRAD 930 (AA) *M. a. malaccensis*
6. *Pahang (AA)*
7. Matavia (Bluggoe) – ABB
8. Banksii (AA)
9. Tuu Gia (AA)

We want to phenotype the entire ITC!

Musa phenotyping for Foc TR4 resistance

21 dpi



Assessment of East African highland banana (AAA) and plantain (AAB) cultivars in Asia for resistance to Foc TR4"

ITC code	Cultivar	Genome	Subgroup
ITC0081	Igitsiri (Intuntu)	AAA	EAHB
ITC0179	Inkira	AAA	EAHB
ITC0084	Mbwazirume	AAA	EAHB
ITC0166	Ingagara	AAA	EAHB
ITC1354	Enzirabahima	AAA	EAHB
ITC1355	Kazirakwe	AAA	EAHB
ITC1465	Ibwi	AAA	EAHB
ITC0215	Mbi Egome 1	AAB	Plantain - French
ITC0217	Akpakpak	AAB	Plantain - French
ITC0519	Obubit Ntanga green mutant	AAB	Plantain - French
ITC0121	Ihitisim	AAB	Plantain - Horne
ITC0208	Atali Kiogo	AAB	Plantain - False Horne
ITC1165	Curare	AAB	Plantain - False Horne
ITC1325	Orishele	AAB	Plantain - False Horne
ITC0570	Williams (Bell, South Johnstone)	AAA	Cavendish
	GCTCV-119	AAA	Cavendish SC variant
	Grand Nain	AAA	Cavendish
	Lakatan	AAA	(dessert type)
	Latundan	AAB	Silk
	Cardaba	ABB/BBB	Saba
	Baxi	AAA	Cavendish
	Guangfen No.1	ABB	Pisang Awak

Assessment of East African highland banana (AAA) and plantain (AAB) cultivars in Asia for resistance to Foc TR4"

Funded by Global Crop Diversity Trust

Target sites:

- The Philippines
- China

Plants are completing the 1st cycle and all the data obtained so far is preliminary. We need to evaluate at least 2 cycle to deliver reliable data (Molina, pers. comm 2012)

cv. Kazirakwe (AAA) is showing some resistance

How many varieties are affected by Foc TR4 ?

Indonesia

1. Raja (AAB)
2. Raja serai (AAB),
3. Buai (AAA),
4. P.Panjang (AAB),
5. Barangan (AAA)
6. Ambon kuning (AAA),
7. Ambon hijau (AAA)
8. Rejang (Aaw),
9. Jantan (AAB),
10. Kepok (ABB),
11. Mas kirana (AA)

Riska & Hermanto (2012)

Philippines

		1st Crop	// 2nd
1.	Lakatan (AAA),	100	// NA
2.	Latundan (AAA),	41	// 100
3.	Gran Nanine(AAA),	97	// NA
4.	Williams (AAA)	94	// NA
5.	GCTCV 119 (AAA)	1	// 28
6.	GCTCV 218 (AAA)	1	// 24
7.	FHIA 21 (AABB)	81	// NA

Molina (2011)

Australia

~ 25 Varieties susceptible

Walduck & Daly (2007)

At least 50 varieties are affected by TR4

~ 80 % of banana produced are from susceptible varieties

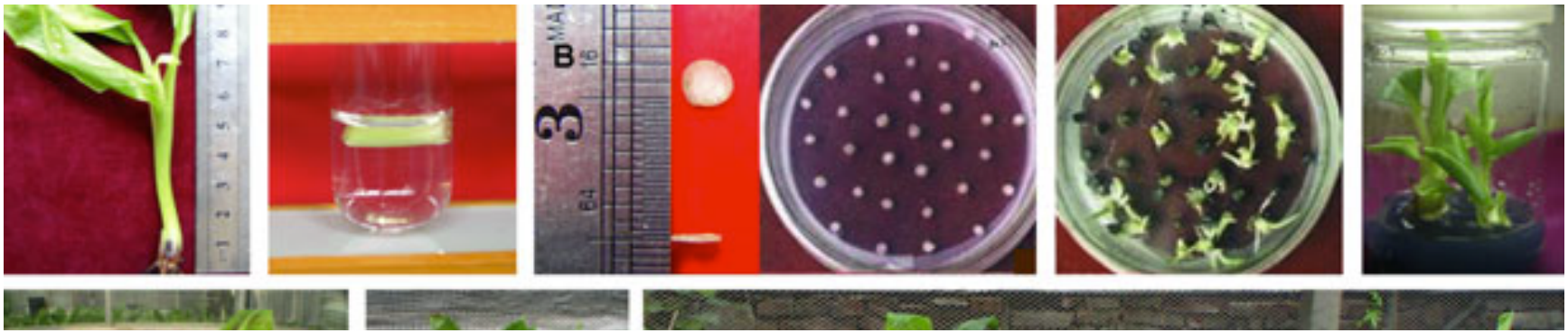
[Ploetz et al, 2005]

Plant Pathology (2012) Doi: 10.1111/j.1365-3059.2012.02620.x

Fusarium wilt-resistant lines of Brazil banana (*Musa* spp., AAA) obtained by EMS-induced mutation in a micro-cross-section cultural system

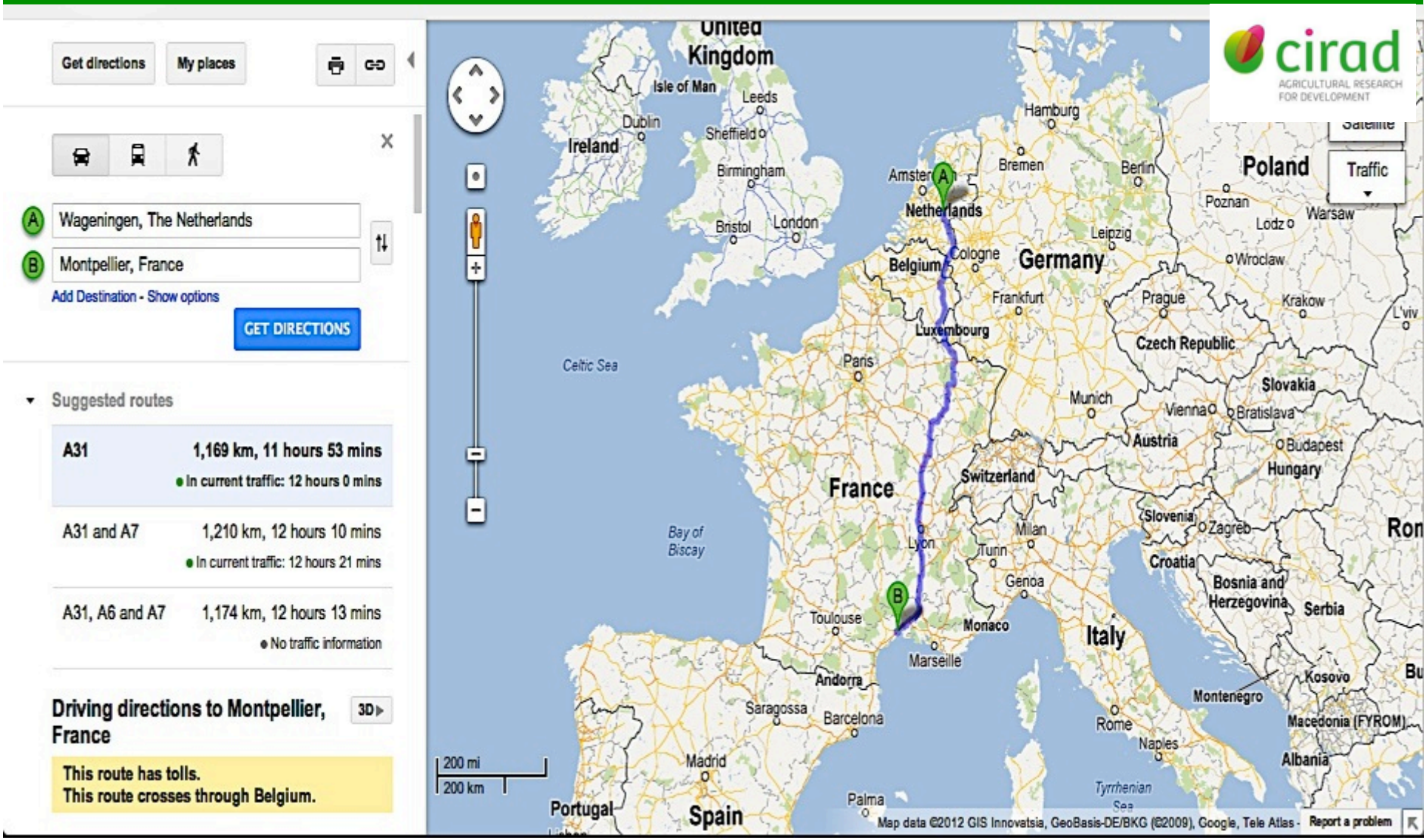
Y. F. Chen, W. Chen, X. Huang, X. Hu, J. T. Zhao, Q. Gong, X. J. Li and X. L. Huang*

The Key Laboratory of Gene Engineering of the Ministry of Education, School of Life Sciences, Zhongshan (Sun Yat-sen) University, Guangzhou 510275, China

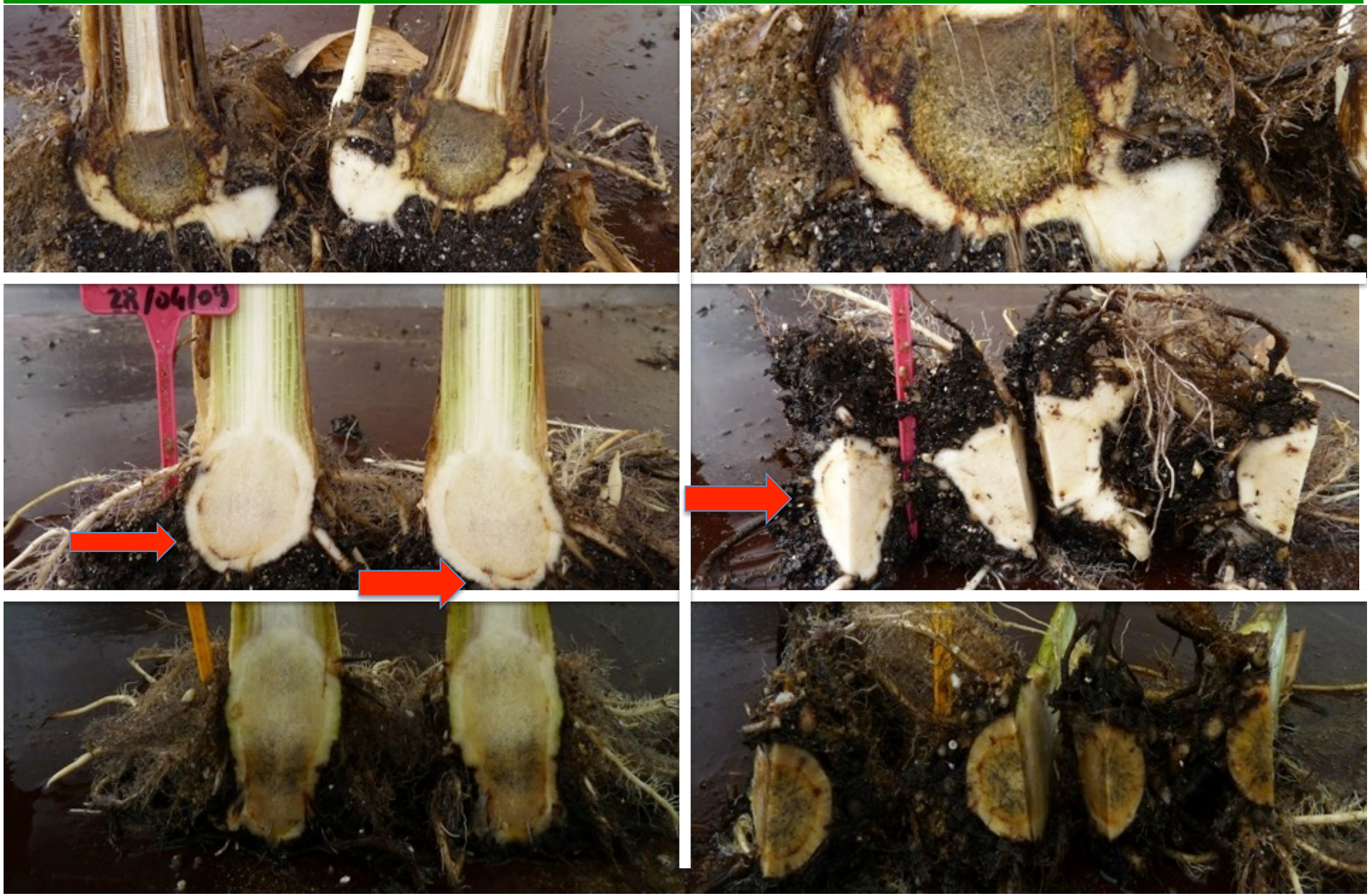


"In the present study, after a preliminary field test, five of six putative fusarium wilt resistant lines found by the early screening technique were resistant to fusarium wilt".

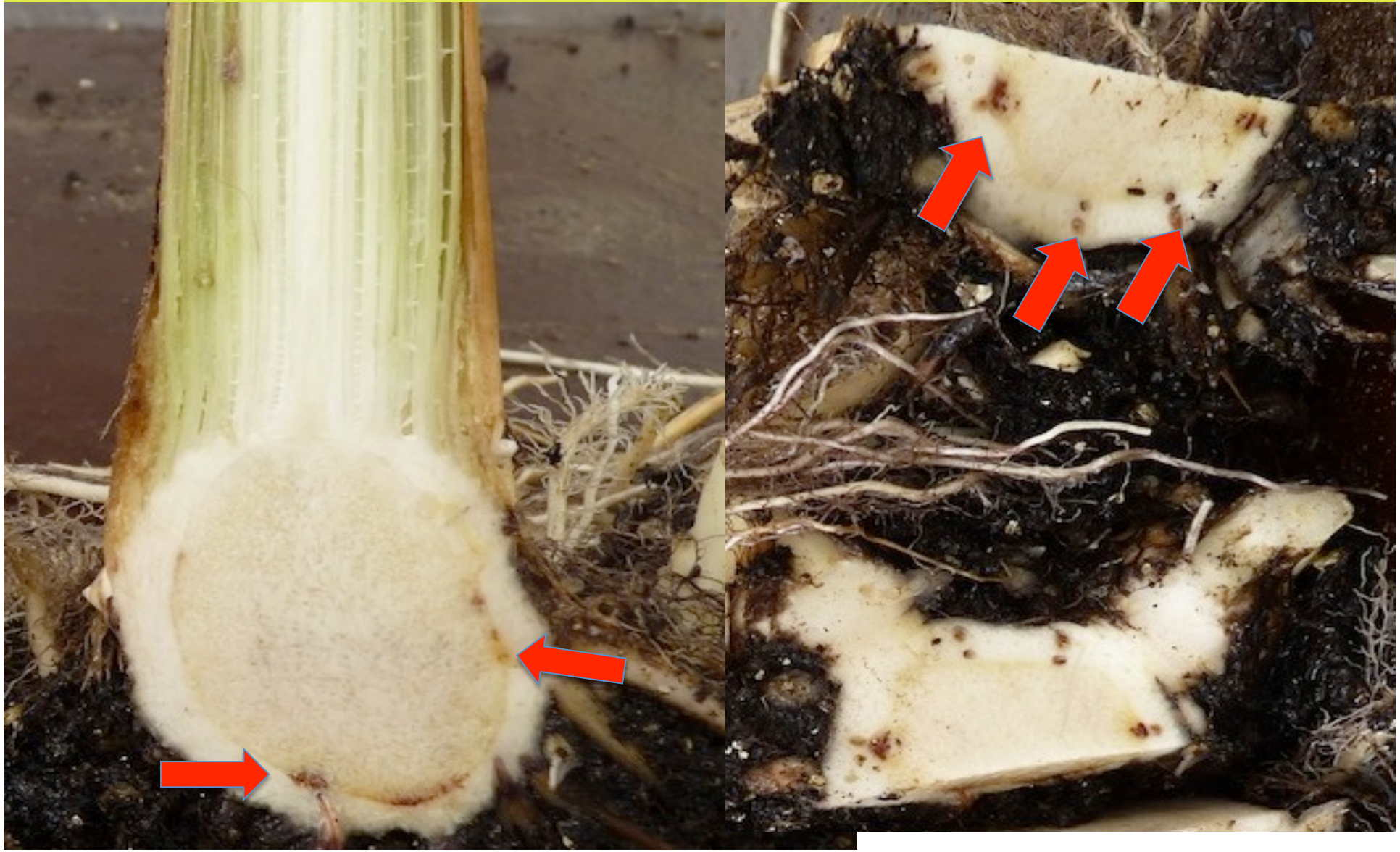
Phenotyping a segregating population of Pahang



Phenotyping a Pahang segregating population



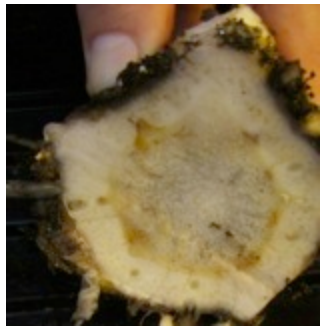
HR? – more research on Foc- banana interaction!

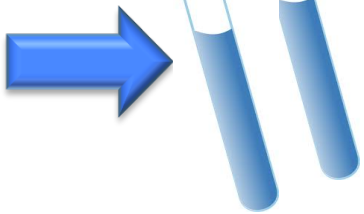


Comparative transcriptome analyses of compatible and incompatible Musa- FOC interactions

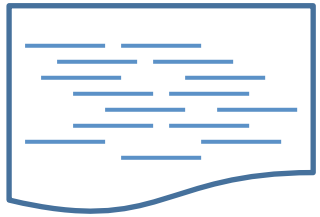
Race 1

TR4





454- seq



EST data
single reads

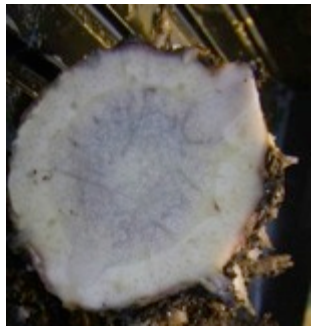
Some old questions:

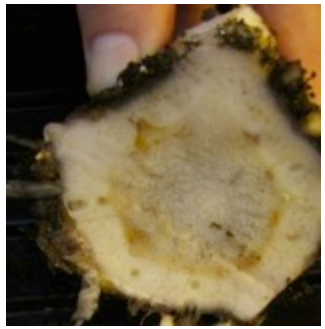
- When and where is Foc stopped in Cavendish during Race 1 infection?
- Which gene(s) are involved? At what level?
- Which mechanisms are responsible for resistance (effective >60 years)

Banana - Foc interaction

Two different cultivars were infected with Foc R1 and/or TR4

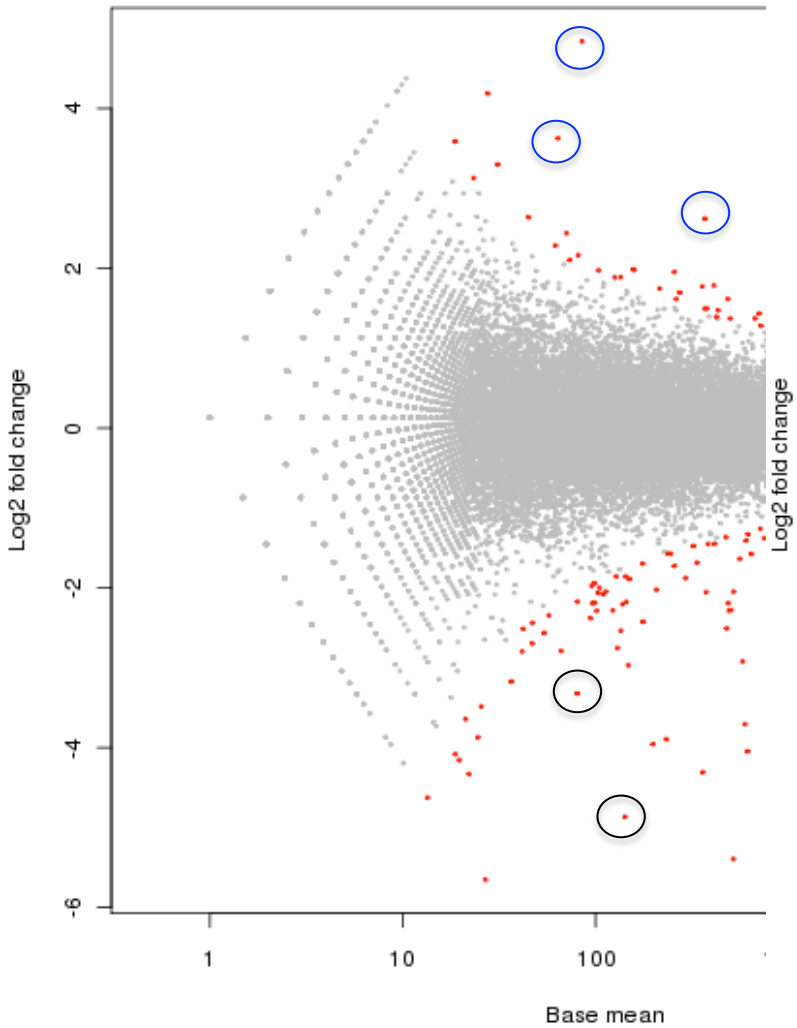
Foc race	Cultivar	Library type
Race 1	Grande Naine	**Incompatible interaction**
TR4	Grande Naine	**Compatible interaction**
Control	Grande Naine	Non-infected Control
TR4	Pahang	Highly resistant
Control	Pahang	Non-infected (control)



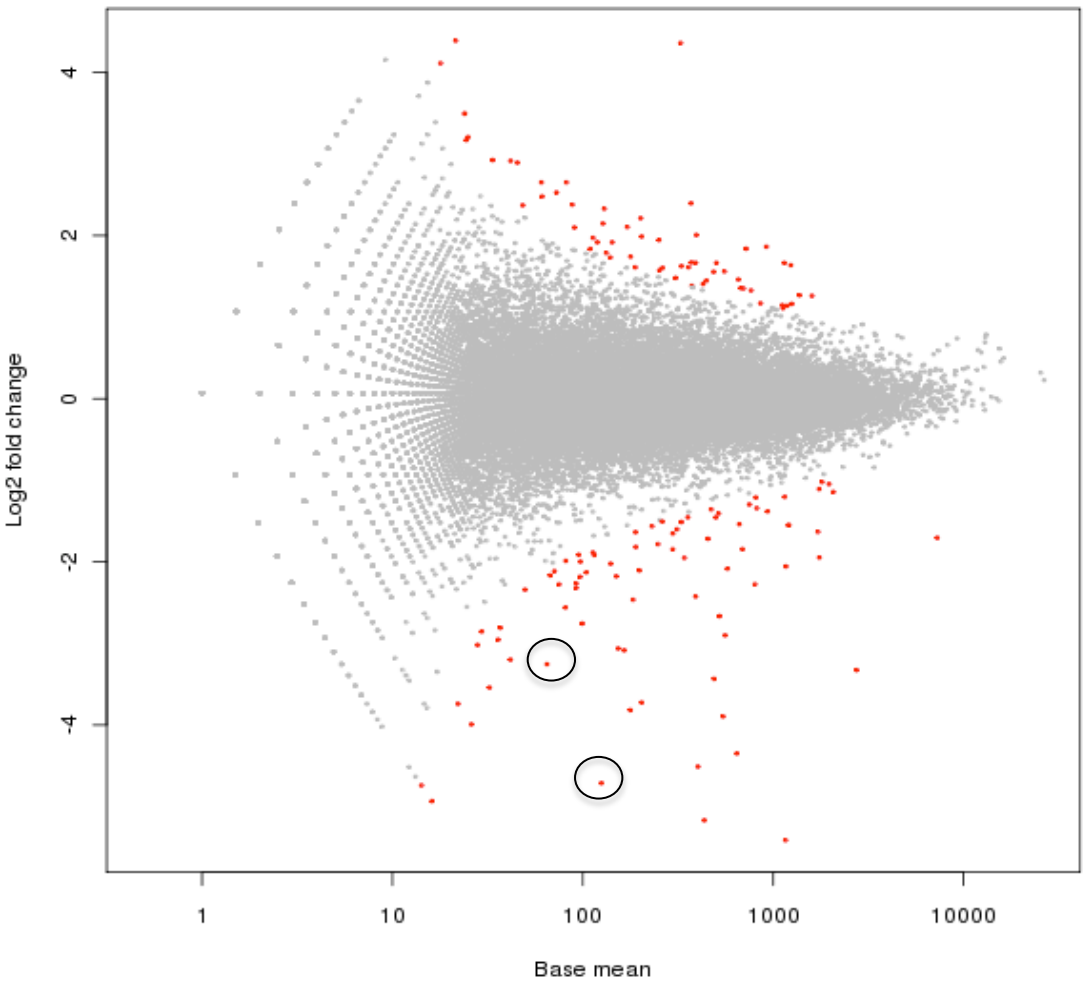


Comparative transcriptome analyses of compatible and incompatible Musa- FOC interactions

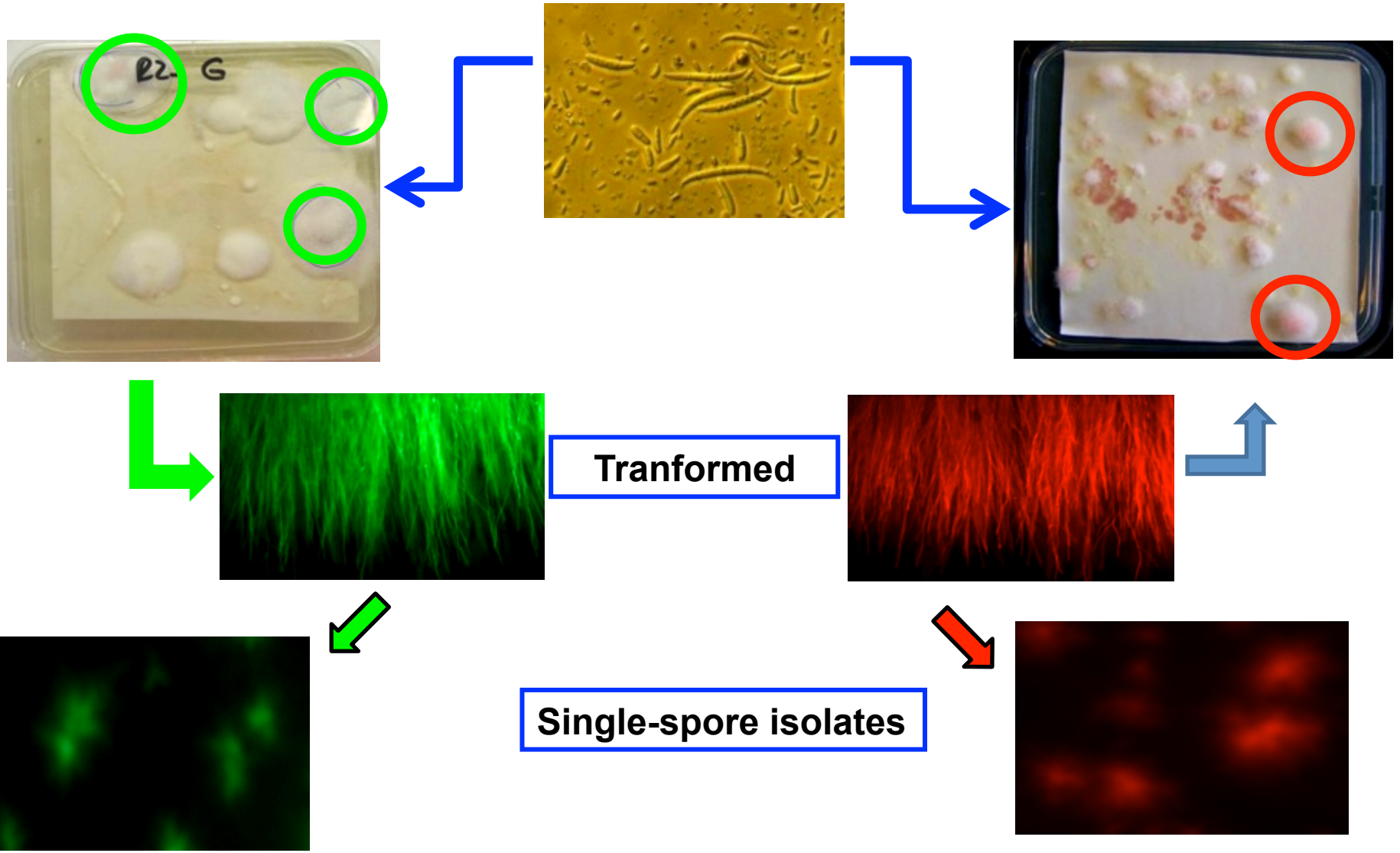
Gran Naine Control vs. Foc R1

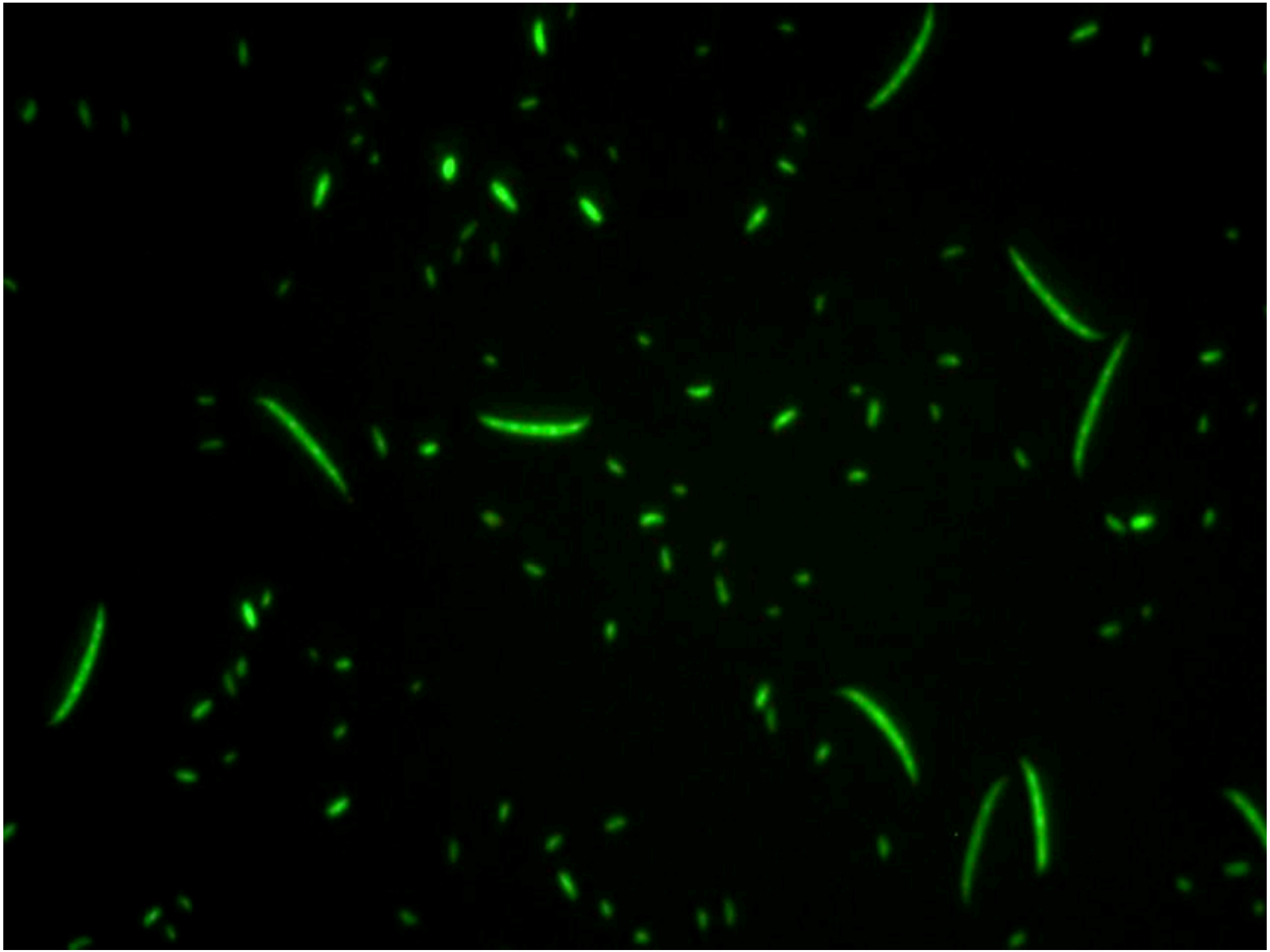


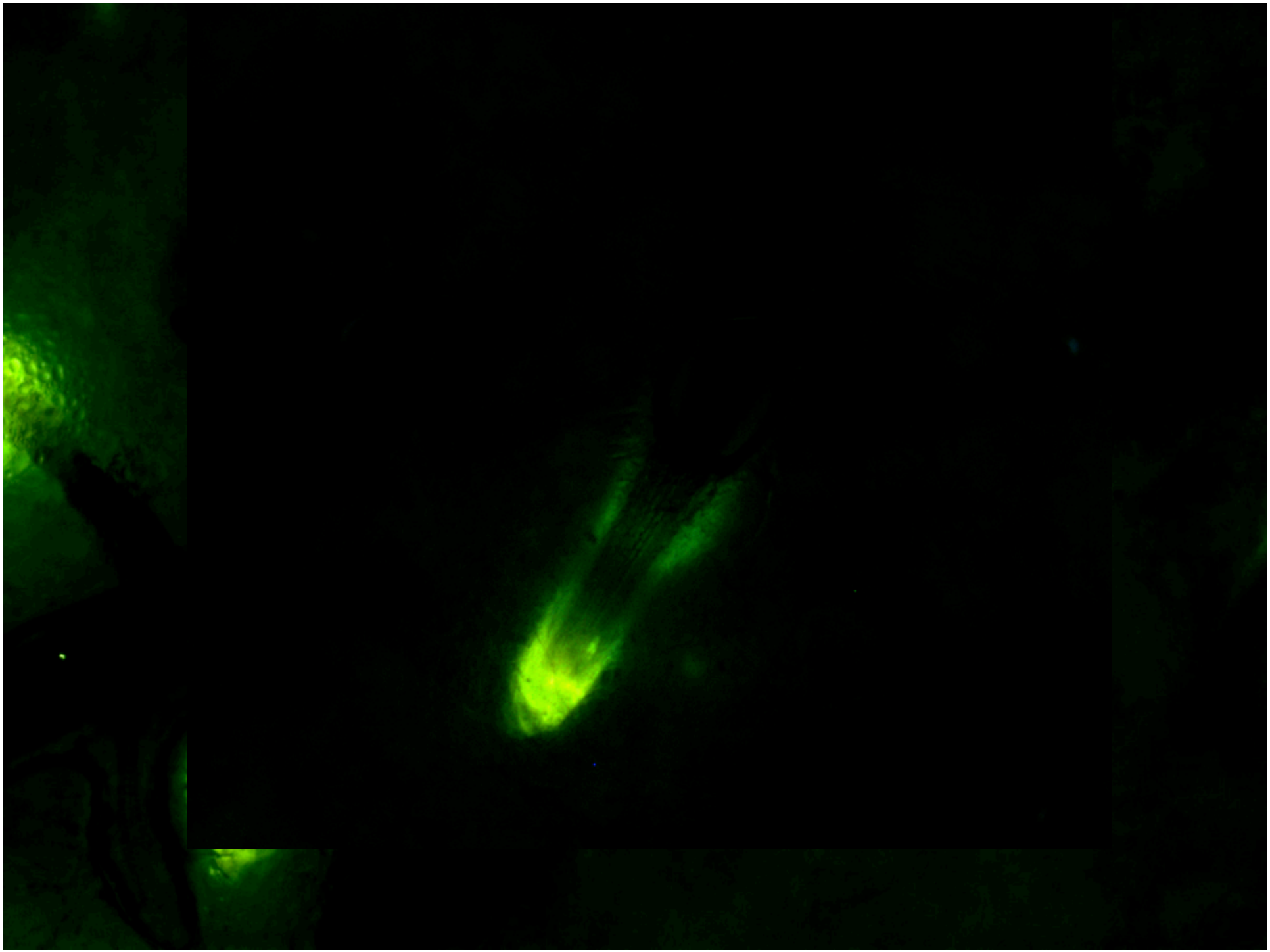
Gran Naine Control vs. Foc TR4

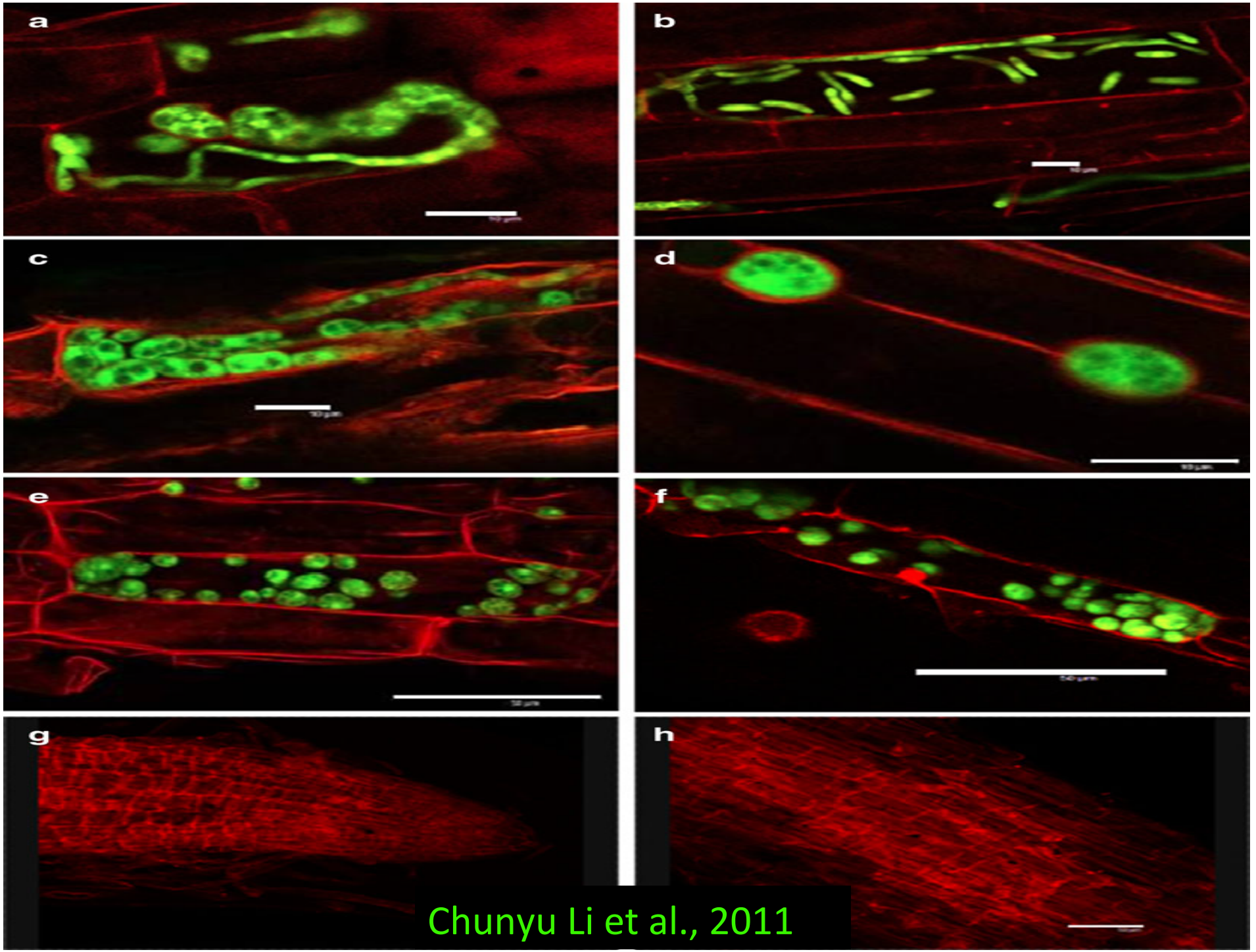


Foc expressing fluorescent proteins for detailed plant-pathogen interactions









Chunyu Li et al., 2011

Fusarium wilt: iniciatives and current actions in LAC

ORGANISMO INTERNACIONAL REGIONAL DE SANIDAD AGROPECUARIA

OIRSA

PLAN DE CONTINGENCIA ANTE UN BROTE DE LA RAZA 4 TROPICAL DE

FUSARIUM OXYSPORUM F. SP. *CUBENSE*

EN UN PAÍS DE LA REGIÓN DEL OIRSA

SANIDAD VEGETAL
2011

Importante

Fusariosis - Recomendaciones para viajeros

www.musalac.org

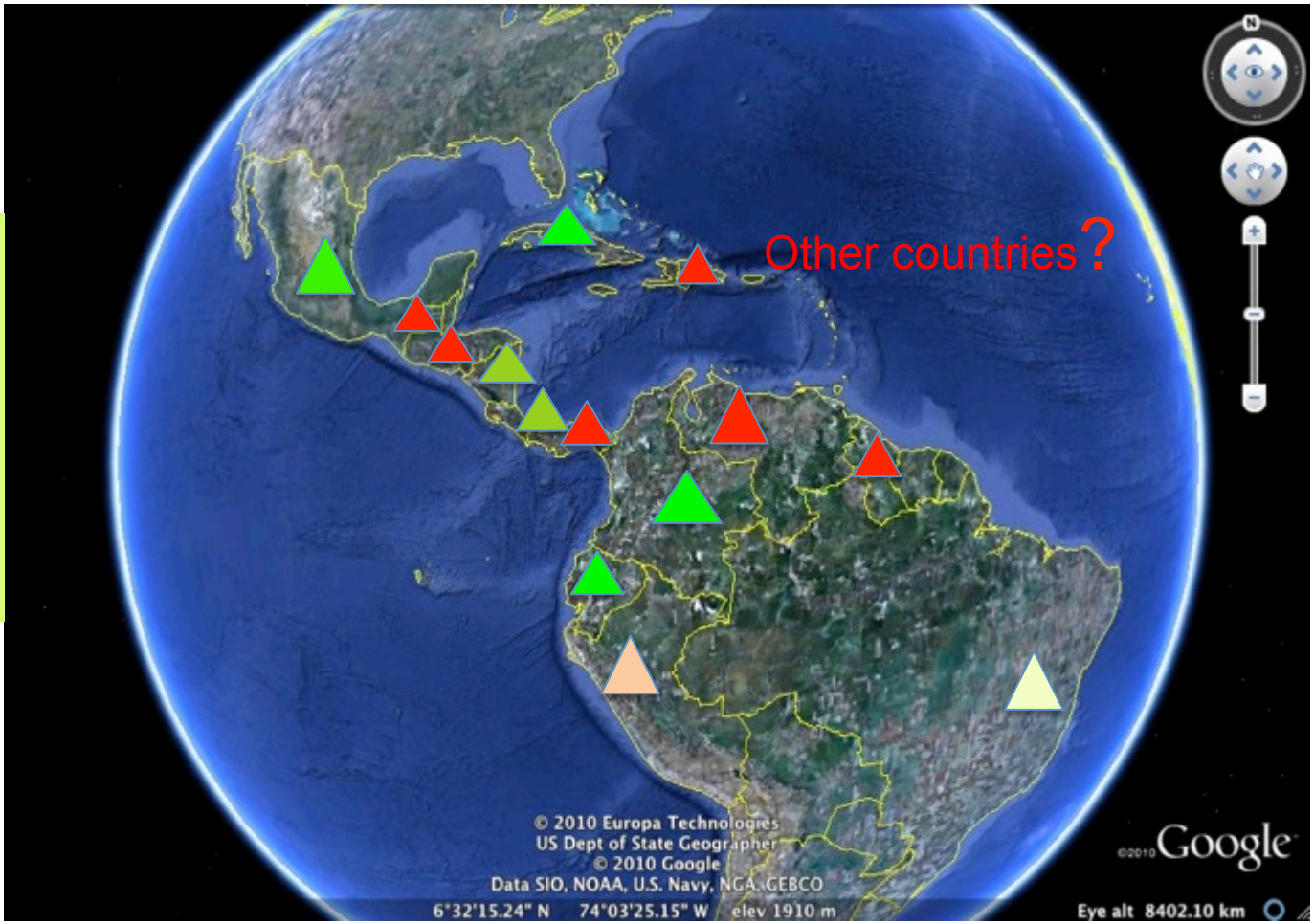
RECOMMENDATIONS TO PREVENT THE ENTRANCE OF QUARANTINE PLANT DISEASES OF MAJOR ECONOMIC IMPORTANCE FOR BANANA AND PINEAPPLE

Aimed at: Employees of the major fruit producing and processing companies, representatives of agrochemical companies and NGOs, certification inspectors, and any other visitor to banana plantations in South East Asia and pineapple plantations in South America

Fusarium wilt: iniciatives and current actions in LAC

Training courses on prevention, diagnostic and management of Fusarium wilt in banana

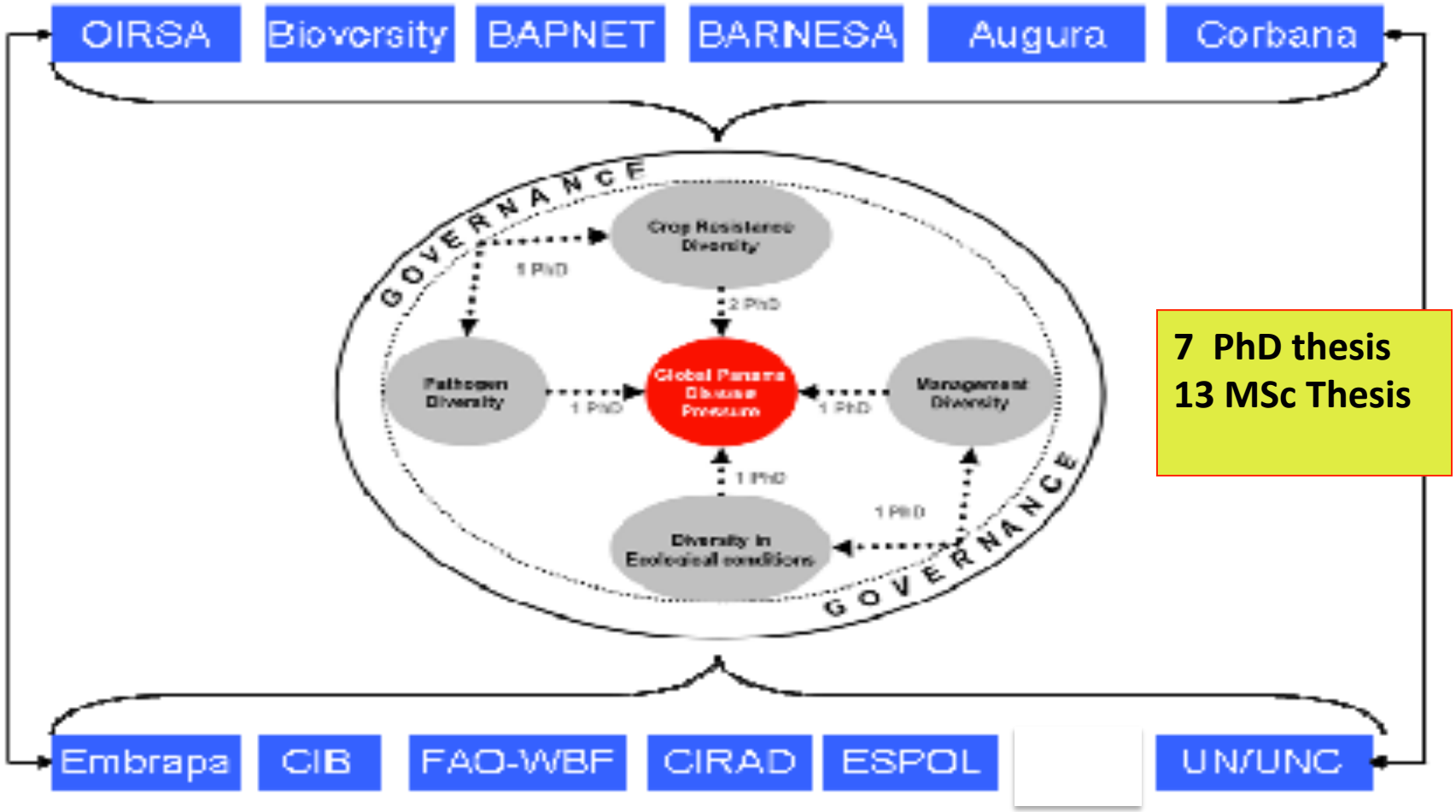
A Bioversity International and MUSALAC initiative for reducing the current impact of FW in LAC and prevent the entrance of Foc TR4



Fusarium wilt: iniciatives and current actions in LAC

Panama Disease in Banana: Multi-level solutions for a global problem

Plant Research International: Gert Kema



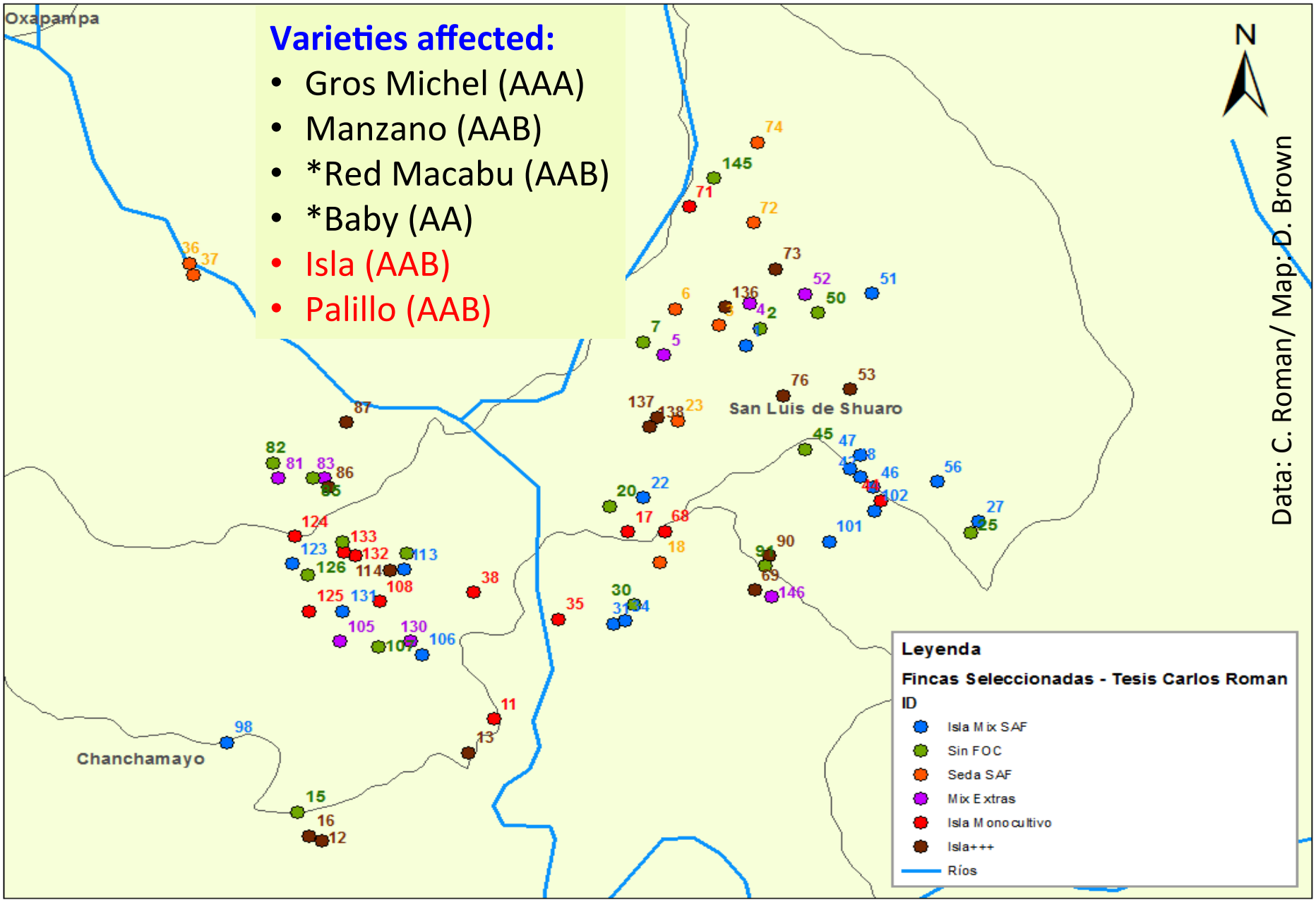
7 PhD thesis
13 MSc Thesis

Mapping and epidemiological studies of Foc in Peru

Foc is currently a big problem
for million smallholders in LAC

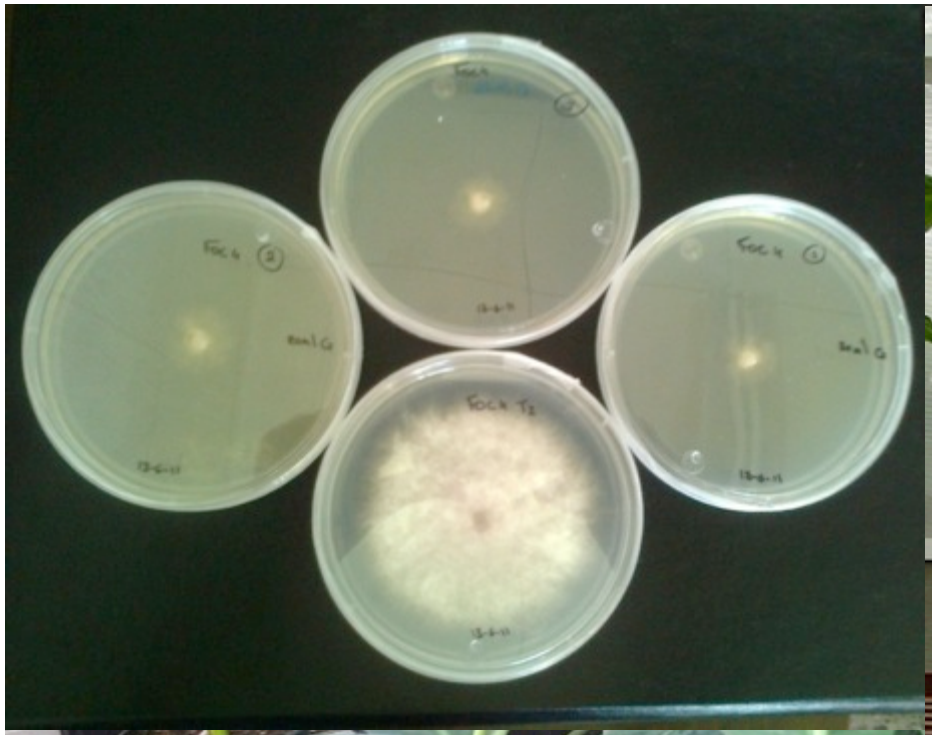
Mapping and epidemiological studies of Foc in Peru

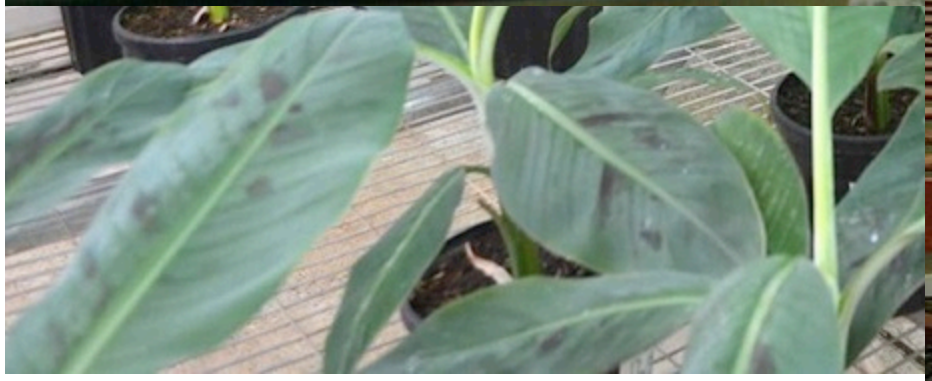
Mapping and epidemiological studies of Foc in Peru



Eradication methods & epidemiological studies of Foc race 1

Is glyphosate effective against Foc ?





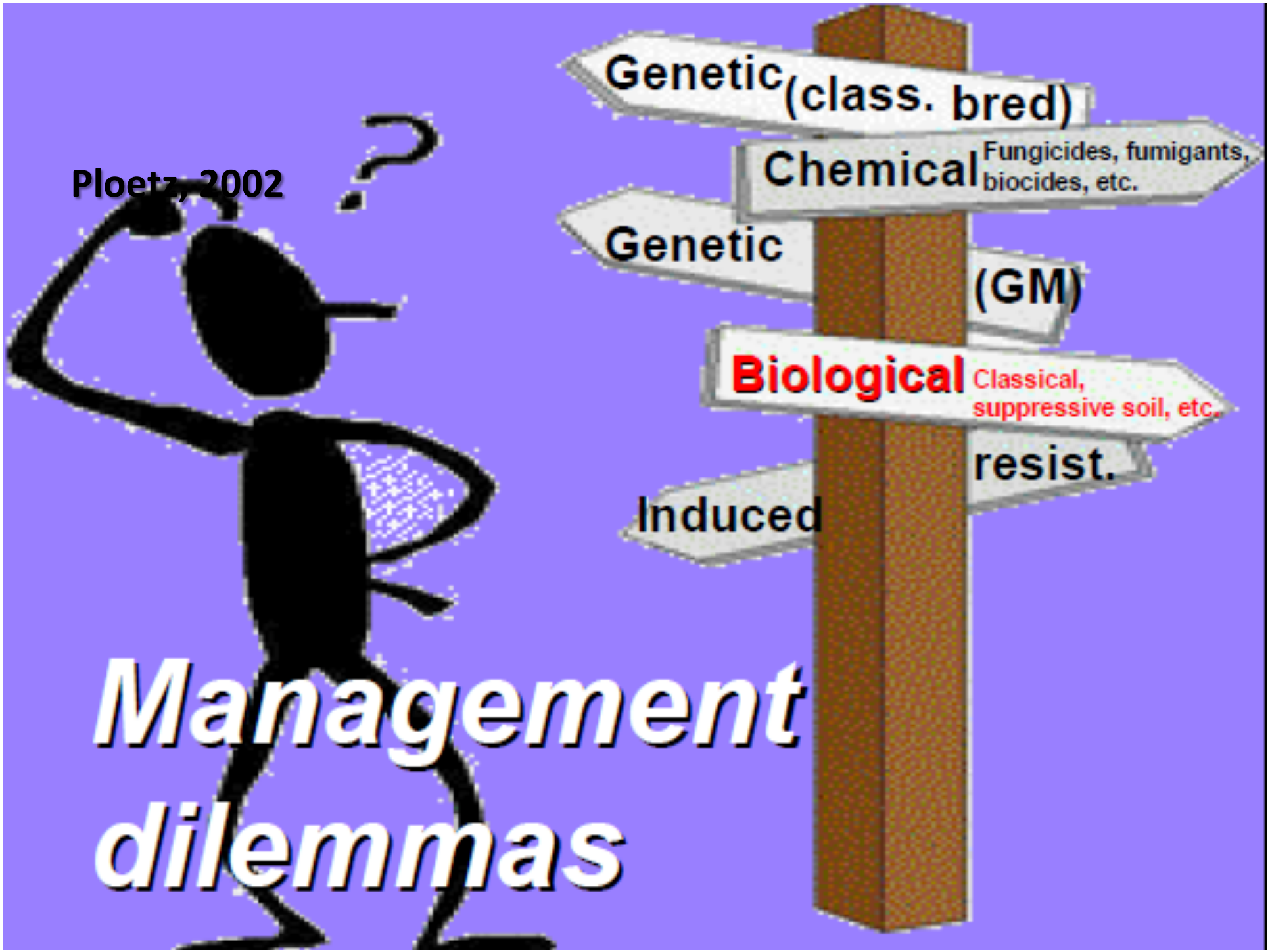
Eradication methods & epidemiological studies of Foc race 1

Is glyphosate effective against Foc ?

Eradication methods & epidemiological studies of Foc race 1

Is glyphosate effective against Foc ?

Opciones a considerar en caso de un brote de Foc R4T


Ploetz, 2002
Genetic (class. bred)
Chemical Fungicides, fumigants, biocides, etc.
Genetic (GM)
Biological Classical, suppressive soil, etc.
resist.
Induced
Management dilemmas

Características biológicas y epidemiológicas de Foc R4T a tener en cuenta para su manejo

Síntomas similares a los de las demás razas

Largo período de latencia; su presencia puede ser evidente después de muchos años de su introducción.

Clamidosporas pueden permanecer viables en el suelo por largos períodos

Puede ser movido en hijos asintomáticos utilizados para plantar

Puede infectar asintomáticamente malezas y otras plantas

Se distribuye fácilmente en partículas de suelo y agua de escorrentía entre áreas infectadas y libres

Principios de Control de Enfermedades en Plantas

1. **Exclusión** : evitar la entrada del patógeno o del inóculo
2. **Erradicación**: eliminar, destruir o inactivar el inóculo/patógeno
3. **Evasión** (escape) : evitar la enfermedad – épocas menos favorables, areas libres
4. **Protección**: Evitar/redicir la infeción, e.j. productos químicos
5. **Resistencia**: Usar cultivares resistentes
6. **Terapia**: "Curar" las plantas ya infectadas

Manejo integrado del marchitez por Fusarium

Resistencia genética

- ✓ Resistencia presente?
- ✓ Mejoramiento genético?
- ✓ Mutaciones - Somaclones
- ✓ Ingeniería genética?

Control biológico

- ✓ Suelos supresivos
- ✓ Hongos
- ✓ Bacterias
- ✓ Actinomycetos

Control cultural

- ✓ Cuarentena y saneamiento
- ✓ Cultivo de tejidos
- ✓ Cultivo anual
- ✓ Rotación de cultivos
- ✓ Enmiendas de suelo y fertilizantes

Control químico

- ✓ Fungicidas
- ✓ Esterilizantes
- ✓ Fumigantes de suelo
- ✓ Activadores químicos

ESTRATEGIAS DE MANEJO DE FOC TR4 EN ASIA

Dispersión a largas distancias

Este MAPA es un intento aproximado de la distribución de Foc realizado para fines académicos, no está basado en estudios científicos y ***no debe ser tomado*** *como referencia por las autoridades*

Dispersión a distancias medias y cortas

Los rizomas son también responsables de la diseminación del Mal de Panamá a medias y cortas distancias

…pero el patógeno se mueve también en herramientas suelo y agua de escorrentía

(R. Ploetz)

Exclusión- Erradicación

Medidas de cuarentena y saneamiento

Eradicatiion of infected banana plant in Australia [Australian Bananas – 19p]

Exclusión- Erradicación

Eliminación de plantas enfermas

Zanja alrededor de la planta afectada

Exclusión- Erradicación

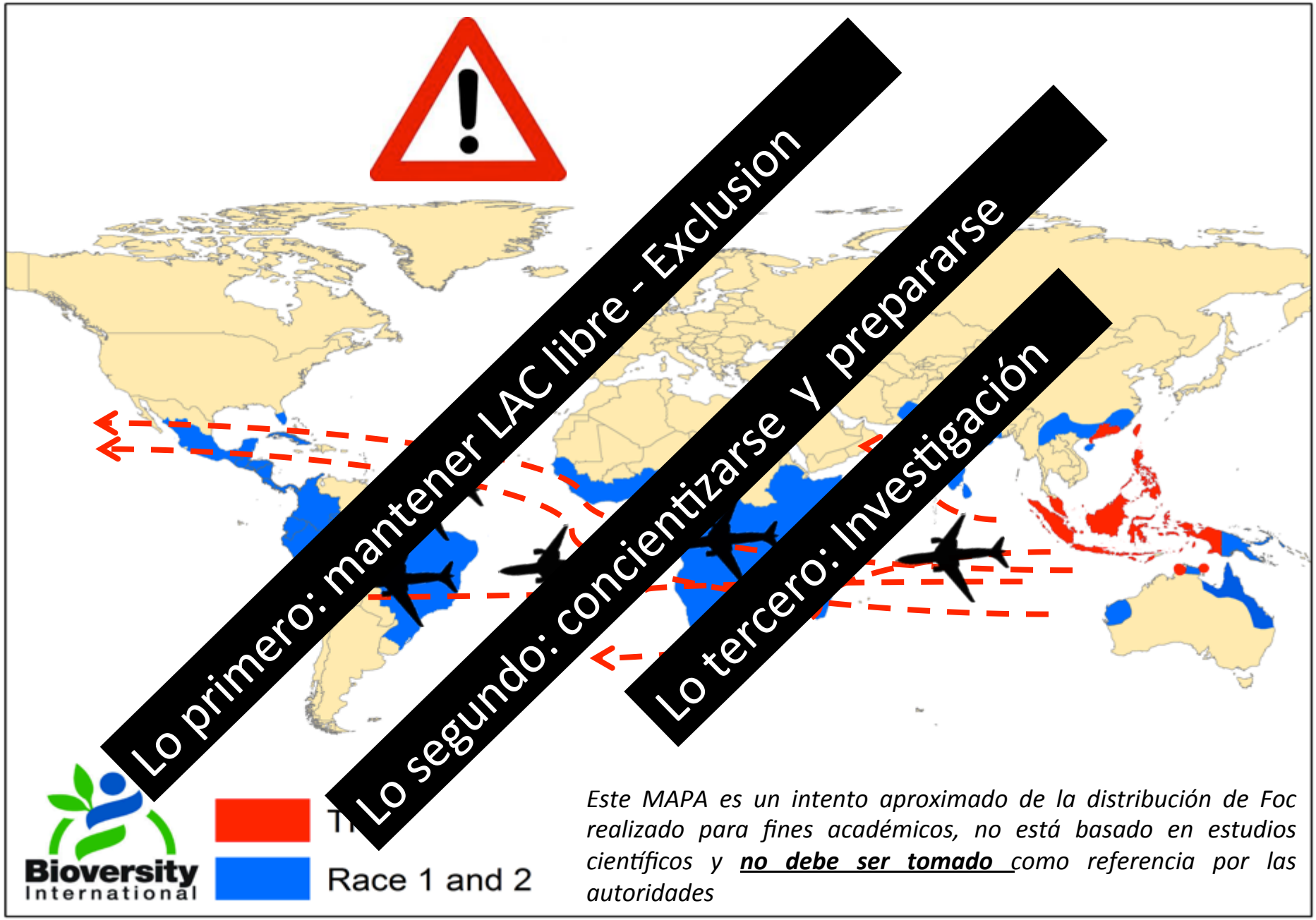
Medidas de cuarentena y saneamiento

Erradicación

Fundas con desinfectante a base de hipoclorito de sodio o amonio cuaternario para la desinfección de machetes durante eliminación de cada planta

Exclusión- Erradicación

Utilización de MeBr


Lo primero: mantener LAC libre - Exclusion
Lo segundo: concientizarse y prepararse
Lo tercero: Investigación
Bioversity International
Race 1 and 2
Este MAPA es un intento aproximado de la distribución de Foc realizado para fines académicos, no está basado en estudios científicos y no debe ser tomado como referencia por las autoridades

Sozinho é muito difícil

Melhor juntos!!

Collaboradores

PLANT RESEARCH INTERNATIONAL
- Gert Kema, Cees Waalwijk

BIOVERSITY INTERNATIONAL
- Miguel Dita, Gus Molina

CIRAD
- Nabila Yahiaoui, Angelique D'Hont

AUSTRALIA
Andrew Daly, WAYNE O'NEILL

NATIONAL CHUNG HSING UNIVERSITY
- P.F.L. Chang

TADECO
- B.M. Corcolon

CIB
- Rafael Arango

CORBANA
- Mauricio Guzmán, Jorge Sandoval

UNIVERSITY OF FLORIDA
- Randy Ploetz

EMBRAPA MANDIOCA E FRUTICULTURA
- Edson Amorim,
- Zilton Cordeiro
- Sebastião Silva

EMBRAPA INFORMÁTICA
- Paula Kuser Falcao
- Michel E B Yamagishi
- Poliana F Giachetto

EMBRAPA AGROENERGIA
- Manoel Souza

EMBRAPA AMAZONIA OCIDENTAL
- Gilvan Ferreira

UNICAMP
- Roberto H Herai

UFLA
- Luciano Paiva

Bioversity International

Obrigado

*email: m.dita@cgiar.org