

## FUSARIUM WILT OF BANANA: GLOBAL EPIDEMIOLOGICAL SITUATION OF TROPICAL RACE 4 OF *Fusarium oxysporum f. sp. cubense* AND PREVENTION PROGRAM.



Luis Pérez Vicente



Regional Workshop on the prevention and diagnostic of *Fusarium* Wilt (Panama disease) of bananas and plantains caused by *Fusarium oxysporum cubensis* – Tropical Race 4 (TR4)  
Port Spain, Trinidad and Tobago April 28th-May 9th, 2014



### Main production constraints in LA&C

| Production systems   | Main constrains  |
|--|--|
| Intensive tropical Cavendish for export  | Black Sigatoka, nematode, bacterial wilt or moko ( <i>R. solanacearum</i> ); environmental and labor safety regulation; abiotic stresses (hurricane, flooding/ drought)  |
| Organic Cavendish production   | Black Sigatoka, nematode; fruit trips; BSV   |
| Subtropical Cavendish production   | Fusarium wilt ( <i>Fusarium oxysporum sp. cubense</i> ); abiotic stresses (low temperatures)   |
| Plantain monoculture   | Black Sigatoka, nematode; , <i>Cosmopolites sordidus</i> , Banana streak badnavirus (BSV), pseudostem rots by <i>Dickeya spp.</i> , finger soft rot by <i>Pectobacterium carotovorum</i> , bacterial wilt ( <i>R. solanacearum</i> ) |
| Mix crops of Musa with cocoa, coconuts, coffee, etc.   | Black Sigatoka, Panama disease, bacterial wilt, black weevil, etc.   |
| Mix crops/ banana and plantain monocultures in small plots (for home consumption or local markets) | Black Sigatoka, Panama disease, bacterial wilt, black weevil, etc.   |

## Fusarium wilt of banana or Panama disease



## Symptoms of Fusarium wilt or Panama disease



Yellow leaf syndrome



Non-Yellow leaf syndrome



### External symptoms of Panama disease



Shortening of emergent leaf



Reddish brown streaks in the inner side of sheath



Pseudostem split



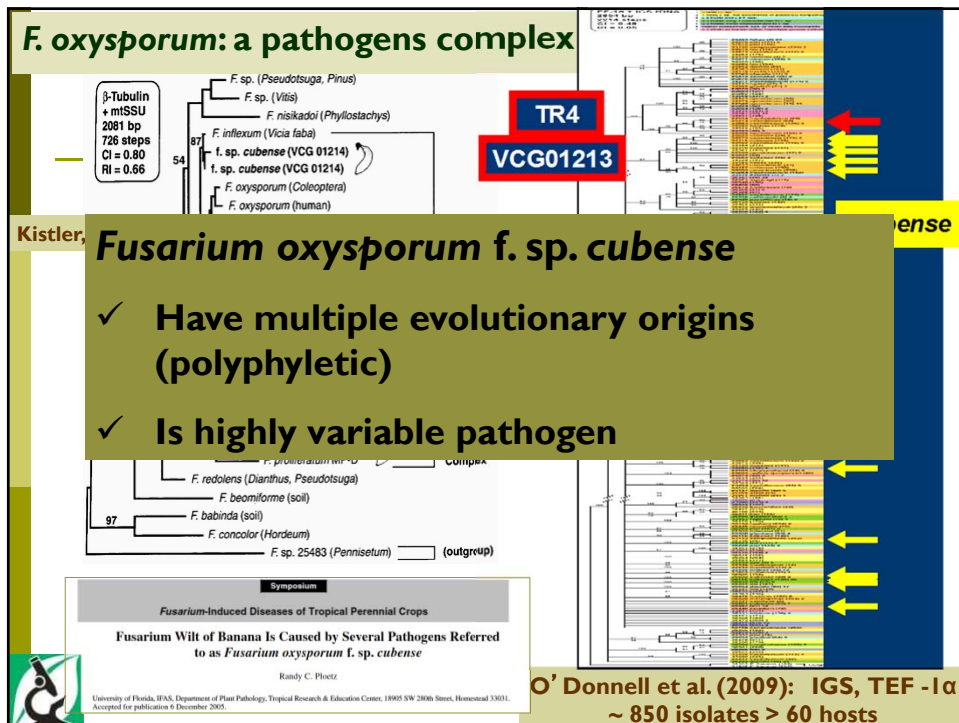
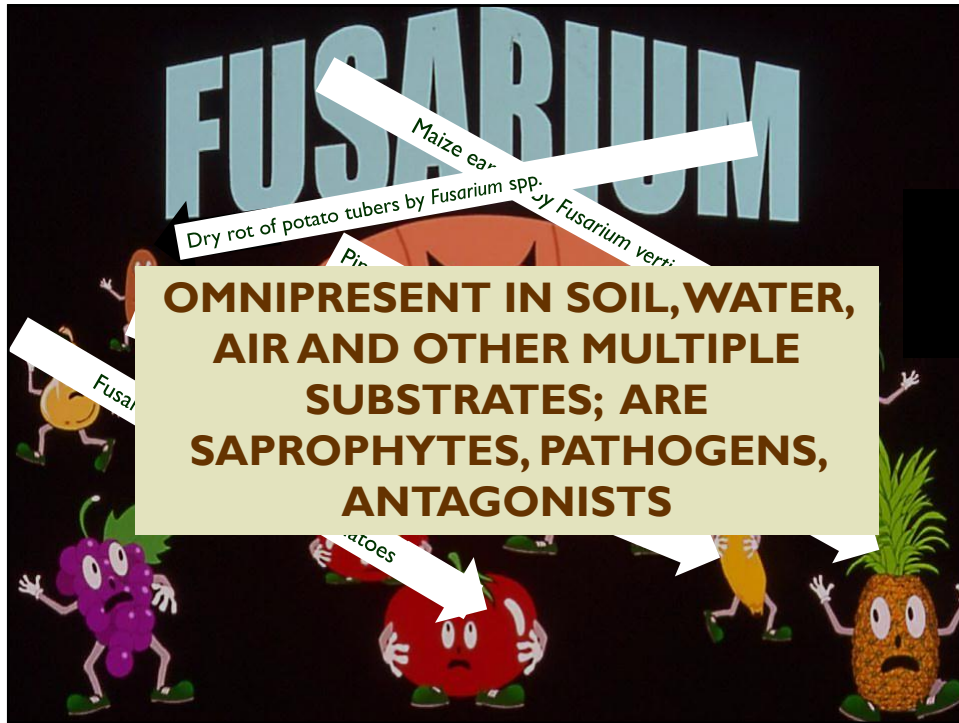
### Internal symptoms of Fusarium wilt



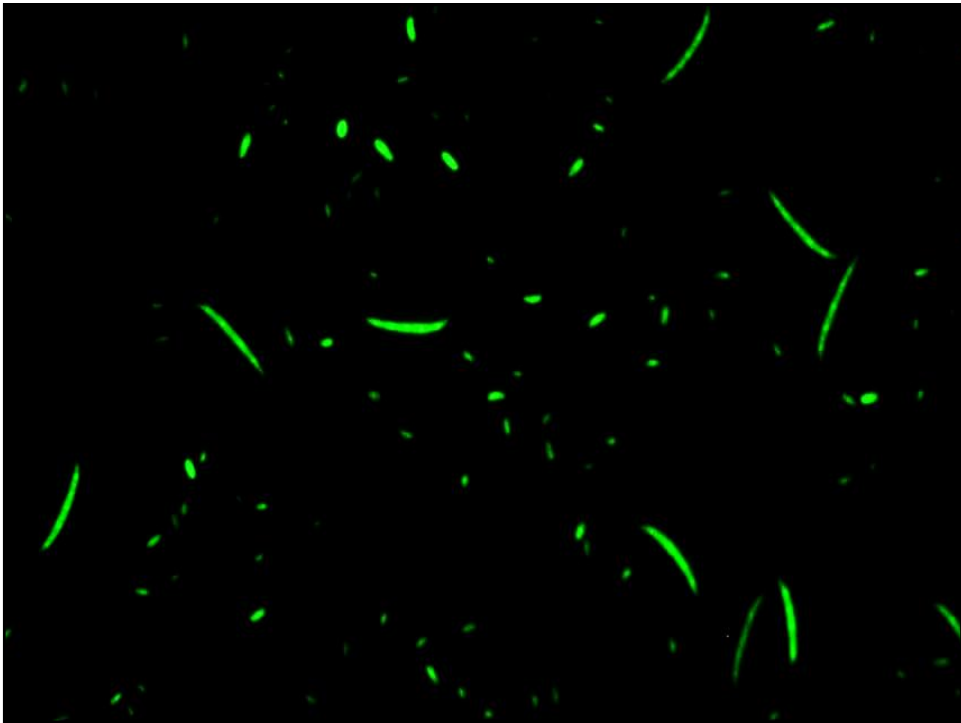
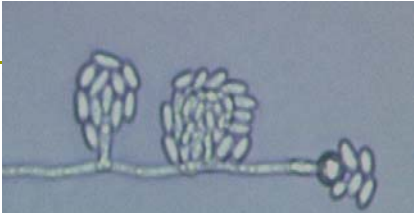
Distinctive symptoms between bacterial wilt (Moko) by *Ralstonia solanacearum* race 2 and Panamá disease by *Fusarium oxysporum* f. sp. *cubense*.

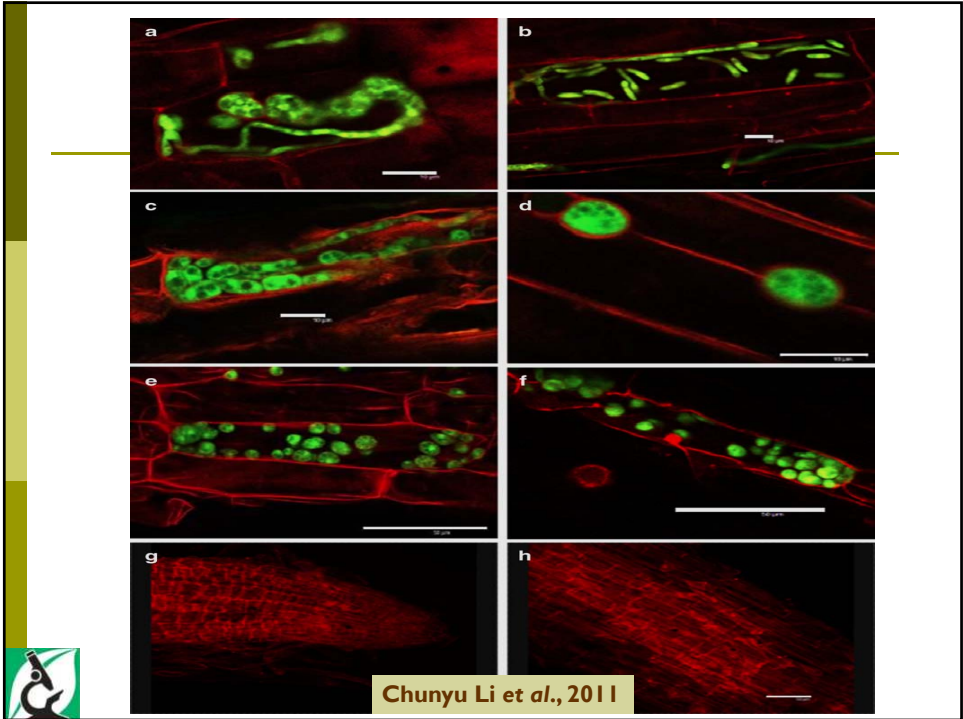
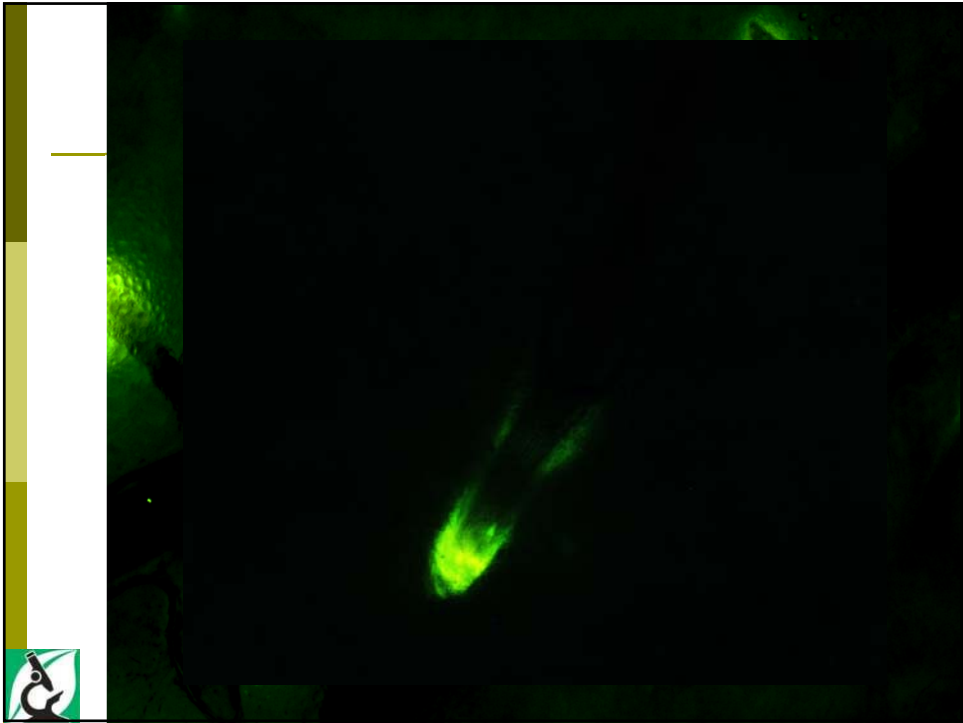


***Fusarium oxysporum* f. sp. *cubense***



***Fusarium oxysporum* f. sp. *cubense***





## Pathogenic races of *F. oxysporum* f. sp. *cubense*

(Stover and Waite, 1960; Stover, 1962)

| Differentials cvs.   | Races |   |   |   |
|----------------------|-------|---|---|---|
|                      | 1     | 2 | 3 | 4 |
| Gros Michel          |       |   |   | + |
| Apple Siskin         |       |   |   | + |
| Bluggoe              |       |   |   | + |
| <i>Heliconia</i> sp. | -     | - | + | + |
| Cavendish            | -     | - | - | + |

**Current classification lack genetic sense; are populations that infect plants of a particular cultivar**



**There are no symptoms differences among Fusarium wilt pathogen races.**



Gros Michel, CR



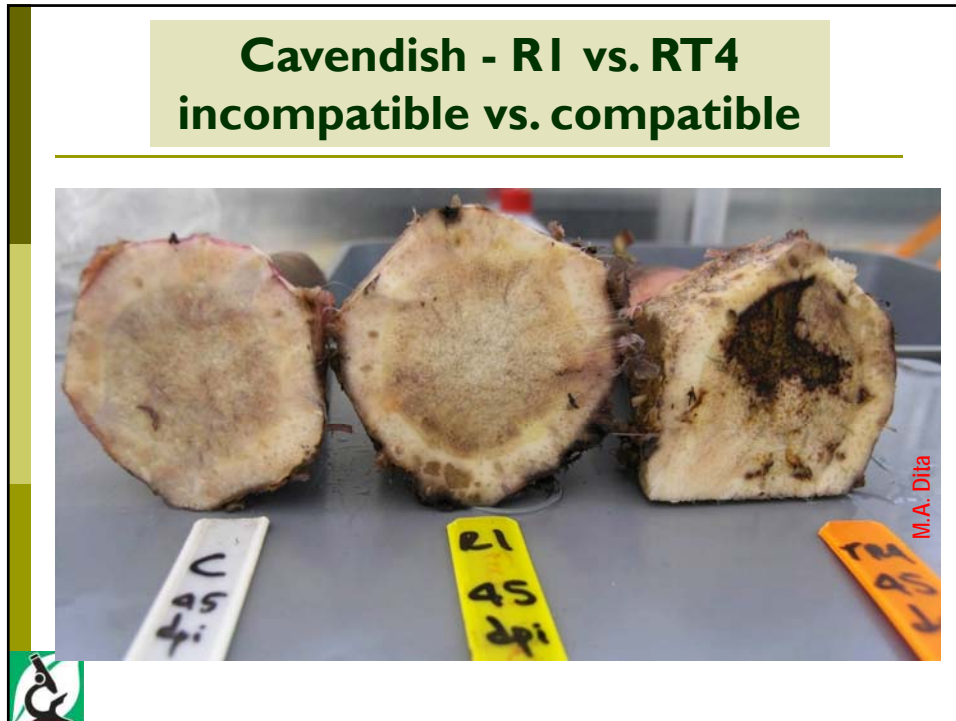
Bluggoe, Cuba



TR4, Malaysia







### Heterokaryon development and vegetative compatibility groups (VCGs)

Haploid Homokaryons

When two lines develop a viable heterokaryon are named vegetative compatibles.

Vegetative compatibility requires that at least alleles of 10 loci vic of vegetative incompatibility are identical. (Puhalla and Spieth, 1985)

(From Leslie, 1990)

### Mating of *nit 1* (generated) in the study with Nit M of an international collection .

**Heterokaryon**

**No heterokaryon**

**Cofactor Mo deficient**

**Reductase Nitrate deficient**

**Heterokaryon**

**(Battle y Pérez, 1998)**

### World *Foc* population structure.

(Ploetz and Pegg, 2000)

| VCG*   | Genomic group/cultivar(s)†   | Origin(s)   |
|--------|--|---|
| 0120-  | Musa sp.; AA: 'SH-3142', 'SH-3362'   | Australia, Brazil, Costa Rica, France   |
| 01215  | AAA: 'Cros Michel', 'Highgate', 'Pisang Ambon Putih', 'Pisang Ambon', 'Dwarf Cavendish', 'Williams', 'Mons Mari', 'Grand Nain', 'Lacatan'; AAB: 'Prata', 'Lady Finger', 'Pacovan', 'Huamoa', 'Silk'  | (Guadeloupe, Guyane), Honduras, Indonesia (Java), Jamaica, Malaysia (Sarawak), Nigeria, Portugal (Madeira), South Africa, Spain (Canary Islands), Taiwan, USA (Florida)                               |
| 0121   | AAA: 'Cros Michel', Cavendish clone  | Indonesia (Sumatra), Taiwan   |
| 0122   | AAA: Cavendish clone ABB: 'Saba'   | Philippines   |
| 0123   | Mosa textilis; AAA: 'Cros Michel', 'Grand Nain'; AAB: 'Silk', 'Lutundian', 'Pisang Keling'; ABB: 'Pisang Awak', 'Kluai Namwa'  | Malaysia (West and Sarawak), Philippines, Taiwan, Thailand  |
| 0124-  | AA: 'Niyama Yik'; AAA: 'Cros Michel', 'Highgate', 'Mons Mari', 'Williams', 'Grand Nain', 'Mbuzazirume'; AAAA: Jamaica 1242; AB: 'Ney Poovan', 'Sukali Nalar', 'Kamanmasaeng'; AAB: 'Lady Finger', 'Maçã', 'Manzano', 'Maqueho'; ABB: 'Pisang Awak', 'Ducasse', 'Kayinga', 'Zambia', 'Kluai Namwa', 'Bluggoe', 'Harare', 'Kholobowa', 'Dwarf Bluggoe', 'Mbuku', 'Bumo Criolla', 'Pelipita', 'Ice Cream' | Australia, Brazil, Burundi, China, Cuba, Democratic Republic of Congo, Haiti, Honduras, India, Jamaica, Malawi, Malaysia (West), Mexico, Nicaragua, Rwanda, Tanzania, Thailand, Uganda, USA (Florida) |
| 0126   | AA: 'Pisang Berlin'; AAA: 'Highgate'; AAB: 'Maqueho'; ABB: 'Pisang Manung'   | Honduras, Indonesia (Irian Jaya, Sulawesi), Papua New Guinea, Philippines   |
| 0129   | AAA: 'Mons Mari'; AAB: 'Lady Finger'   | Australia   |
| 01210  | AAA: 'Cros Michel'; AAB: 'Manzano'   | Cayman Islands, Cuba, USA (Florida)   |
| 01211  | AA: 'SH-3142'  | Australia   |
| 01212  | AB: 'Ney Poovan'; AAB: 'Silk'; ABB: 'Pisang Awak', 'Kisubi', 'Bluggoe'   | Tanzania  |
| 01213- | AA: 'Pisang Lilin', 'Pisang Mas'; AAA: 'Pisang Ambon', 'Valery', 'Williams', 'Grand Nain', 'Novaria', 'Pisang Nangra', 'Red', 'Pisang Raja Udang', 'Pisang Samu', 'Pisang Barangan'; AAB: 'Pisang Raja Serah', 'Pisang Rastali', 'Pisang Raja', 'Relong'; ABB: 'Pisang Awak', 'Pisang Awak Legor', 'Saba', 'Pisang Kepok', 'Pisang Caputur', 'Pisang Kosta'; Unknown: 'Pisang Batan'                   | Australia (Northern Territory), Indonesia (Halmahera, Irian Jaya, Java, Sulawesi, Sumatra), Malaysia (West), Taiwan   |
| 01214  | ABB: 'Harare', 'Mbuku'   | Malawi  |
| 01217  | AAB: 'Pisang Rastali'  | Malaysia  |
| 01218  | AAB: 'Pisang Rastali', 'Pisang Raja Serah'; ABB: 'Pisang Awak', 'Kluai Namwa', 'Pisang Kepok', 'Pisang Siam'   | Indonesia (Java, Sumatra), Malaysia (West), Thailand  |
| 01219  | AAA: 'Pisang Ambon', 'Pisang Ambon Putih'; Unknown: 'Pisang Raja Garing'   | Indonesia (Java, Sumatra)   |
| 01221  | ABB: 'Kluai Namwa'   | Thailand  |

## VCG's identified in *F. oxysporum* f. sp. *cubense*

| RACES      | VCG's                        |
|------------|------------------------------|
| TR4        | 01213                        |
| StR4       | 0120, 0121, 0122, 0129, 1211 |
| R1 and R 2 | All except VCG 01213         |



## Vegetative compatibility groups of Cuban populations.



| VCGs       | Race | Frequency | Total number of isolates (%) |
|------------|------|-----------|------------------------------|
| 1210       | 1    | 17,3      | 9                            |
| 1210       | 2    | 5,8       | 3                            |
| 0124       | 2    | 50,0      | 26                           |
| 0124       | 1    | 3,8       | 2                            |
| 0124/125   | 2    | 9,6       | 5                            |
| 0128       | 2    | 1,9       | 1                            |
| New VCG's? | 2    | 7,7       | 4                            |
| CRN        | 2    | 3,8       | 2                            |
| Total      |      |           | 52                           |

**Deacon** | **Character of Fusarium/Other**

Vegetative compatibility groups of *Fusarium oxysporum* Schlecht f. sp. *cubense* (E. F. Smith) Snyder and Hans. in Cuba

2012 have been used in the study of population structure.

Dr. Ken Peleg of UQAT, Queensland, Australia.

**Results and discussion**

Group 0120 including isolates of race 1 was found in Matanzas and group 0124/125 in isolates of three other plants (Sagua, Bayamo).

The presence of group 01210 has only been mentioned in Dade County, Florida (Pérez 1996) whereas group 0124/125 is widely distributed in the island (Pérez 1996; Pérez et al. 1998).

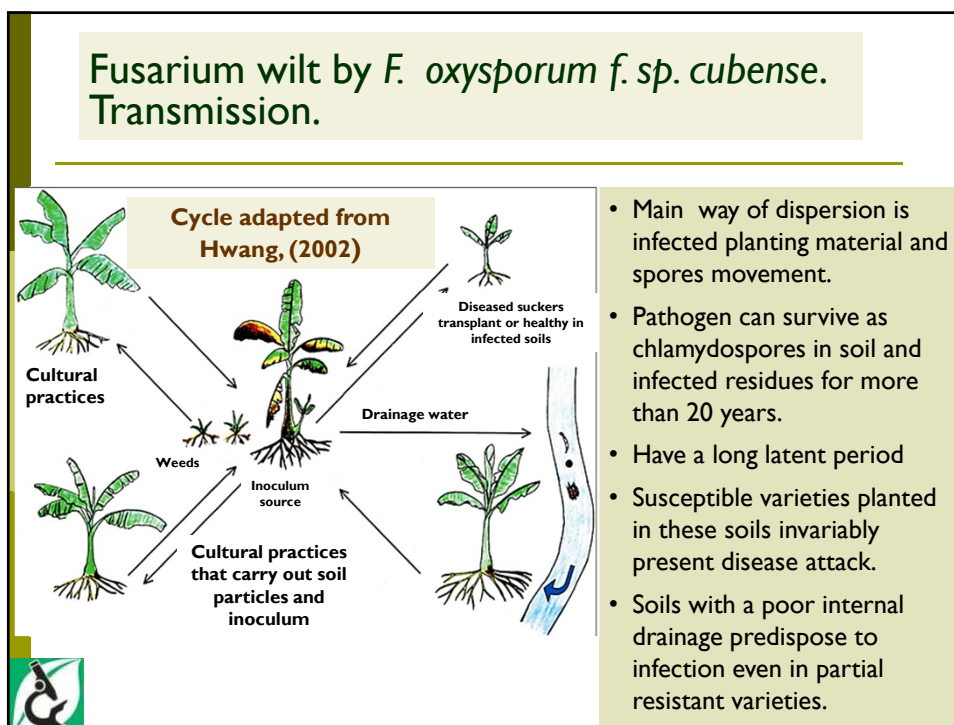
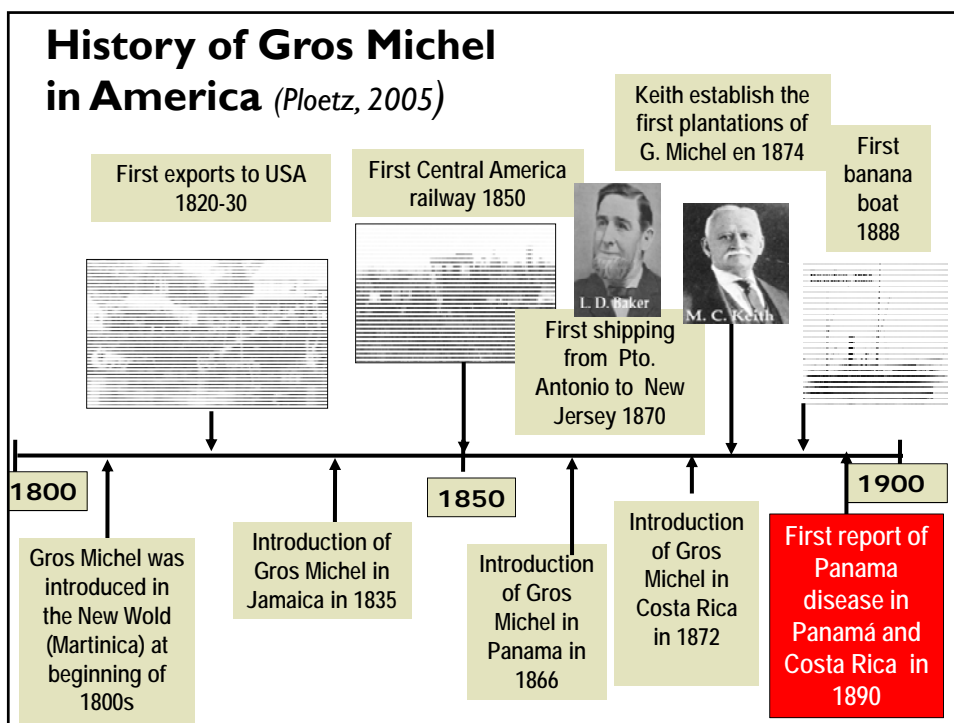
## Epidemiology, disease cycle and *Fusarium oxysporum* f. sp. *cubense* races world distribution



### A chronological summary of more important events regarding the disease and pathogen

- ✓ 1876. First report in Australia by J. Bancroft. *Queensland, [Votes and Proceedings 1877 (3):1011-1038]*
- ✓ 1904. J.E. Higgins propose a fungi as causal agent of disease in Hawaii (*Hawaii Agric. Expt. Stn. Bull. 7*)
- ✓ 1908. E.F. Smith realize the first isolation of the fungus in samples from Cuba, that named *Fusarium cubense*. [*1rst. APS Meeting, Boston, 1908; Science (Abstr.) 31, 754 – 755*].
- ✓ 1919. E.W. Brandes shows that “*Fusarium cubense*” causes Panama disease and described symptoms in cultivar Bluggoe (Moko). (*Phytopathology 9: 339- 389*).
- ✓ 1940. C. Snyder y H.N. Hansen renamed the fungus as *F. oxysporum* f. sp. *cubense* (*Foc*). (*Amer. J. Bot. 27:64-67*.)
- ✓ 1890 - In America, > 50,000 ha of cultivar Gros Michel (AAA) destroyed by 1965 *Foc* race I (Stover, 1962; 2,300 millions USD of losses)
- ✓ 1990 - Outbreak and distribution of TR4 and strong impact on 2013 *Musa* production in countries where it is present





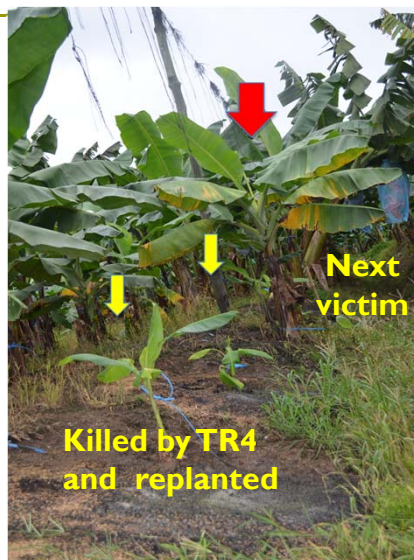
### Dissemination by infected asymptomatic suckers



- ¿Healthy plant?
- Growers use it as planting material

- Diseased plant, growers do not know that suckers are infected, do not eliminate it and inclusive sell suckers to other growers

### Plant to plant dissemination in soil



## Dissemination by soil infected from chlamydospores on rests of infected plants

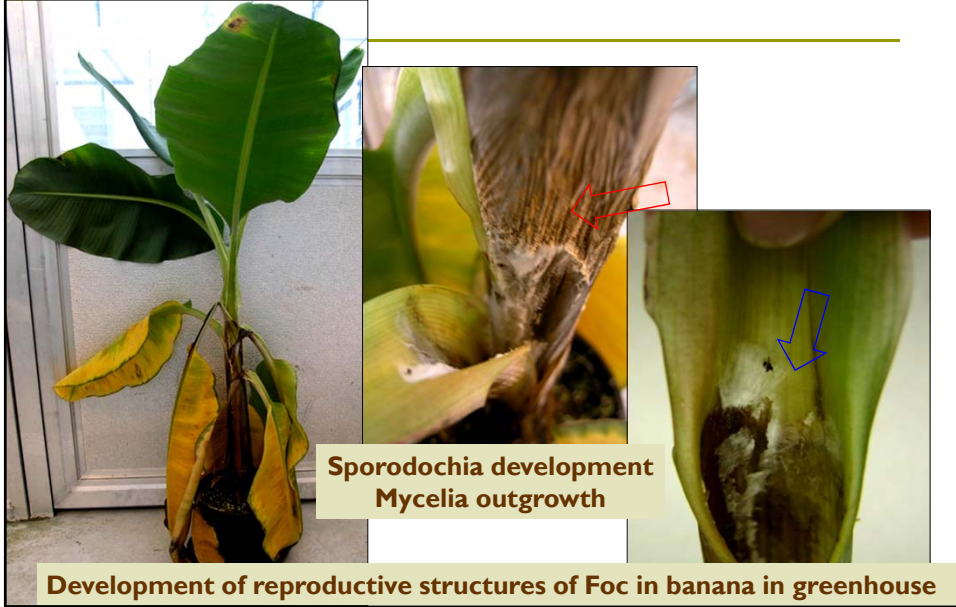


## Dissemination of *Foc* in water



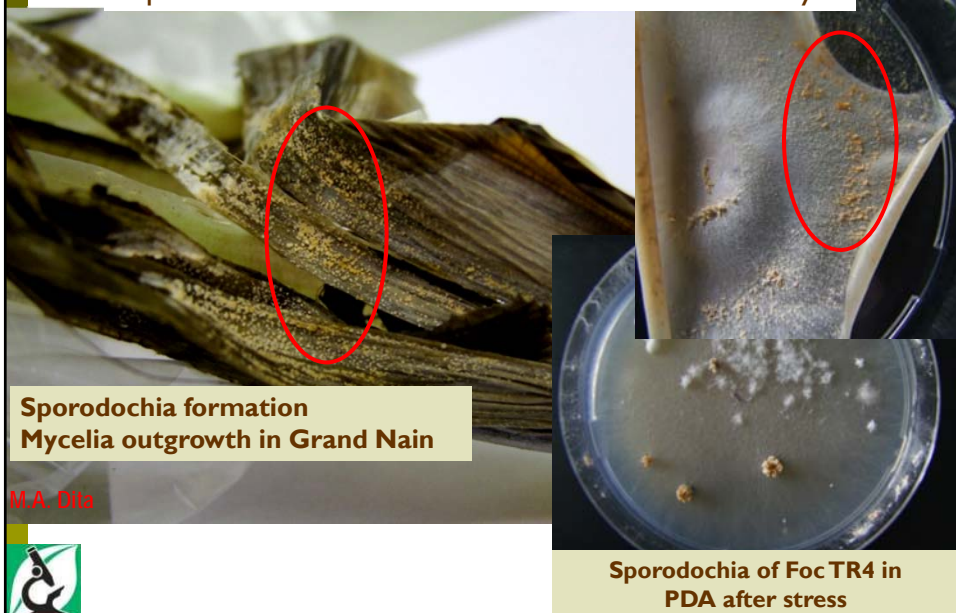
### Aerial dissemination?

Experimental evidences in greenhouse (Dita, 2009)



### Aerial dissemination?

Experimental evidence in Greenhouse and Laboratory





## Panama disease host plants

Henessy et al., 2007

### Primary hosts

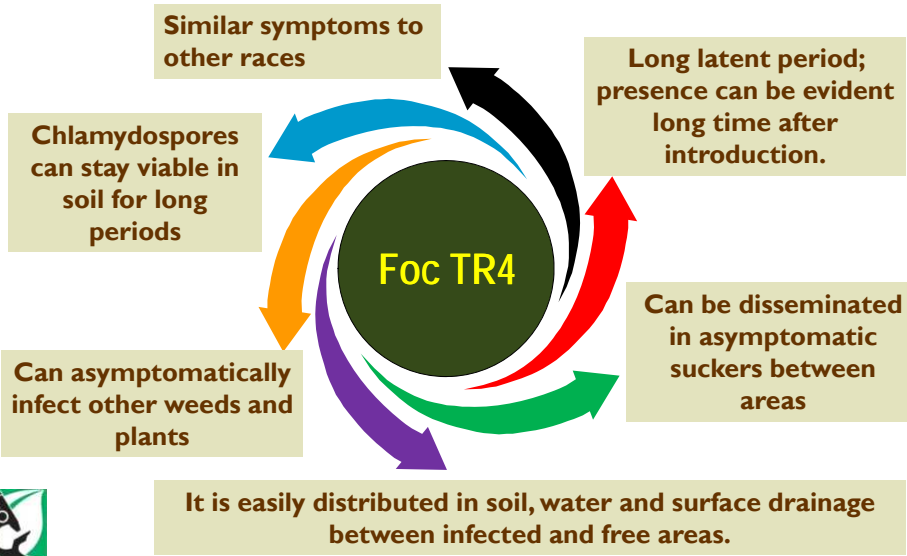
- ✓ *Musa spp.* (bananos)
- ✓ *Musa acuminata* (bananos silvestres)
- ✓ *Musa textilis* (Abacá)
- ✓ *Heliconia spp.*

### Wild host by artificial inoculation:

- ✓ *Heliconia caribaea*
- ✓ *Paspalum fasciculatum* (Poaceae)
- ✓ *Panicum purpurascens* [Brachiaria mutica] (Poaceae)
- ✓ *Ixophorus unisetus* (Poaceae)
- ✓ *Commelina diffusa* (Commelinaceae)
- ✓ *Chloris inflata* (Poaceae)
- ✓ *Euphorbia heterophylla*
- ✓ *Tridax procumbens* (Asteraceae)
- ✓ *Cyanthilium cinereum*

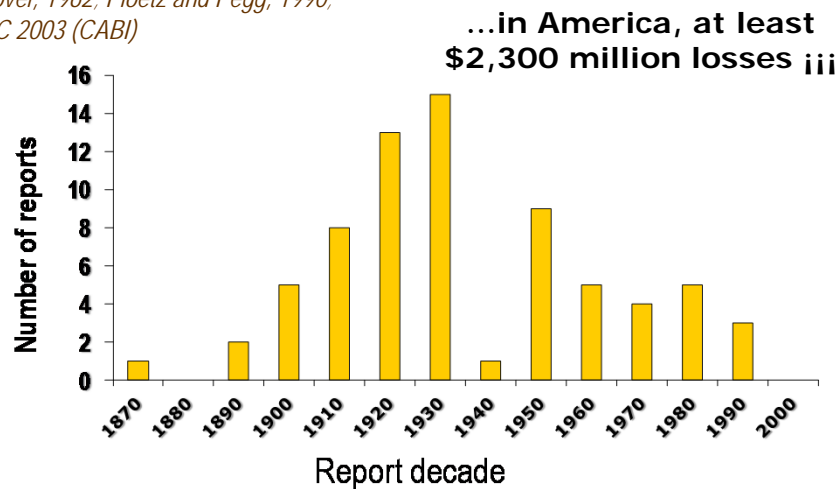


## Conclusions: Foc TR4 biological and epidemiological characteristics



## Number of first reports by decades of race I of Panamá disease in Gros Michel.

(Stover, 1962; Ploetz and Pegg, 1990;  
CPC 2003 (CABI))




## Factors which contribute to *Foc* race I epidemic in Gros Michel that still present in region.

- ✓ High dependence of production on a reduced number of cultivars (Cavendish, AAB plantains, ABB types Bluggoe and Pisang awak)
- ✓ Poor knowledge and perception among growers on disease impact, infection cycle and management tactics.
- ✓ Lack of surveillance programs in region.
- ✓ Lack of certified healthy clean planting material among growers that determine their proper planting material use.
- ✓ Poor efforts and resources on *Foc* management research.



### Replacement of Gros Michel by Cavendish, 1950s

Gros Michel Cavendish





>50,000 ha, of Gros Michel destroyed by race 1 between 1890 and 1950

Resistant to *Foc Raza 1*





### Gros Michel era → Cavendish era



*Radopholus similis*

Crown rot



Current banana industry is a 'Cavendish' ocean




Solved problem?  
...For how long?


Cavendish - Colombia 2010



Foc subtropical race 4 (VCG 0120)




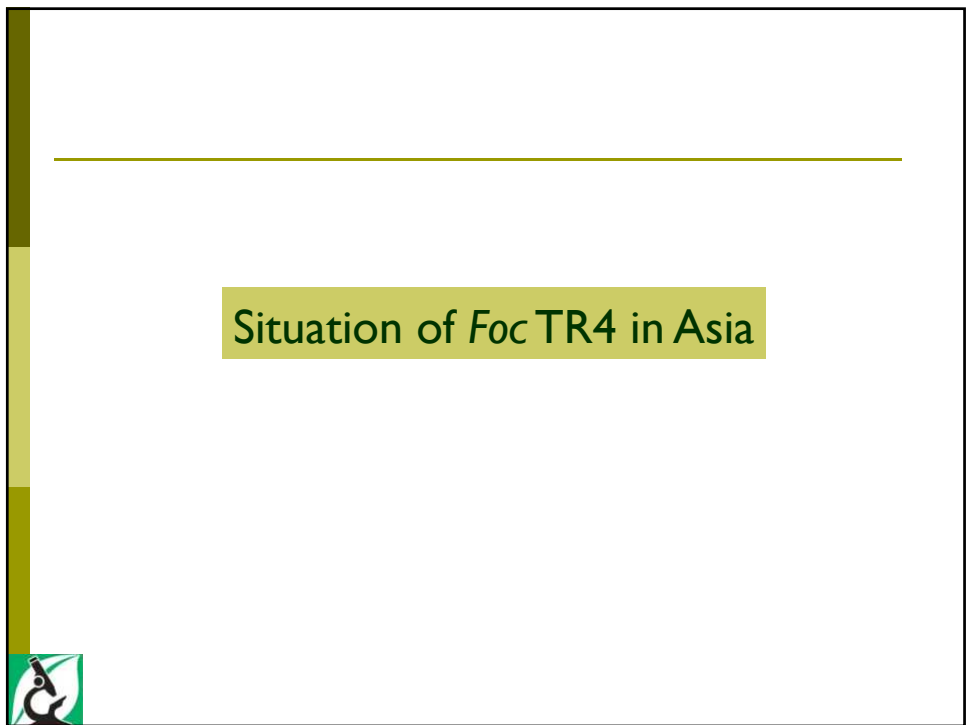
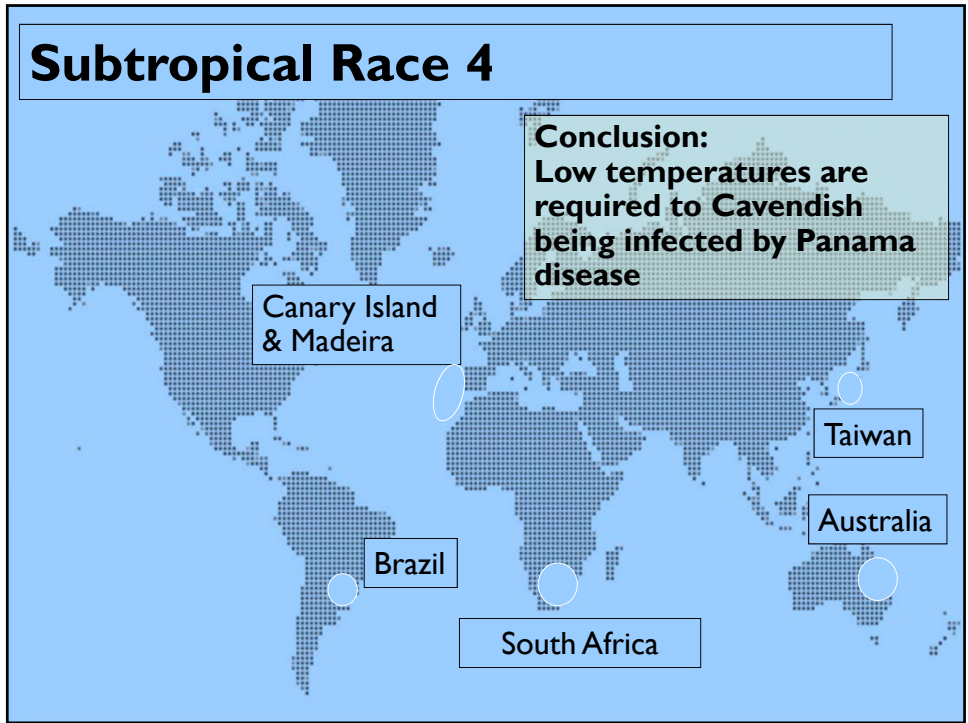
Viljoen, 2002

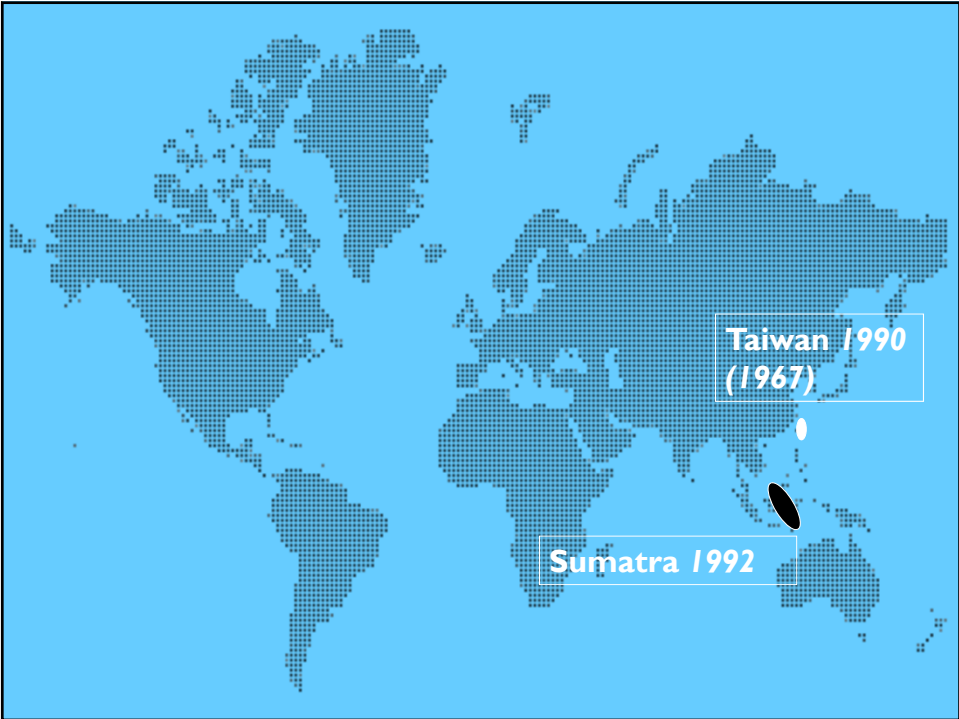
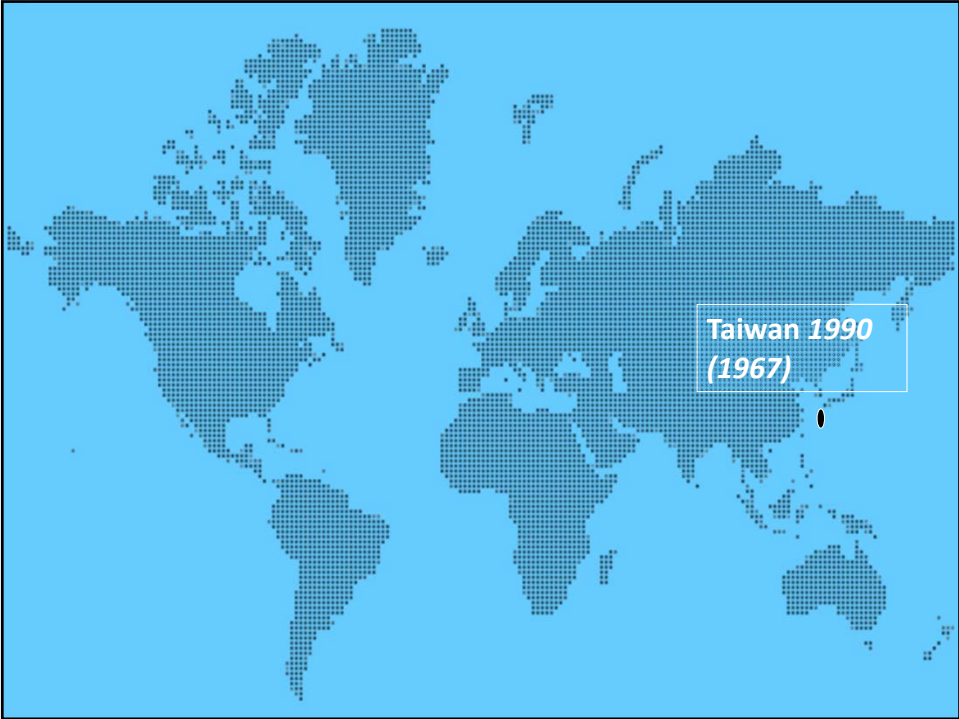


South Africa, 1989

...serious losses in Cavendish plantations in subtropics ...





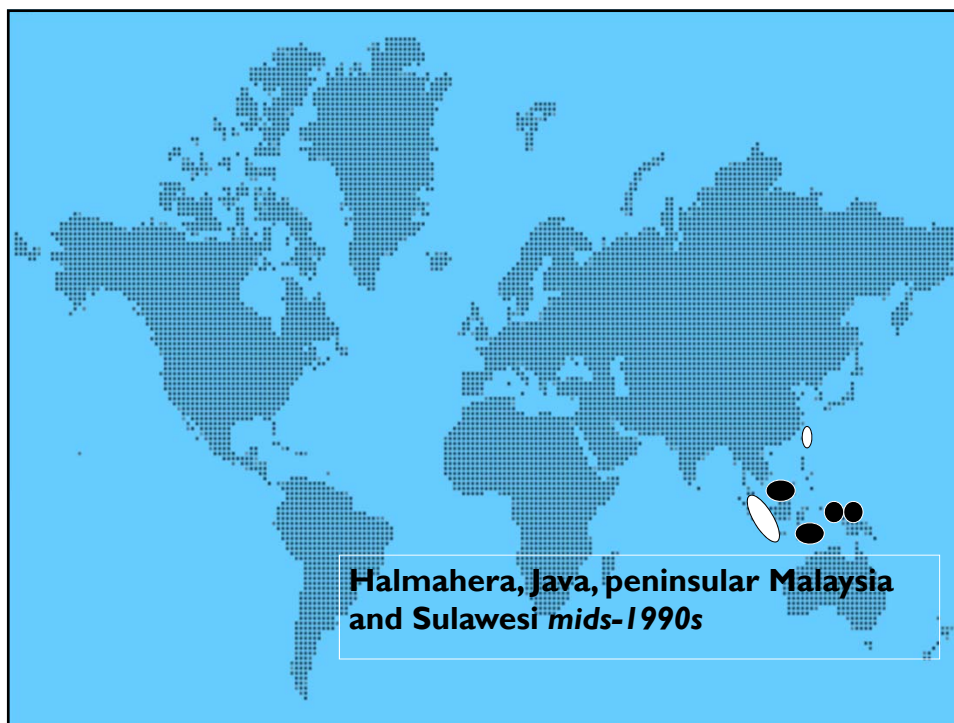


## Taiwan



### Fusarium wilt in Cavendish

- First report in 1967 (introduction from Sumatra, Indonesia?)
- General epidemic in 70's
- VCG 1213/16 – 1989
- Cultivated surface: 1960's = 60,000 ha
- Now = only on 6,000 annual cropping



## Commercial plantations in Indonesia and Malaysia



Nasdir, N.

- 1990's – Cavendish banana plantations were established in Sumatra and Java in Indonesia and Johor, Malaysia to export to Japan.
- A severe epidemic of *Foc* destroy plantations
- $\pm$  8 million of plants in traditional plantations were destroyed in five years in Indonesia. Export industry collapse.



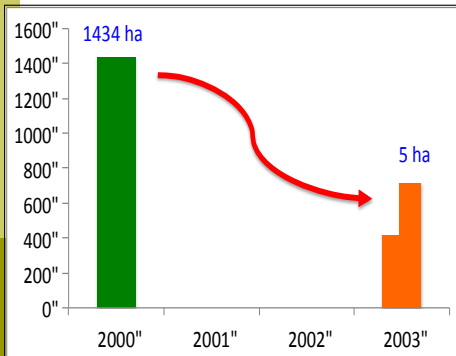
## Epidemic development of *Foc* TR4 in Grand Nain. (Kulim Montal Farm , Johor, Malaysia, 1993-95).





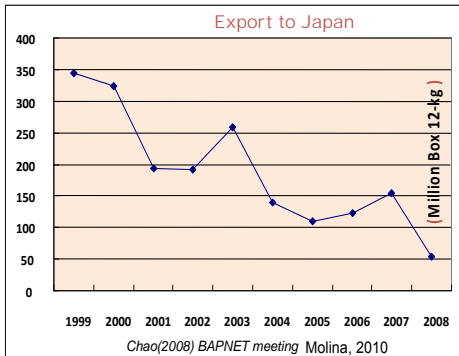
## Foc TR4 Impact in Asia: A global threat

### Indonesia



West Sumatra  
(Horticulture Processing and Marketing  
Department, 2005)

### Taiwan



IN ONLY A  
DECADE *Foc* TR4  
BECAME A  
SERIOUS  
PROBLEM

Australia, China, Iran Jaya,  
Philippines end of 1990's

## Australia

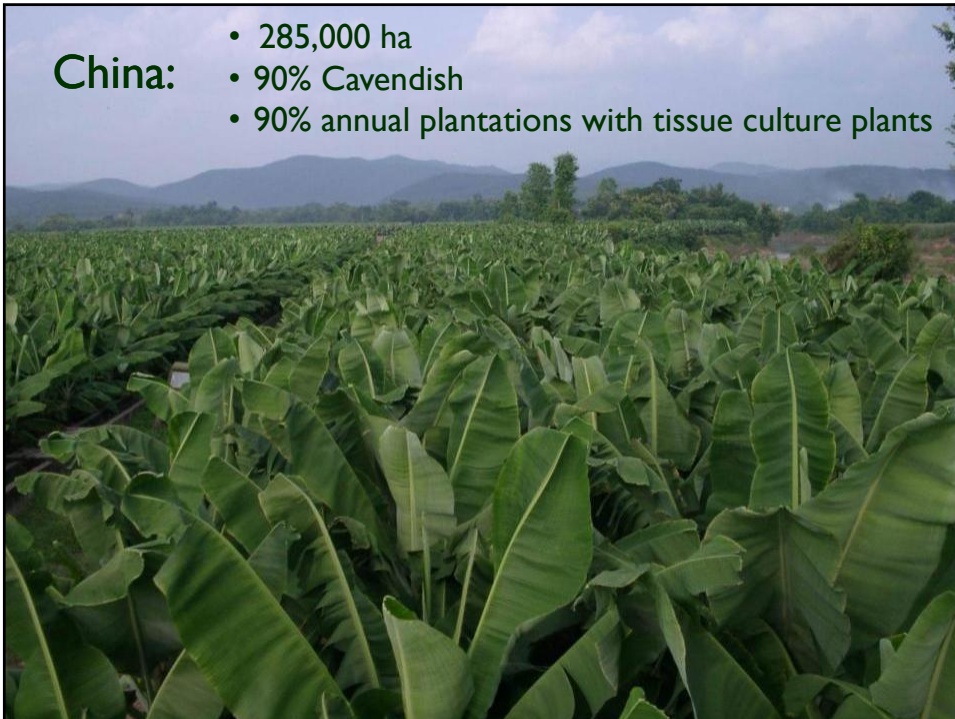


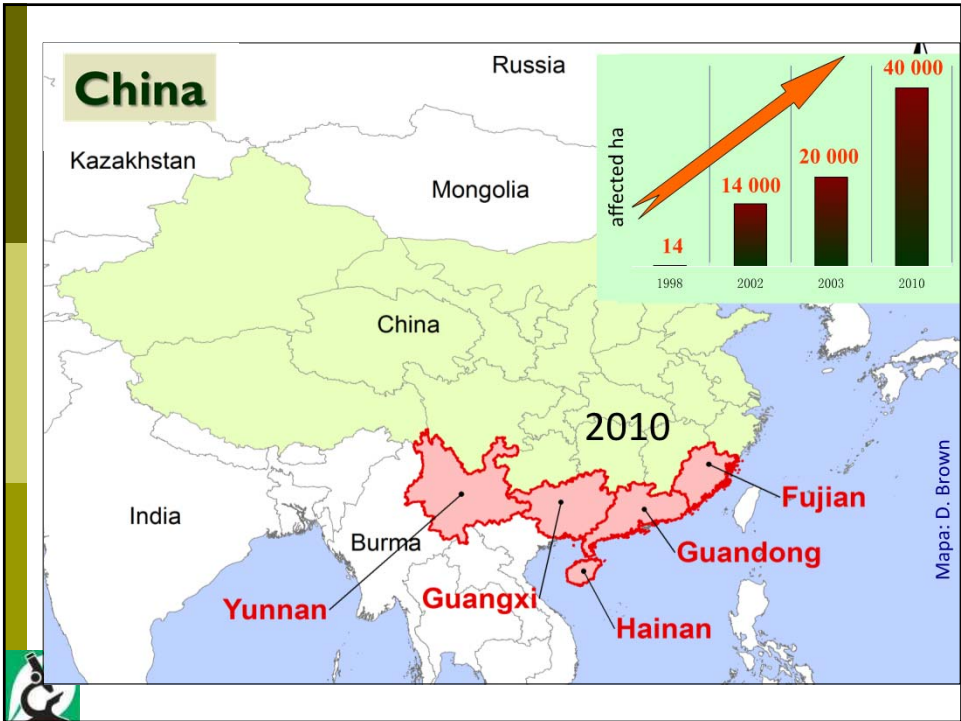
- 1997-1999 – TR4 epidemic in three sites close to Darwin in North Territories: VCG 01213-01216
- Strict quarantine politics prevent the movement to main cropping areas of banana in North Queensland during long time
- Important affectations in commercial plantations where is present. Enterprises has broken due to disease incidence.



## China:

- 285,000 ha
- 90% Cavendish
- 90% annual plantations with tissue culture plants







- Year 2000 : Fusarium wilt in Cavendish banana plantation at South China.
- 2001 –VCG 1213/16
- In 2002: 60,000 ha *Foc* TR4 infected plants
- Still dispersing along Pearl river.




### **Foc TR4 in China – Homogeneous distribution**



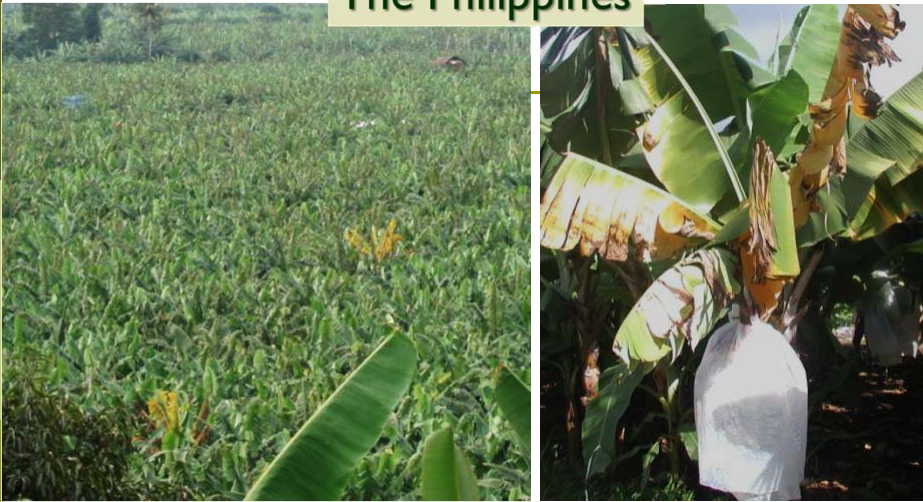
## The Philippines



**Commercial export Cavendish plantation**

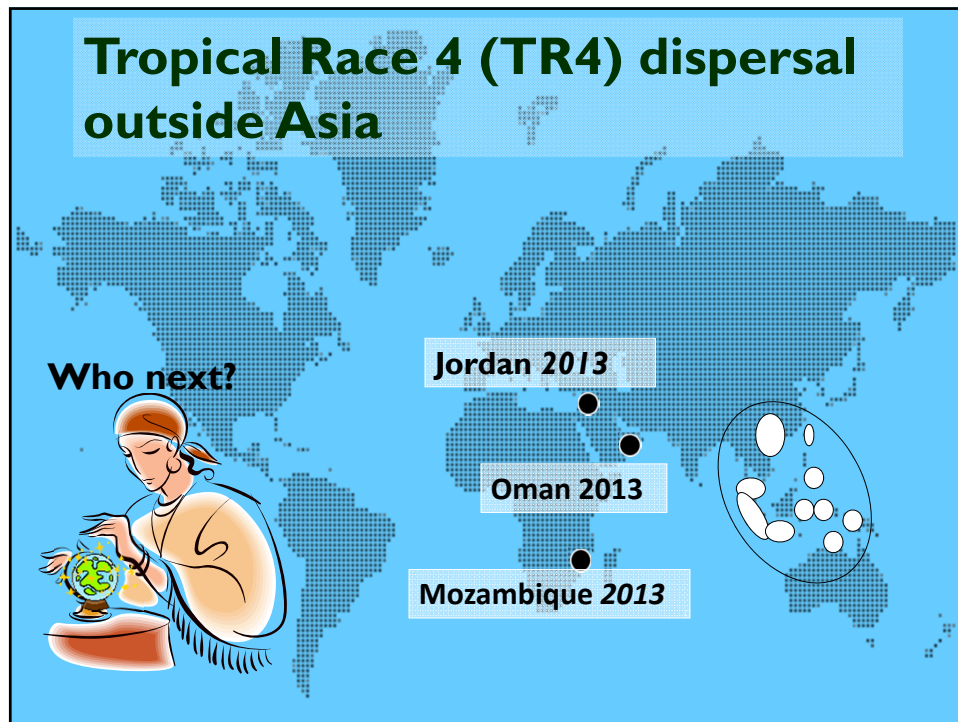
- First export commodity among fruits (> \$ 400 USD millions)
- Fruit more widely cropped and food source for many small farmers.

## The Philippines



- > 30,000 official reports of Foc between 1974 and 1991 of Fusarium wilt in Cavendish plantations
- 2005 = VCG 1213/16





### Summary of management practices in Asia

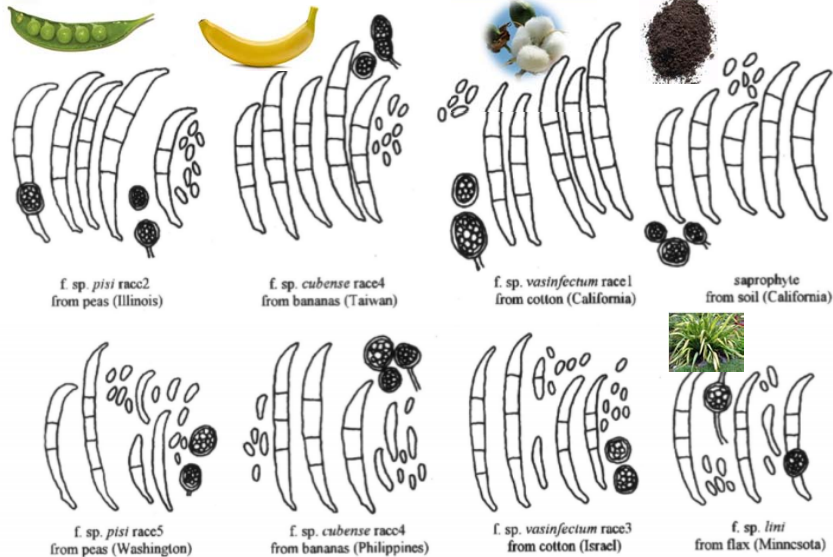
- ✓ Pathogen introduction prevention by quarantine procedures.
- ✓ Threat perception build up among growers.
- ✓ Introduction and adoption of high density annual cropping systems(>3000 plants/ha).
- ✓ Healthy planting material use. Development of healthy planting material production programs among growers.
- ✓ Development and validation of disease management strategies and practices:
  - Sanitation practices
  - Chemical control (has not bring results and are costly)
  - Use of resistant mutant cultivars (until present only delay the epidemic)
  - Long rotations with non host plants.
  - Biocontrol (until present with contradictory and unsatisfactory results).



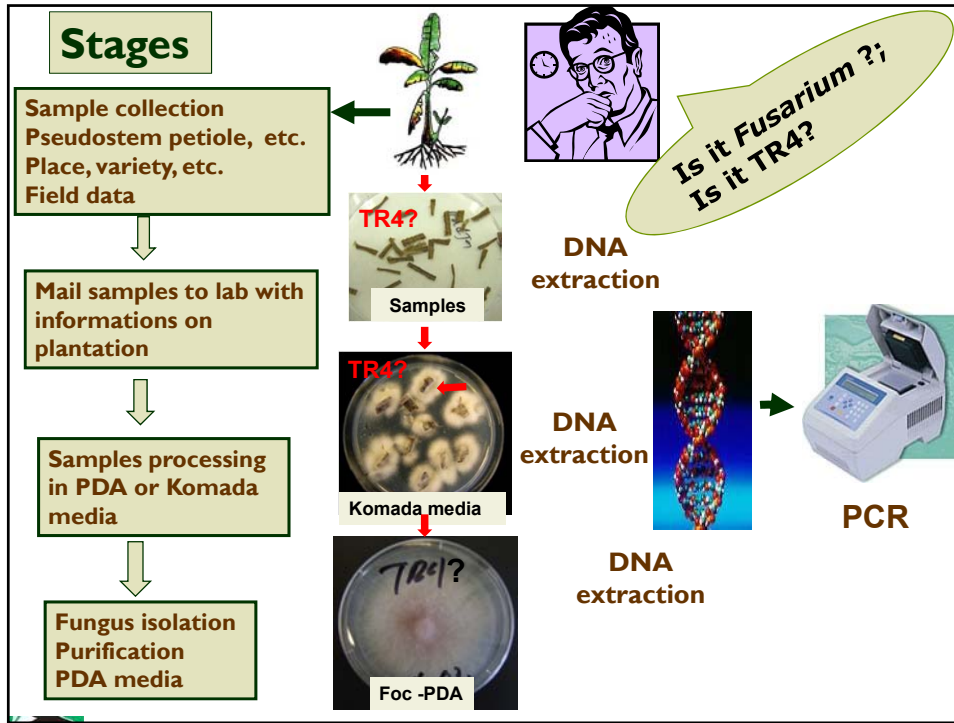
*Fusarium oxysporum* f. sp. *cupense*  
diagnostic



Foc can **NOT** be morphologically discriminated  
from other *F. oxysporum*







### Molecular diagnostic of *Foc* TR4

Elongation factor 1- $\alpha$  (*Tefa-1a*) and Intergenic spacer region- IGS

28S 18S 28S 18S

*Plant Pathology* (2010) Doi: 10.1111/j.1365-3059.2009.02221.x

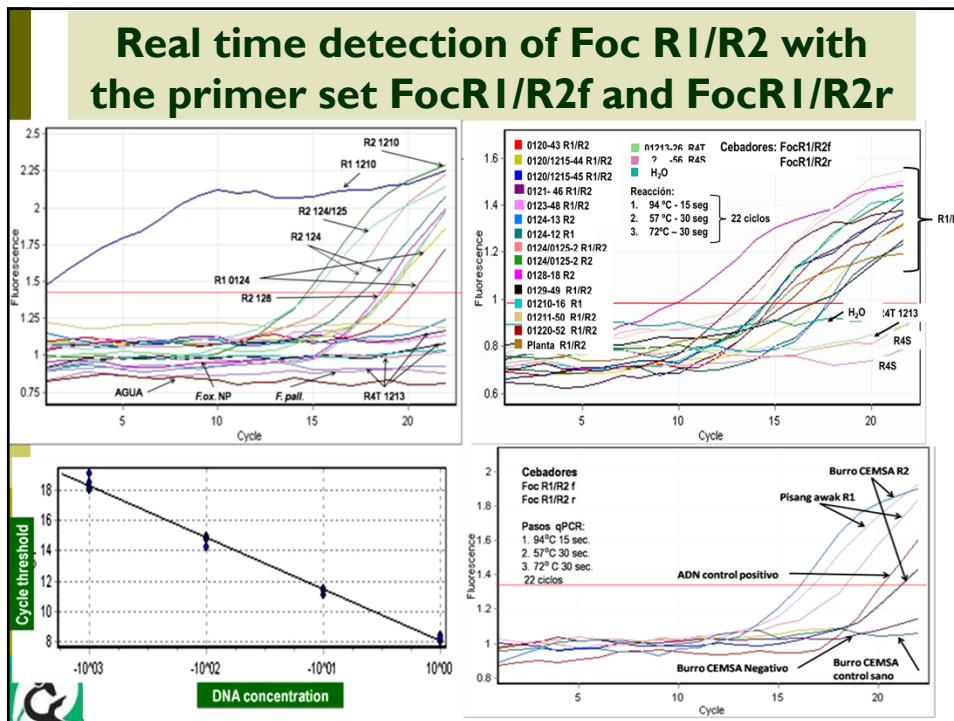
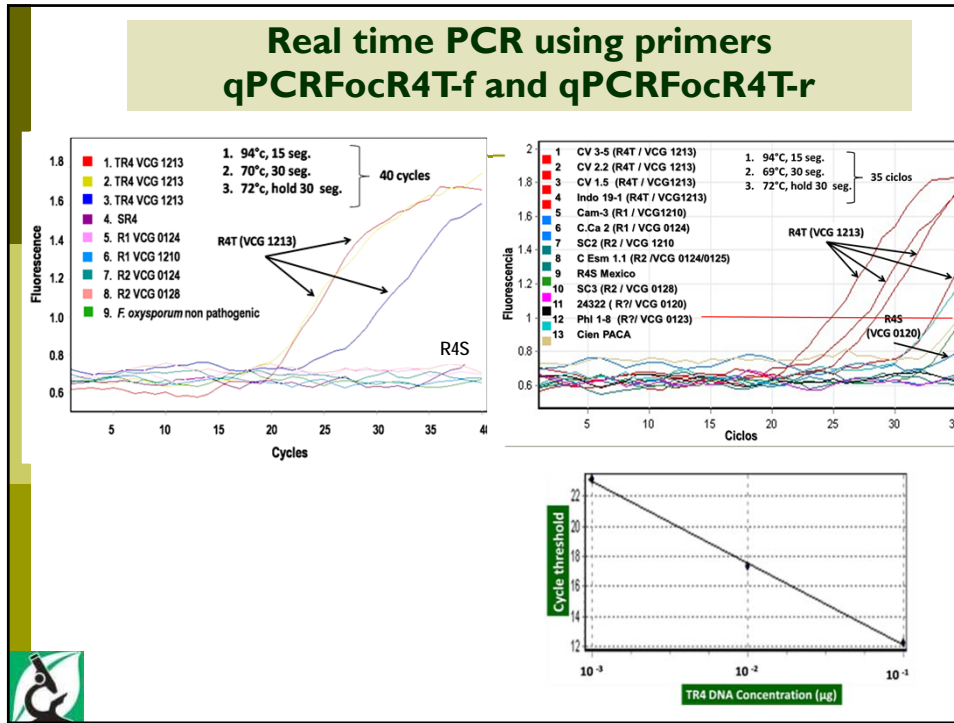
**A molecular diagnostic for tropical race 4 of the banana fusarium wilt pathogen**  
M. A. Dita<sup>a,b</sup>, C. Waalwijk<sup>a</sup>, I. W. Buddenhagen<sup>c</sup>, M. T. Souza Jr<sup>b,d</sup> and G. H. J. Kema<sup>a</sup>

*Plant Pathology* (2011) 46, 344 Doi: 10.1111/j.1365-3059.2010.02417.x

**Corrigendum**  
Dita MA, Waalwijk C, Buddenhagen IW, Souza Jr MT, Kema GHJ. 2010. A molecular diagnostic for tropical race 4 of the banana fusarium wilt pathogen. *Plant Pathology* 59, 348-357.

Contro +/-

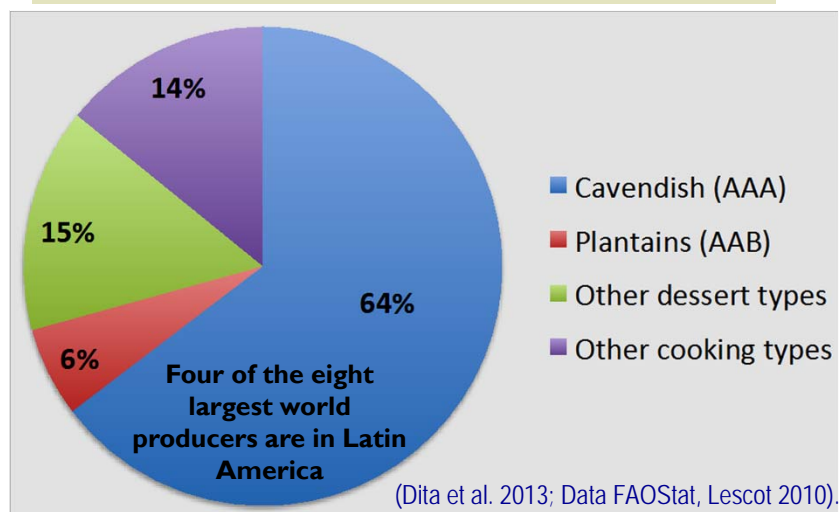
TR4 - (BB) TR4 - (AA) TR4 + (AA) TR4 - (AA)

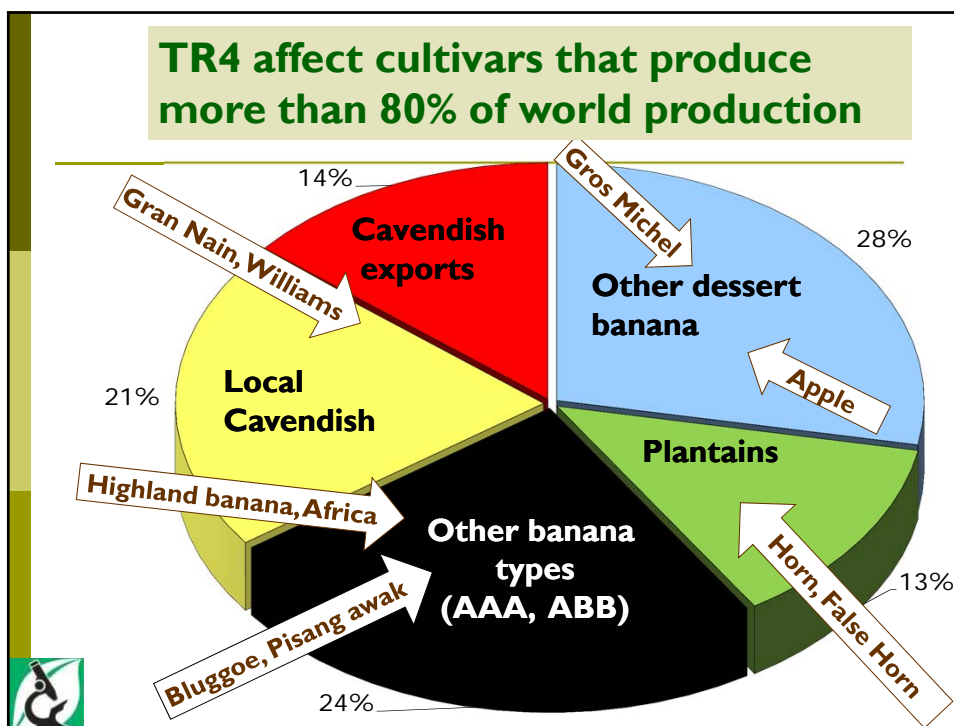


## Impact that could have in America the entry of *Foc* TR4 and action plan



**Cavendish cultivars are 41% of all *Musa* cropped at world level and > 60 % in the 10 main country producers.**





**More important cultivars of banana and plantain in Latin America and Caribbean and possibilities of been affected by Foc TR4**

| Genome/Subgroup   | Cultivars   |
|-------------------|---|
| AA                | Sucrier, O [redacted] nger, Ciento en Boca, Dath.   |
| AAA/ Cavendish    | Grand nain, F [redacted] ish Valery, Williams, Lach [redacted], Red, Green red.   |
| AAA/ Gros Michel  | Gros Michel, Johnson (Seda, Guineo), Cocos.   |
| AAB/ Silk / Prata | Manzano (A [redacted]), Pome  |
| AAB/ Plátanos     | Horn <sup>3</sup> / <sub>4</sub> ; Hembra <sup>3</sup> / <sub>4</sub> ; Hartón, Dominico Harton, Curaré, In [redacted] dwarf, Bellaco, Dwarf plantain, Red Plantain |
| ABB/ Bluggoe      | Bluggoe, B [redacted] Cuatro filos, Cachaco, [redacted] ba, Chato.  |
| ABB/ Pisang awak  | Pisang awak (B [redacted] uba), Fougamou, Burro Cenizo, [redacted]  |

## Risk and noxious factors of an outbreak of *Foc* TR4 in LA&C

- ✓ Similar symptoms to other races and long latent period; evidence of its presence can happen after many years of introduction.
- ✓ High dependency in production of a reduced number of cultivars (Cavendish, AAB plantains, Bluggoe and Pisang awak types, ABB, etc.).
- ✓ Poor knowledge and conscience among growers of disease impact, infection cycle and management tactics.



## Risk and noxious factors of an outbreak of *Foc* TR4 in LA&C

- ✓ Persistence in soil by many years
- ✓ Lack of access of growers to certified free planting material.
- ✓ Limited options of chemical and biological management
- ✓ Easy dissemination by different ways to be introduced
- ✓ Can be easily conserved in filter paper keeping viability by long periods.




# Contingency Plan for FocTR4

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



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**OBJECTIVE:**  
Bring scientific, organizational and reglamentary bases of actions to implement by National Plant Protection Services, for opportune management (identification, diagnostic, eradication-confining, contention- management) of an eventual outbreak of FocTR4 in region.




<http://www.oirsa.org/aplicaciones/subidoarchivos/BibliotecaVirtual/PlandecontingenciacontraFocR4TOIRSA.pdf>


## Content:




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1. General information

2. Identification procedures

3. Technical and economic feasibility

4. Reglament procedures

5. Organization for execution

6. Communication and Advertising

7. Cooperation and Coordination Relationships

8. Surveys procedures


9. Control procedures

10. Assessment of Emergency Program

11. Financing

12. Bibliography

Annexes



✓ **155 pages**


✓ **7 tables**

✓ **18 figures**


## ANNEXES CONTAIN:

ORGANISMO INTERNACIONAL TROPICAL DE SANIDAD AGROPECUARIA  
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1. Foc TR4 data sheet
8. Capacity building program
2. Foc TR4 diagnostic protocols
9. Actions for eradication-confinement of a Foc TR4 outbreak
3. Contacts in case of Foc TR4 outbreaks or incursions
10. Design and assessment of Foc TR4 surveys
4. Amplify list of hosts of Foc TR4
11. Formularies (examples)
5. Glossary
12. Research advances
6. Emergency declaration Form for a Foc TR4 outbreak
13. International financial sources
7. Template to inform to the public the presence of a Foc TR4 outbreak



## SUGGESTED ACTIONS TO PREVENT INTRODUCTION AND ESTABLISHMENT OF FUSARIUM WILT TROPICAL RACE 4

1. Prohibition of banana plants imports others than certified virus, bacteria and fungi free tissue culture indexed plants from trusted sources.
2. Develop of an Emergency Contingency Plan for a case of an incursion of Foc TR4 following the guidelines of the technical document developed by OIRSA, Bioversity International and INISAV.
3. Develop of a survey of Panama disease risky areas based on cultivars and Foc RI/R2 current presence.



### **SUGGESTED ACTIONS TO PREVENT INTRODUCTION AND ESTABLISHMENT OF FUSARIUM WILT TROPICAL RACE 4**

5. Capacity building with extension phytosanitary officials and growers on symptoms identification, sampling, storage, transport and mailing samples.
6. Create brochures for extension officers and growers with disease description and steps to follow in a case of an incursion
7. Tropical race 4 presence in Africa is highly risky. It is possible that due to infrastructure weakness in these countries disease could disseminate.



### **SUGGESTED ACTIONS TO PREVENT INTRODUCTION AND ESTABLISHMENT OF FUSARIUM WILT TROPICAL RACE 4**

8. Development of disease clean seed programs accessible to growers
9. Start to develop the pertinent technical and legal regulations.
10. Distribution of advertising brochures among visitors to countries with presence of Foc TR4.





