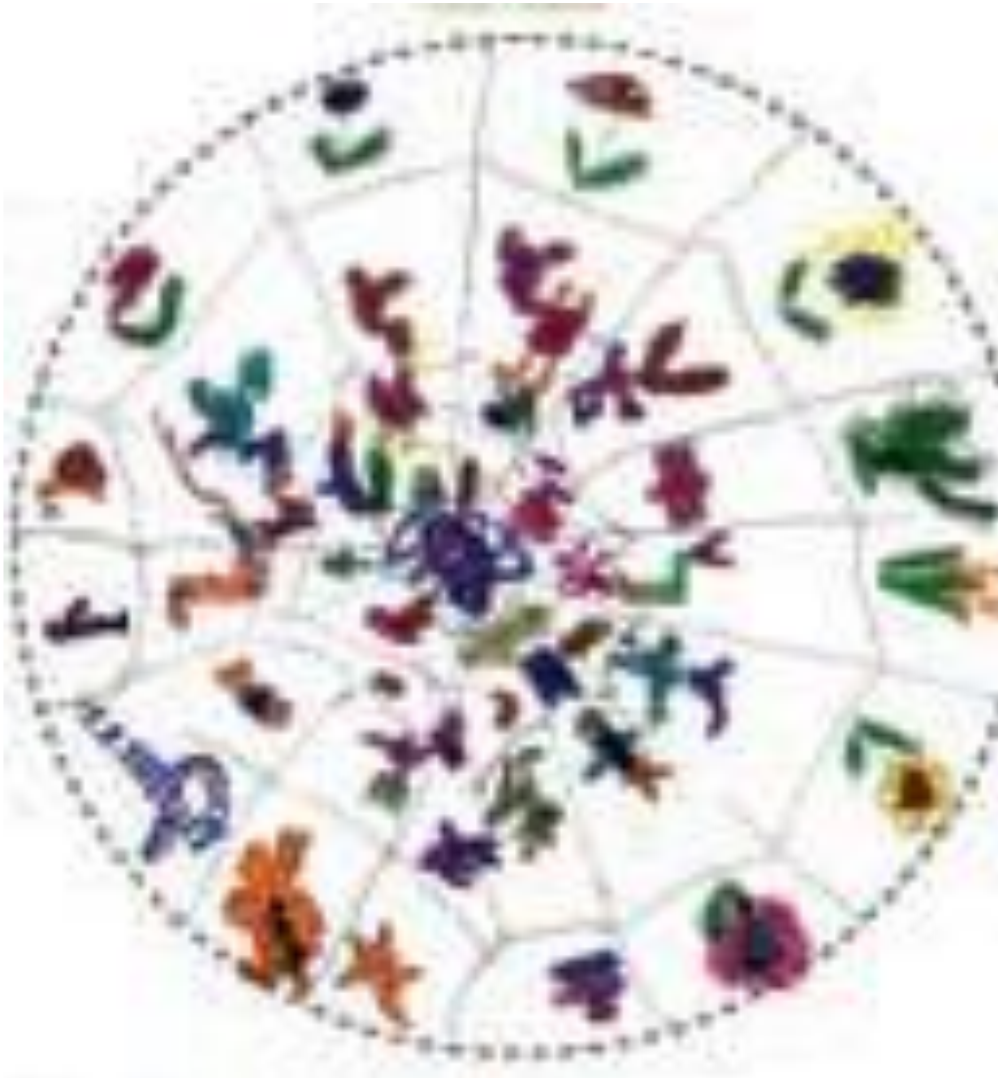
Philippine Fungal Diversity: Benefits and Threats to Food Security

Bangko Sentral ng Pilipinas Professorial Lecture

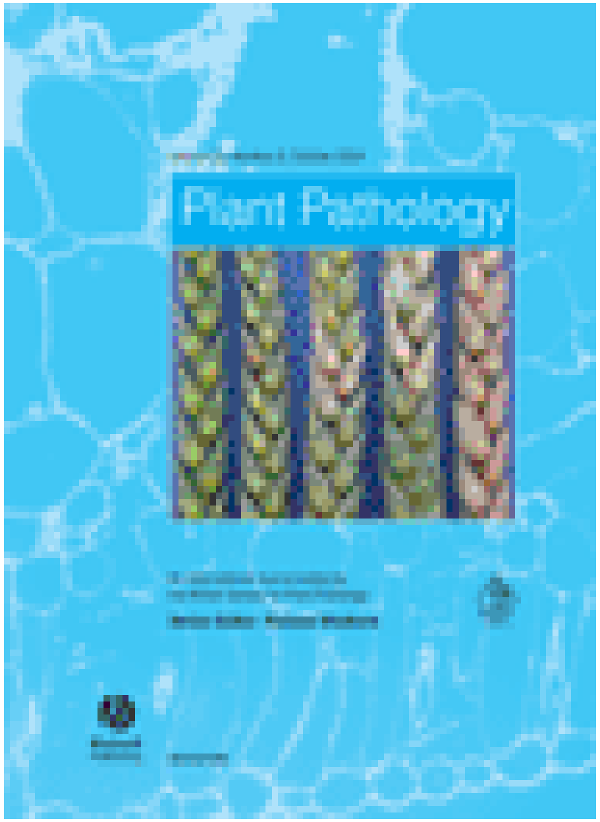
Christian Joseph R. Cumagun
College of Agriculture, UPLB

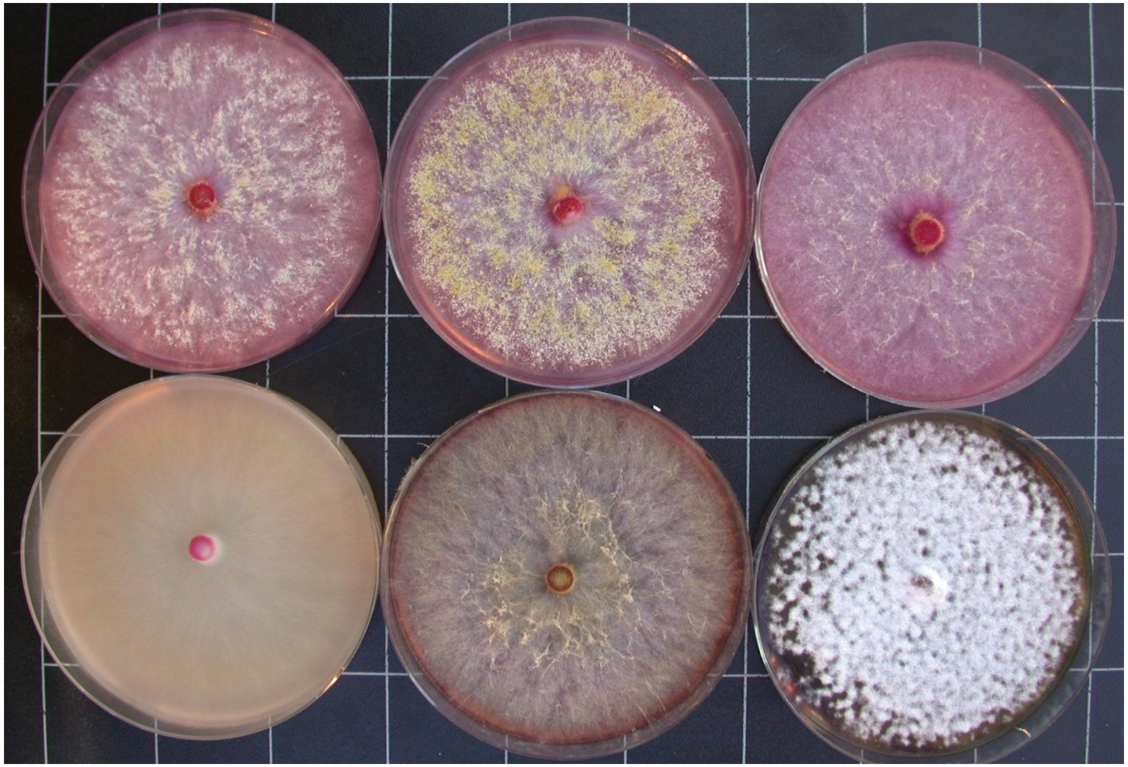
FAO Biodiversity Challenge 2011



Johann Cumagun, age 7

Variation of agressiveness and cultural characters





Front cover of Vol 53 of *Plant Pathology* : Cumagun et al. (2004)

Newspaper headlines associated with 1993 Fusarium head blight epidemic

Diseases ravage wheat

Grain/ Wheat scab is forcing farmers to abandon crops

Valley grain diseased

To harvest or destroy crops? Disasters force tough choices on farms

Vomitoxin rears its ugly head

Wheat scab shocks Valley

•Disease is widespread, elevators expect discounts

A blight on the land

•Lawmakers seek compensation to farmers for diseased wheat

Crop disease, flood damage will be felt in the N.D. economy

Crop scouts think harvests will be smaller than expected

Ruined wheat field

Farmers panic

Fields of disappointment

Will wheat head blight contribute to shortage of world food supply?

Fusarium graminearum infection

Objectives of my Talk

1. To demonstrate the potential biological control of plant diseases using fungi to address food security and environmental safety (Case Study 1)
2. To harness the diversity of fungi from the rainforests to generate useful products for agriculture and medicine (Case Study 2)
3. To tap the diversity of plant resistance genes to solve the alarming disease epidemics caused by fungi (Case Study 3)
4. To discuss the impact of some important *Fusarium* diseases and mycotoxins in the Philippines (Case Study 4)
5. To emphasize the need to secure microbial resources in the Philippines to decrease threats to food security

Estimating the no of fungal species

Hawksworth, H. L. 1991. The fungal dimension of biodiversity: magnitude, significance and conservation. **Mycological Research 95: 641-655.**

Hawksworth, H. L. 2001. The magnitude of fungal diversity: the 1.5 million species estimates revisited. **Mycological Research 105: 1422-1432**

8.74 million eukaryote species on earth

611,000 species of fungi (moulds, mushrooms) of which 43,271 have been described and catalogued

Camillo Mora. *How many species are there on earth and in the ocean?* PLOS Biology, 2011

5.1 M species of fungi

Meredith Blackwell. American Journal of Botany 98: 426-438 2011

Philippine Fungal Diversity

- Estimated at 3956 species and 818 genera (Tadiosa, 2012)
- 53 species under 22 genera of entomopathogenic fungi were reported on selected areas in the Philippines from 1998 to 2001 (Villacarlos and Meija, 2004)
- Fungi on bamboos (Cai et al, 2003; Hyde et al. (2002)

MYCOLOGICAL SOCIETY OF THE PHILIPPINES, INC.

The Mycological Society of the Philippines, Inc. (MSP) is a non-profit and non-stock, professional organization established to nurture and promote interest on fungi. Fungi play a variety of roles as decomposers, mutualists and pathogens in the ecosystem, ultimately and inadvertently affecting other members in the intricate web of life.

THE BEGINNINGS...

The Mycological Society of the Philippines, Inc (MSP) was organized on October 19, 1998 at the University of the Philippines at Visayas (U.P.V.) in Iloilo by a small group of mycologists attending a conference on "Tropical Microbial Diversity". Dr. Tricita H. Quimio, Philippine representative to the International Mycological Association Committee for Asia (IMACA), a professor and mycological head curator from U.P. Los Banos, was appointed chairman of the organizing committee. Dr. Resurrection B. Sadaba and Dr. Maria Vicenta V. Gacutan, both from U.P. Visayas, served as vice chairman and secretary, respectively. Two other members of IMACA witnessed the organization of this committee: Dr. Kevin D. Hyde of Hongkong and Dr. Komagata of Japan.

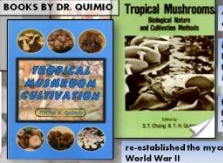
With the encouragement from IMACA, an official group of mycologists was subsequently formed at UPLB to represent the first board of directors. These were Dr. T.H Quimio as chairman, Dr. Teresita U. Dalisay, Dr. Lourdes M. Tapay, Dr. Marilyn B. Brown, Dr. Nenita L. Opina, Ms. Elsa M. Luis, Dr. Silvino D. Merca, Dr. Ernesto P. Militante, Dr. Nelly S. Aggangan, and Dr. L. Dangan.

Thus, after months of planning, the first scientific meeting of the society was held on April 1999 at APEC Building UP Los Banos with an elite 167 charter members. Dr Kevin D. Hyde of the University of Hongkong talked on "Where are the Missing Fungi" and Dr. T.K. Tan of the National University of Singapore talked on "Mycology in Asean: where are we?".

MSP FOUNDER:

DR. TRICITA H. QUIMIO

- a professor at the Department of Plant Pathology, University of the Philippines at Los Baños (UPLB)
- obtained her MS from the University of Florida and PhD from North Carolina State University
- published over 100 papers and other works including several standard reference books on tropical fungi
- conducted research on the cultivation of tropical mushrooms
- instrumental in establishing in 1980 the International Mushroom Society for the Tropics, and the Philippine Mushroom Society in 1988
- founded a Mushroom Mycelial Bank for the Tropics, headed a Mushroom Training and Demonstration Unit
- re-established the mycological herbarium destroyed during World War II



BOOKS BY DR. QUIMIO

THROUGH THE YEARS...

SCIENTIFIC MEETINGS AND SYMPOSIA

- 1ST "Philippine Mycology Faces the Challenges of the Next Millennium"
- 2ND "Mycology at the Threshold of the 21st Century"
- 3RD "Role of Mycology in Boosting Food Security"
- 4TH "Fungal Diversity: Conservation and Utilization"
- 5TH "Fungal Biotechnology for Food Security"
- 7TH "Recent Trends in Fungal Research"
- 8TH "Fungi as Nutriceuticals"
- 9TH "Fungi and Health"
- 10TH Annual Scientific Meeting and Symposium
- 11TH "Fungi in Agriculture and Alternative Medicine"
- 12TH "Fungi in Agriculture and Alternative Medicine"
- 13TH "Fungi and Climate Change"
- 14TH "Doing Business with Fungi"
- 15TH "Fungi in Human and Animal Health"

SOUVENIR PROGRAMS

COMPETITIONS

ORAL PAPER COMPETITION

POSTER PAPER COMPETITION

THQ BEST UNDERGRADUATE THESIS

TRAINING MANUALS AND FLYERS

MEMBERS

OVER 700 MSP MEMBERS

TRAININGS

SyenSaya

Table 1. BIOTECH commercialized products derived from Philippine fungi.

Product Name	Fungi	Uses
Brown Magic	Endomycorrhiza	Growth promoter of orchid seedlings and protects them from diseases
Bio Quick	*Trichoderma sp.*	Bio-organic fertilizer
Bio Green	*Trichoderma sp.*	Bio-organic fertilizer
Mycogroe	Ecto Mycorrhizal Fungi	Bio fertilizer
Mycovam	Vesicular Arbuscular Fungi	Soil-based biofertilizer for crops except crucifers and lowland rice
VAM Root Inoculant	Vesicular Arbuscular Fungi	Growth promoting subtances and disease control
Lipase	*Rhizopus sp.*	Hydrolyses coconut oil to produce high value β- monoglyceride
Pectinase	*Aspergillus* sp.	Juice and wine clarification oil extraction from freshly grated coconut and essential oil extraction
Microbial Rennet	*Rhizopus chinensis*	Milk coagulation for cheese production

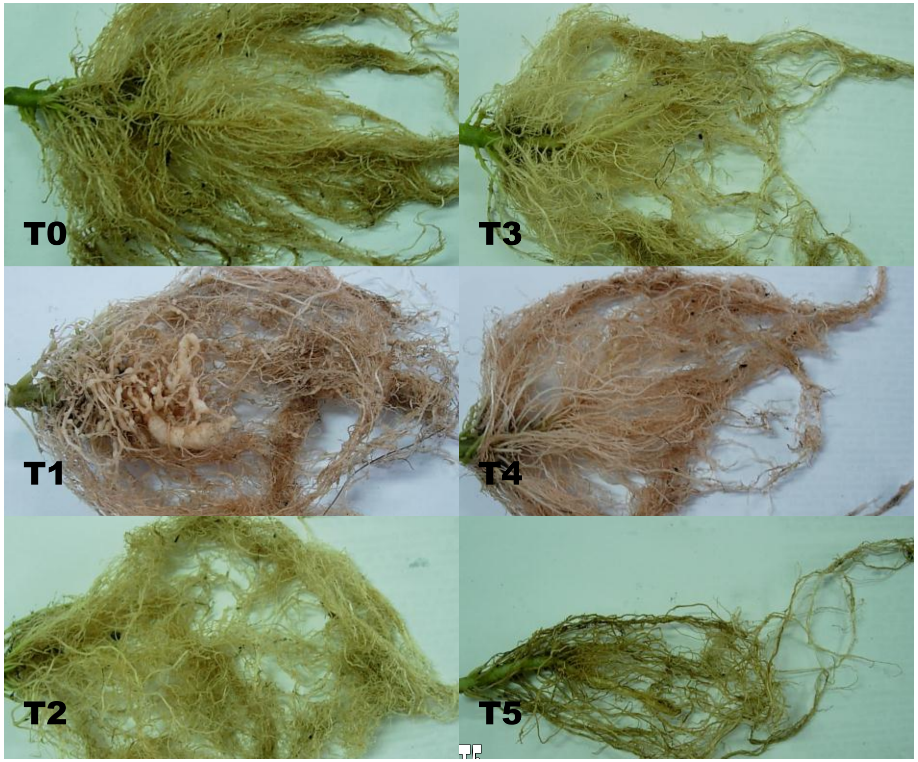
Major repositories of fungal cultures and specimens in the Philippines

1. UPLB Mycological Herbarium
2. UPLB Microbial Culture Collection
3. Philippine National Herbarium Collection (PNHC)
4. Microbial Research and Service Laboratory (MRSL), University of the Philippines, Natural Sciences Research Institute (UPCC)
5. University of Santo Tomas Collection of Microbial Strains (USTCMS)

Table 3. Effect of *P. lilacinus* on *M. incognita* attacking tomato 37 days after inoculation

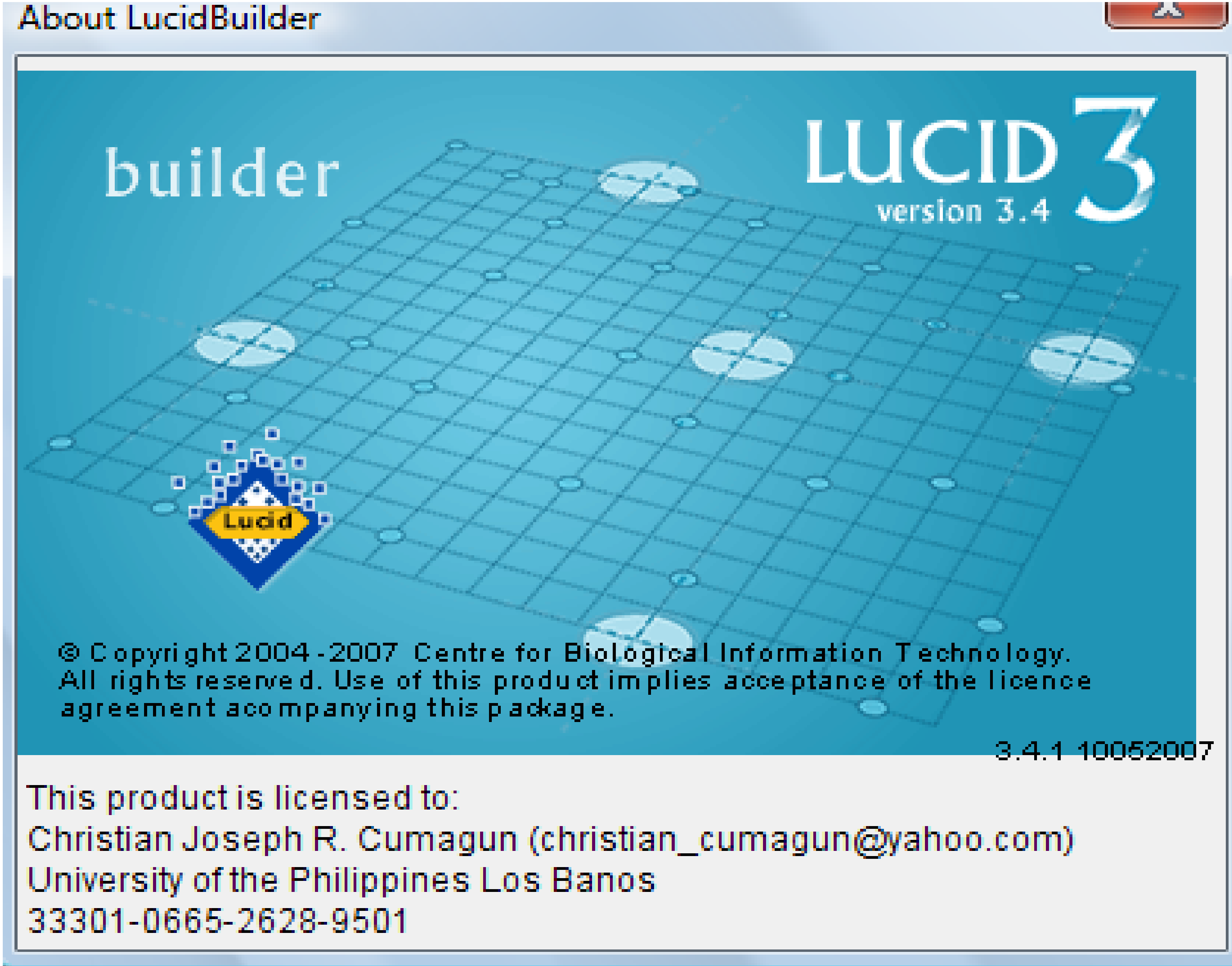
Treatments[1]	Root weight	Gall index rating[2]	No. of galls[3]	No. of nematodes[3]	No. of egg masses[3]	Percent reduction
Uninoculated control	6.025b	1.0c	0	0	0	-
M. incognita alone	9.225a	5.0a	32.5a	245.0a	31.3a	-
M. incognita + *P. lilacinus* (1.584x10^5 spores/ml)	3.175bc	2.3b	23.5b	23.5b	19.0ab	89.89
M. incognita + *P. lilacinus* (7.92 x10^6 spores/ml)	5.725b	2.0b	6.3b	6.3b	4.5bc	97.31
M. incognita +*P. lilacinus* (3.96 x 10^8 spores /ml)	4.725bc	2.0b	10.8b	10.8b	9.0bc	95.38
M. incognita + Nemacur	1.575c	1.0c	0	0	0	100.0

Roots of tomato inoculated with *M. incognita* and *P. lilacinus*



Legend: T0-uninoculated control; T1- *M. incognita* alone; T2 -*M. incognita* + *P. lilacinus* (1.584x105 spores/ml);T3- *M. incognita + P. lilacinus*(7.92 x106 spores/ml); T4- *M. incognita +P. lilacinus* (3.96 x 108 spores /ml.) T5- *M. incognita* + Nemacur

Source: Oclarit & Cumagun, 2009


About LucidBuilder
builder
LUCID 3
version 3.4
Lucid
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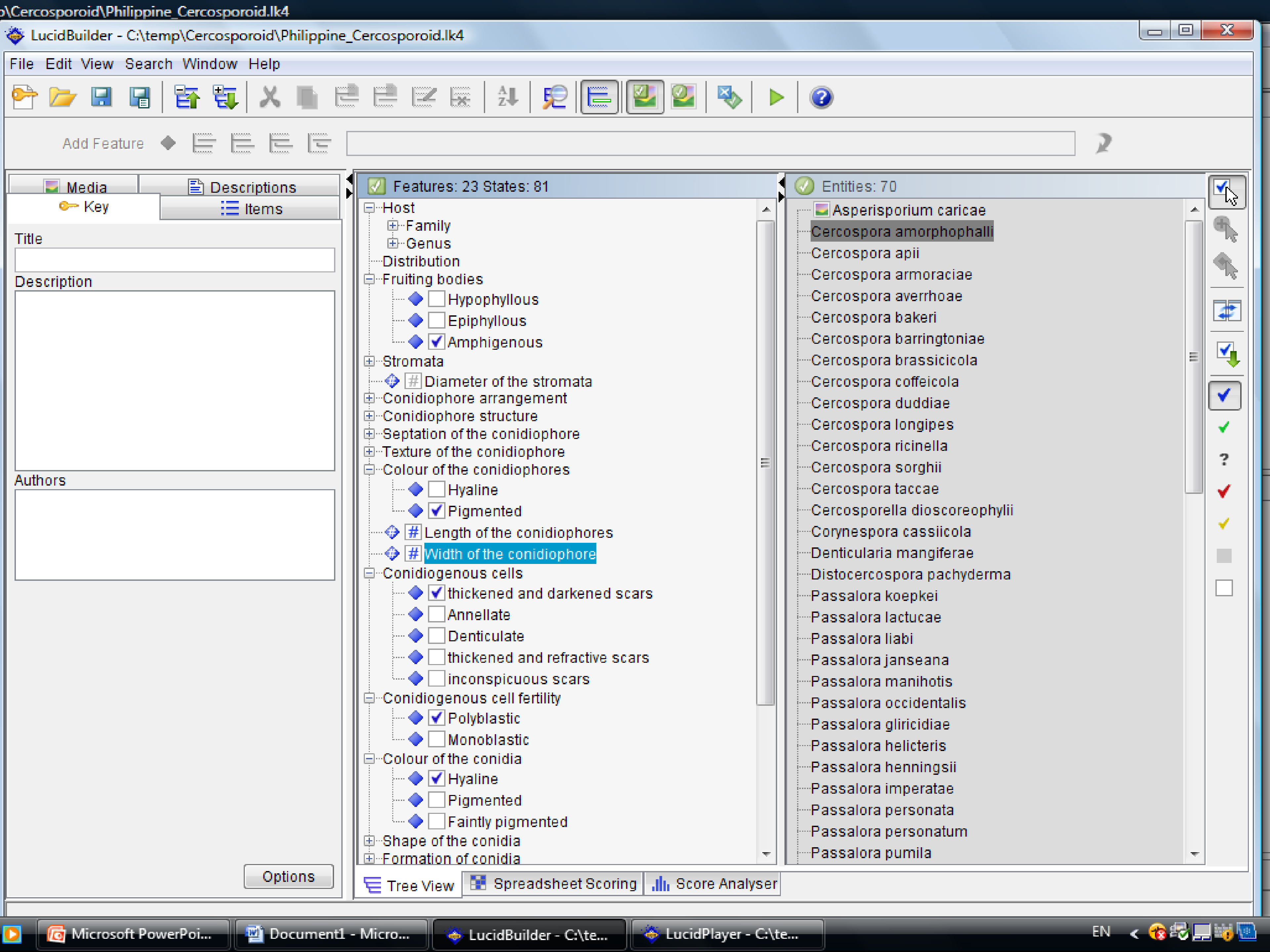
University of the Philippines Los Banos
33301-0665-2628-9501


LucidBuilder - C:\temp\Cercosporoid\Philippine_Cercosporoid.lk4
File Edit View Search Window Help
Add Feature
Media
Descriptions
Key
Items
Title
Description
Authors
Options
Features: 23 States: 81
Host
Family
Genus
Distribution
Fruiting bodies
Hypophyllous
Epiphyllous
Amphigenous
Stromata
Diameter of the stromata
Conidiophore arrangement
Conidiophore structure
Septation of the conidiophore
Texture of the conidiophore
Colour of the conidiophores
Hyaline
Pigmented
Length of the conidiophores
Width of the conidiophore
Conidiogenous cells
thickened and darkened scars
Annellate
Denticulate
thickened and refractive scars
inconspicuous scars
Conidiogenous cell fertility
Polyblastic
Monoblastic
Colour of the conidia
Hyaline
Pigmented
Faintly pigmented
Shape of the conidia
Formation of conidia
Entities: 70
Asperisporium caricae
Cercospora amorphophalli
Cercospora apii
Cercospora armoraciae
Cercospora averrhoae
Cercospora bakeri
Cercospora barringtoniae
Cercospora brassicicola
Cercospora coffeicola
Cercospora duddiae
Cercospora longipes
Cercospora ricinella
Cercospora sorghii
Cercospora taccae
Cercosporella dioscoreophyllii
Corynespora cassiicola
Denticularia mangiferae
Distocercospora pachyderma
Passalora koepkei
Passalora lactucae
Passalora liabi
Passalora janseana
Passalora manihotis
Passalora occidentalis
Passalora gliricidiae
Passalora helicteris
Passalora henningsii
Passalora imperatae
Passalora personata
Passalora personatum
Passalora pumila
Tree View
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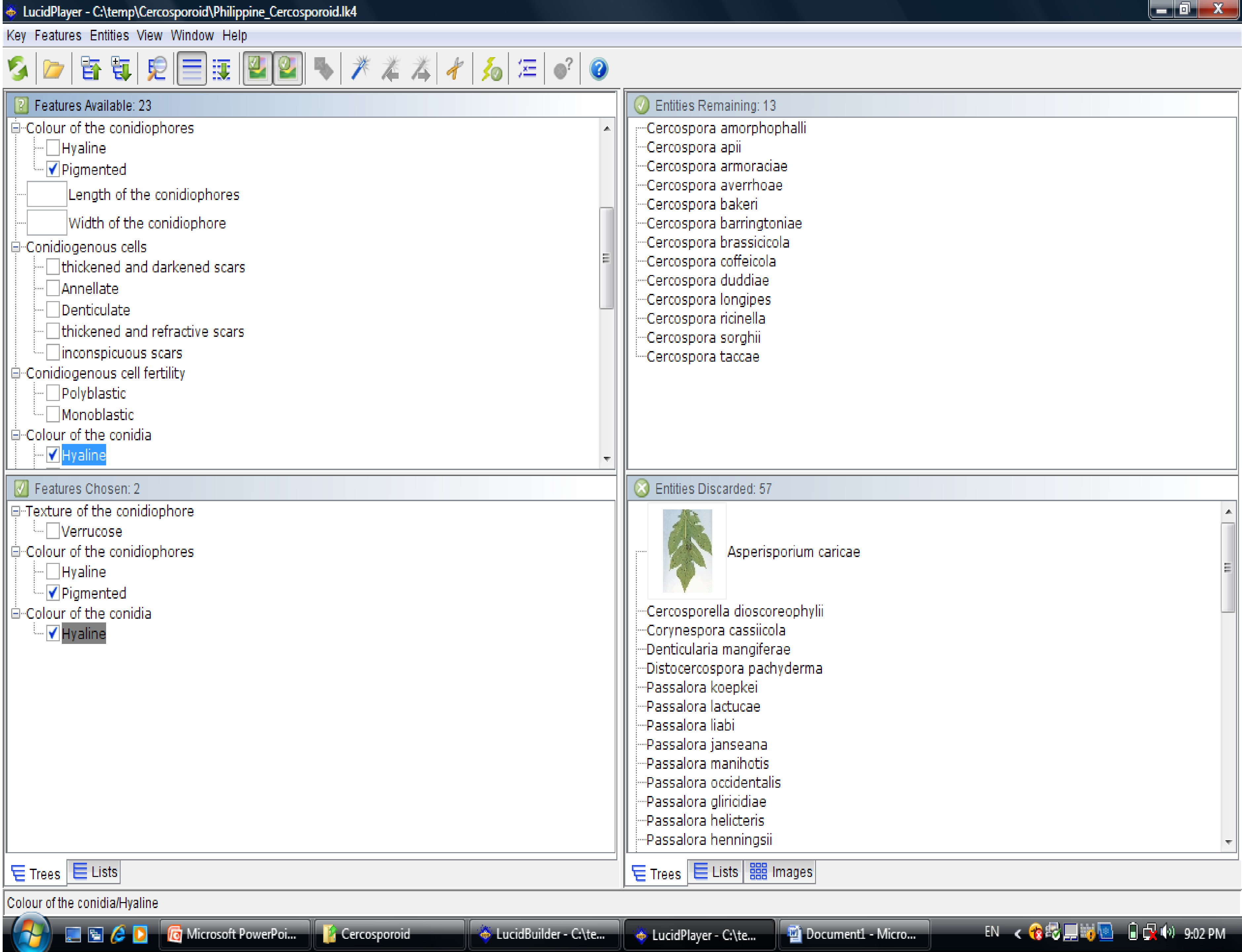
LucidPlayer - C:\temp\Cercosporoid\Philippine_Cercosporoid.lk4
Key Features Entities View Window Help
Features Available: 23
Colour of the conidiophores
Hyaline
Pigmented
Length of the conidiophores
Width of the conidiophore
Conidiogenous cells
thickened and darkened scars
Annellate
Denticulate
thickened and refractive scars
inconspicuous scars
Conidiogenous cell fertility
Polyblastic
Monoblastic
Colour of the conidia
Hyaline
Entities Remaining: 13
Cercospora amorphophalli
Cercospora apii
Cercospora armoraciae
Cercospora averrhoae
Cercospora bakeri
Cercospora barringtoniae
Cercospora brassicicola
Cercospora coffeicola
Cercospora duddiae
Cercospora longipes
Cercospora ricinella
Cercospora sorghii
Cercospora taccae
Features Chosen: 2
Texture of the conidiophore
Verrucose
Colour of the conidiophores
Hyaline
Pigmented
Colour of the conidia
Hyaline
Entities Discarded: 57
Asperisporium caricae
Cercosporella dioscoreophylii
Corynespora cassiicola
Denticularia mangiferae
Distocercospora pachyderma
Passalora koepkei
Passalora lactucae
Passalora liabi
Passalora janseana
Passalora manihotis
Passalora occidentalis
Passalora gliricidiae
Passalora helicteris
Passalora henningsii
Trees
Lists
Trees
Lists
Images
Colour of the conidia/Hyaline
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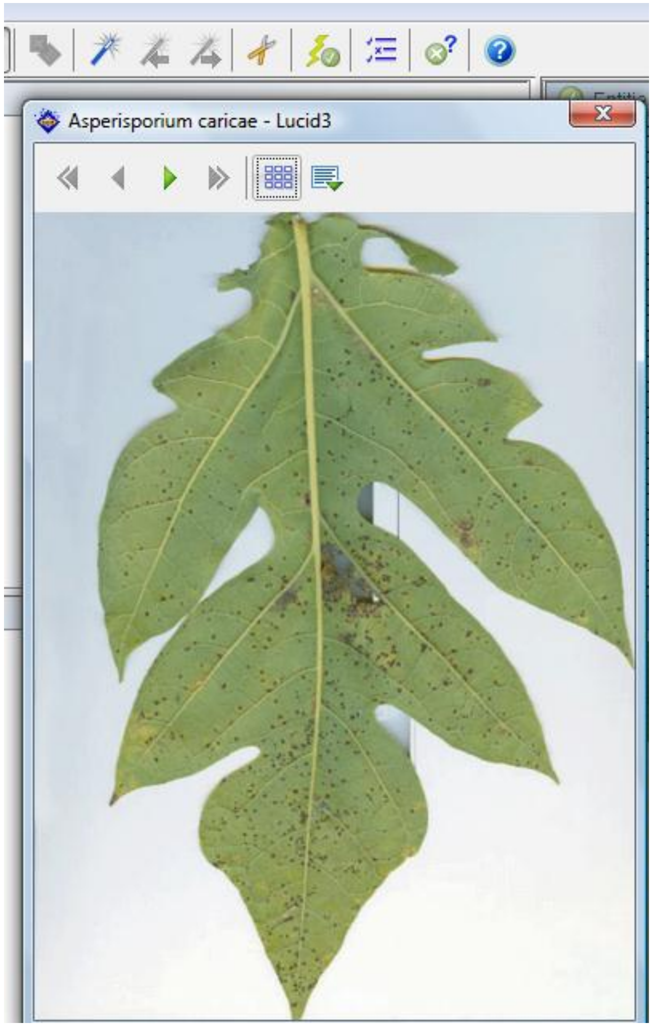
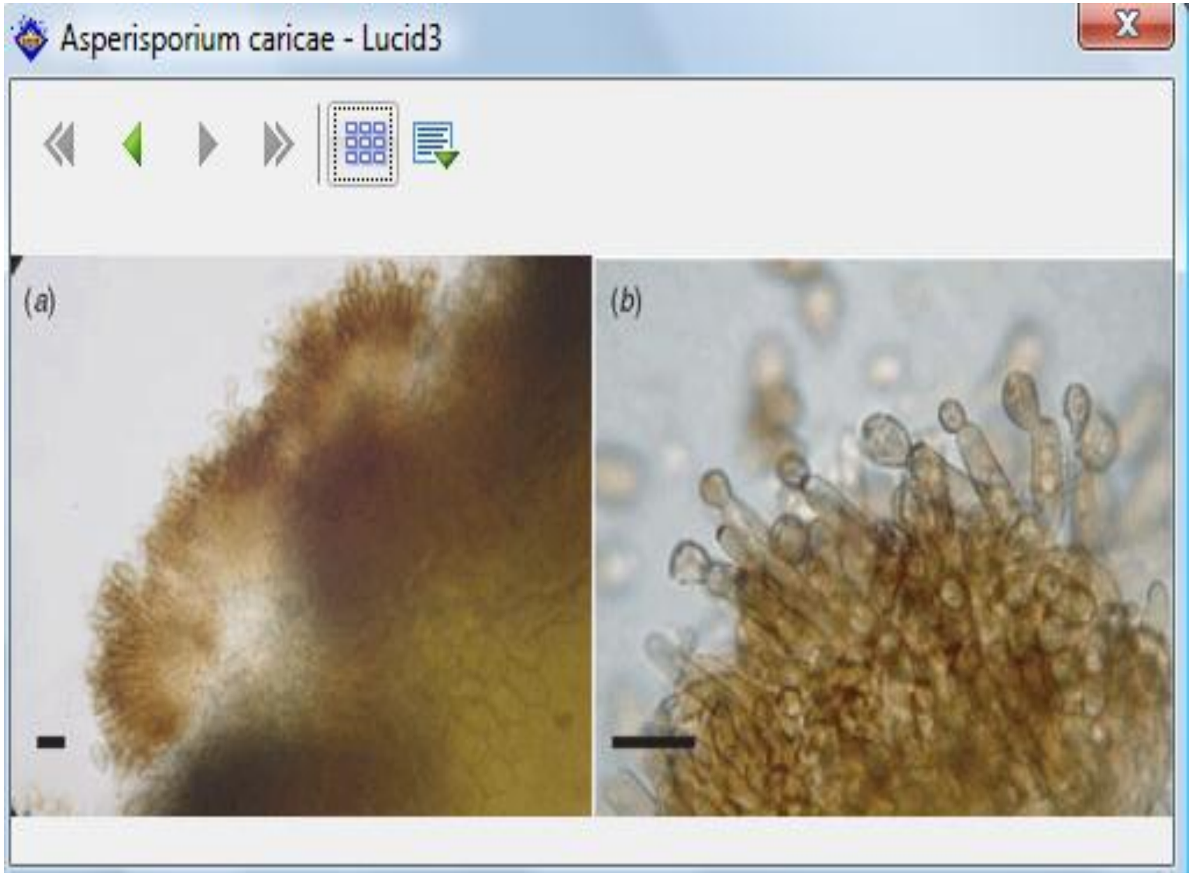

Asperisporium caricae - Lucid3

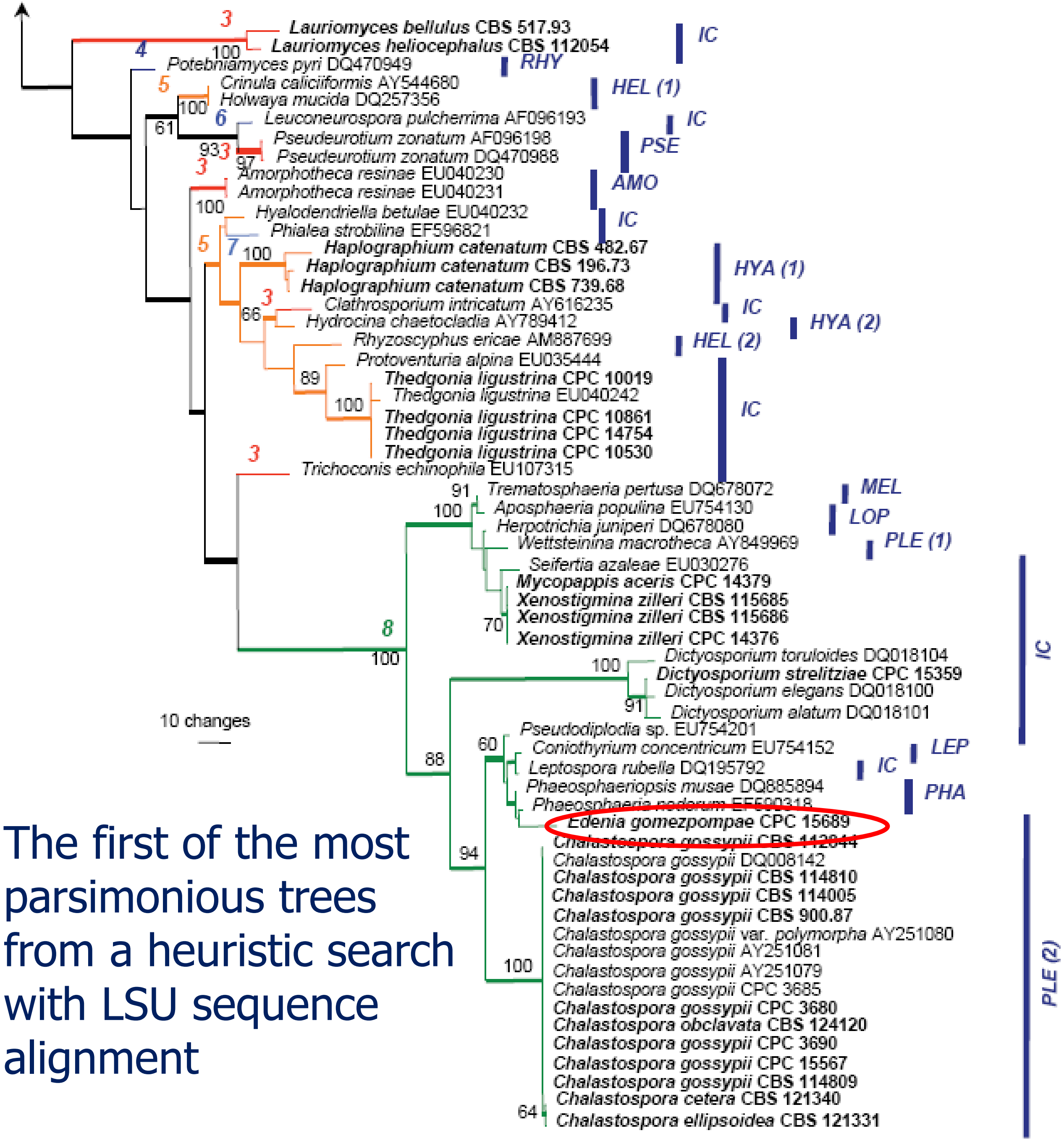

Asperisporium caricae - Lucid3
(a)
(b)

Edenia gomezpompae causing leaf spots in *Cassia alata*

Phylogeny and taxonomy of obscure genera of microfungi

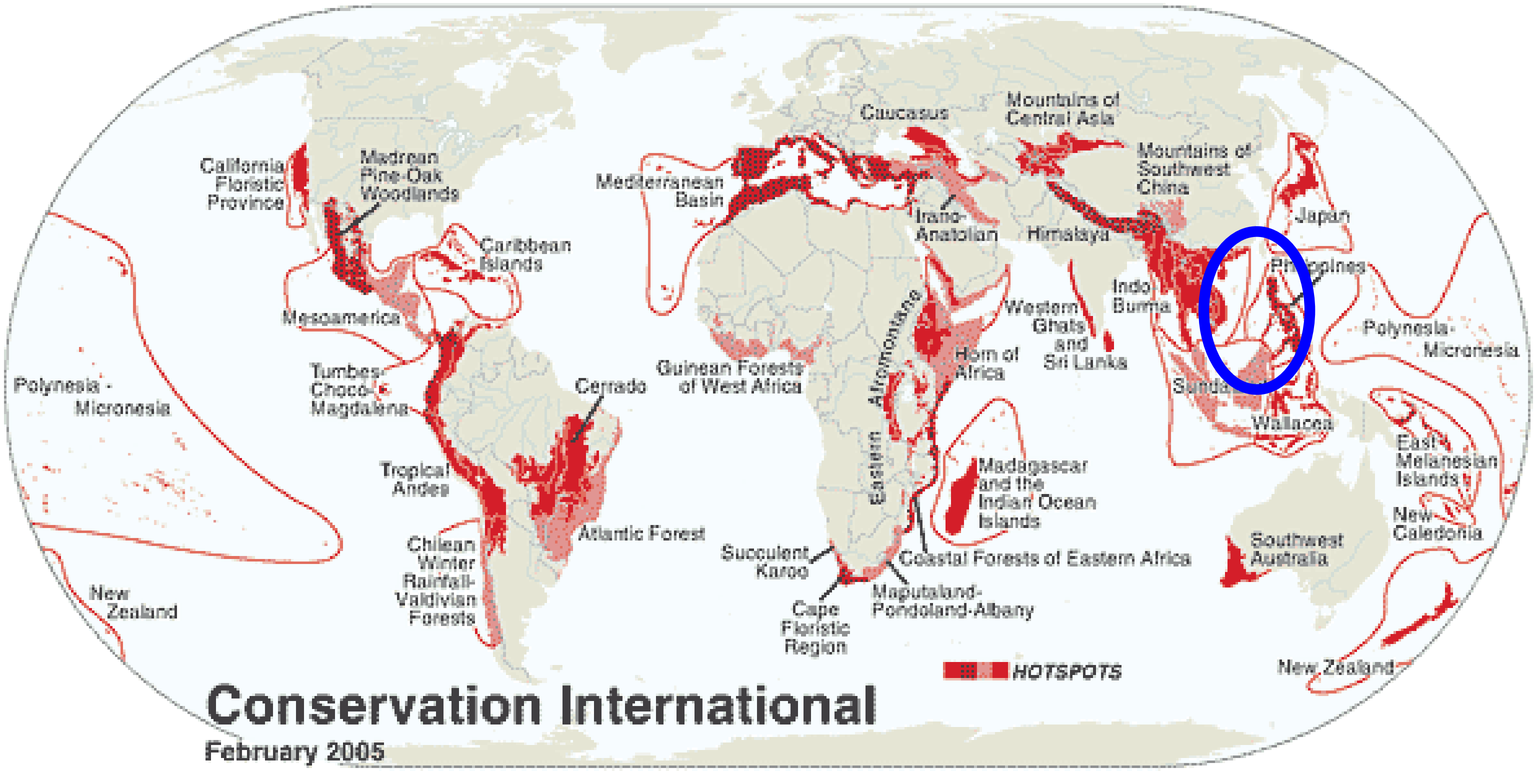
P.W. Crous, U. Braun, M.J. Wingfield, A.R. Wood, H.D. Shin, B.A. Summerell, A.C. Alfenas, C.J.R. Cumagun, J.Z. Groenewald

Persoonia 22, 2009: 139–161

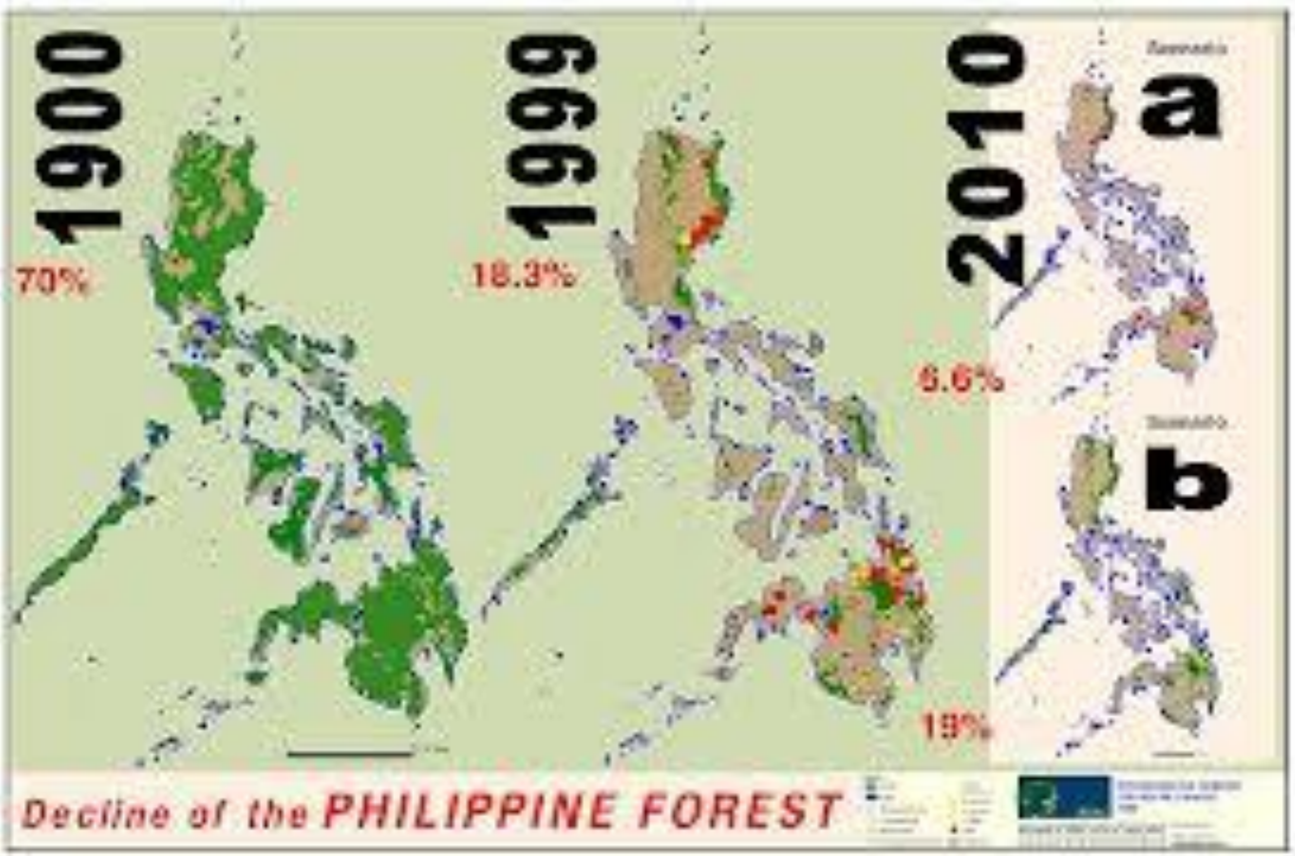


The first of the most parsimonious trees from a heuristic search with LSU sequence alignment

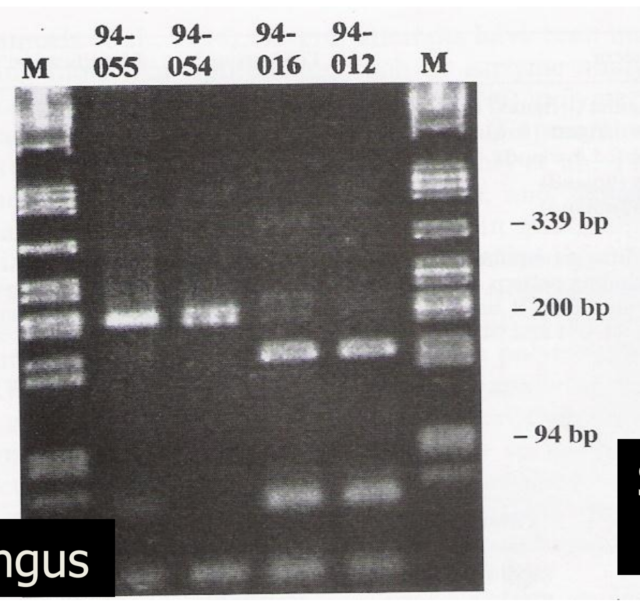
THE PHILIPPINES: A BIODIVERSITY HOTSPOT



In light of deforestation, the beneficial microbes are being destroyed and perhaps lost forever.



Identification of molecular markers for promising biocontrol agents
rDNA-ITS1 analysis of selected isolates (University of Copenhagen,Denmark)



Sheath blight of rice caused by *Rhizoctonia solani*

Trichoderma- a biocontrol fungus

Cumagun et al. 2000 J. of Phytopathology

TWO FUNGAL DISEASES COULD WIPE-OUT BANANA INDUSTRY IN 5 YEARS!

Photo courtesy of Sunstar and APS

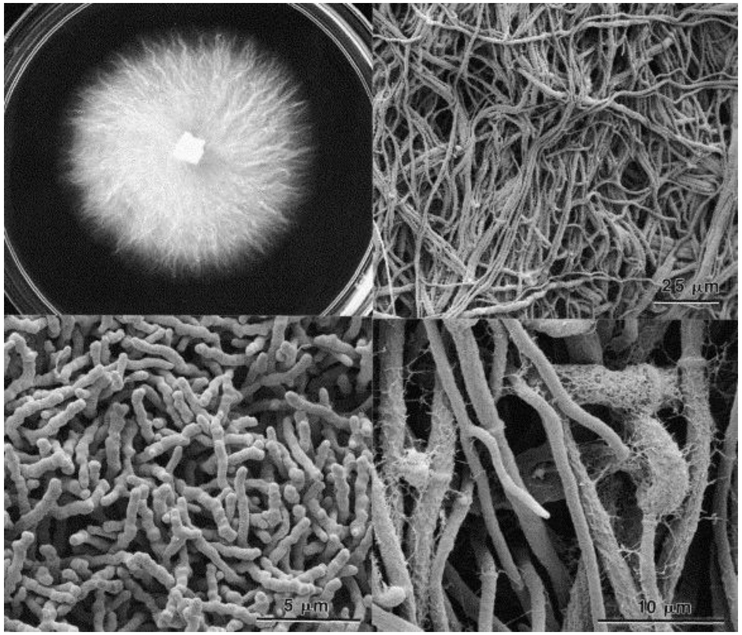
***Fusariun oxysporum* f. sp. *cubense* causing Panama wilt**

***Mycosphaerella* spp. causing Sigatoka disease of banana**

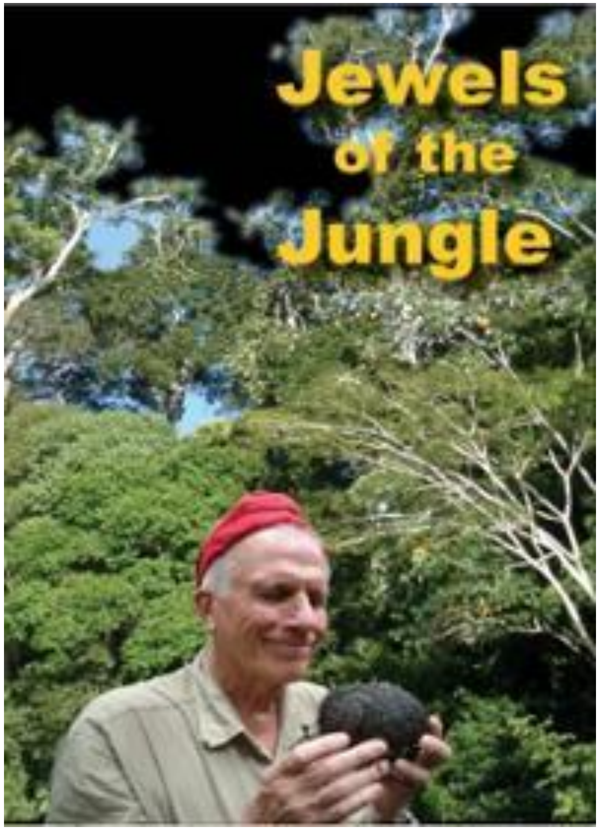
AERIAL SPRAYING: BAN OR NOT TO BAN?

Photo courtesy of, Romeo Gacad

AN ENDOPHYTE FUNGUS : A PROPOSED SOLUTION IN PARTNERSHIP WITH A WORLD-RENOWNED MICROBIOGIST

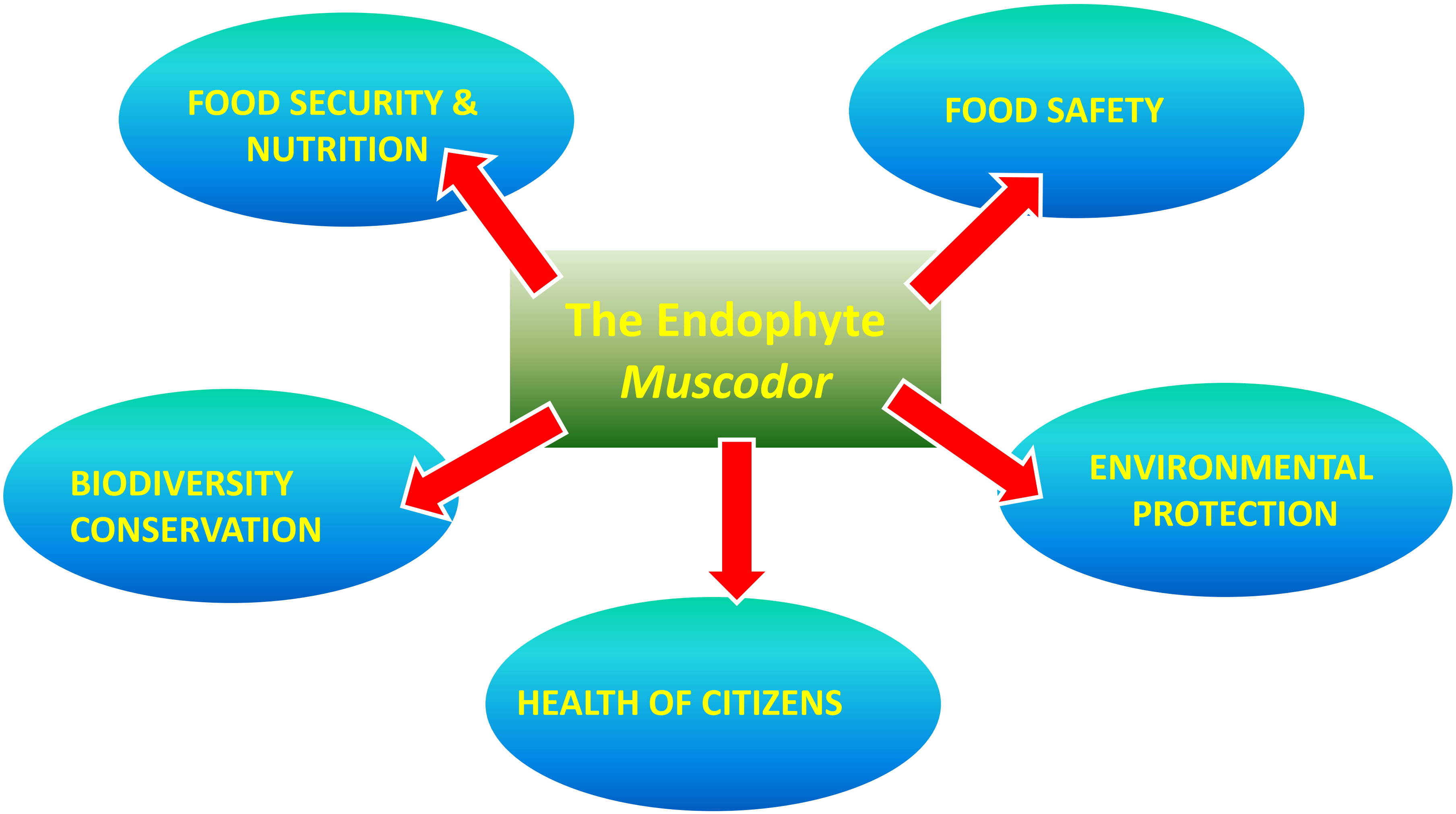


Muscodor albus



MONTANA
STATE UNIVERSITY

BENEFITS DERIVED FROM MUSCODOR TECHNOLOGY



Pestalotiopsis from Makiling Rainforests

Adiova et al. , 2015, unpublished results

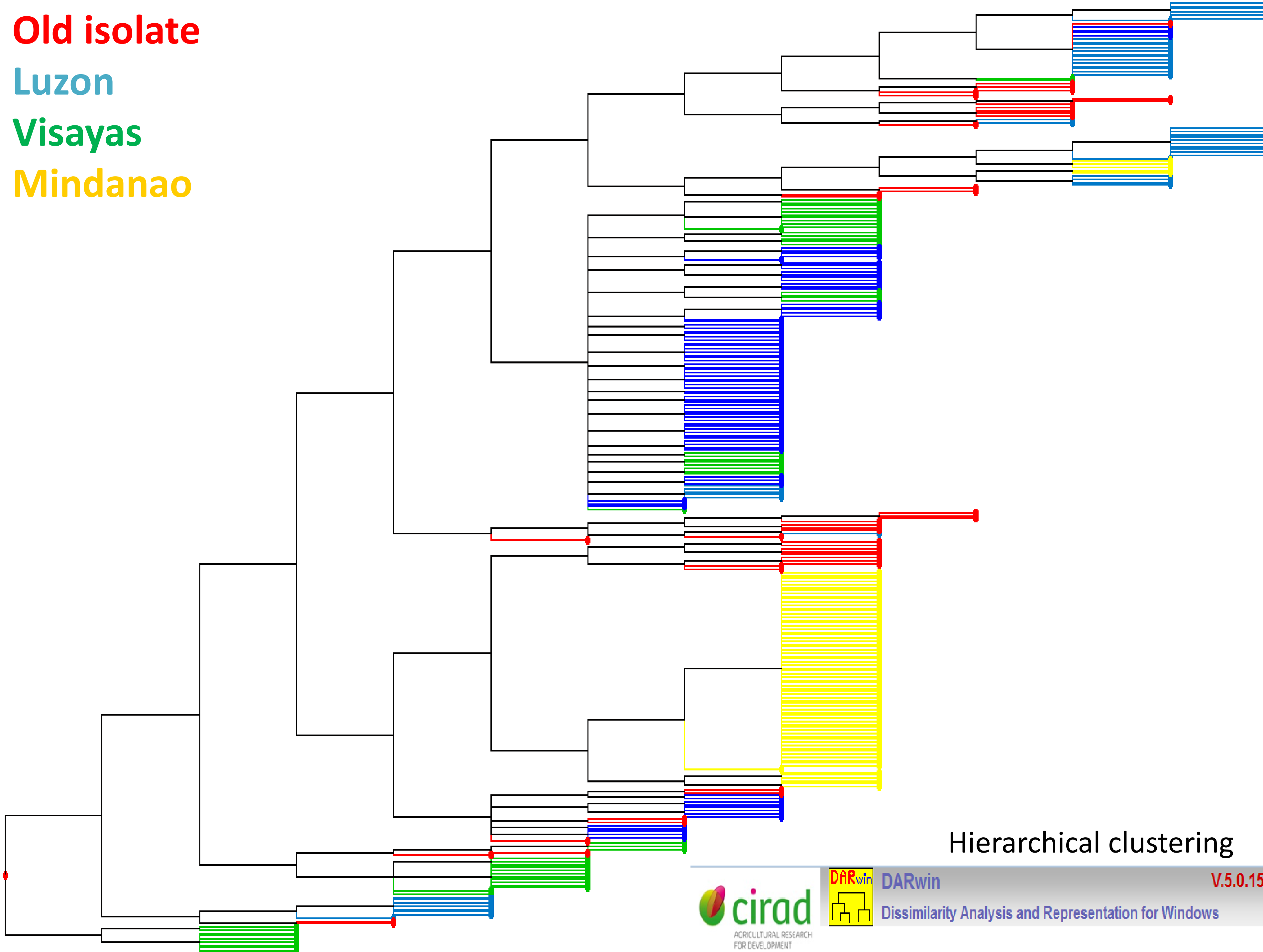
"for their discoveries concerning the activation of innate immunity”

Biovision LifeScience Forum, Lyon, France 2013

Genetic structure of populations of *Magnaporthe oryzae* in the Philippines

Lopez, A., **H. Adreit, J. Milazzo**
C. Cumagun and D.Tharreau

LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT



Hierarchical clustering

Inoculation and scoring

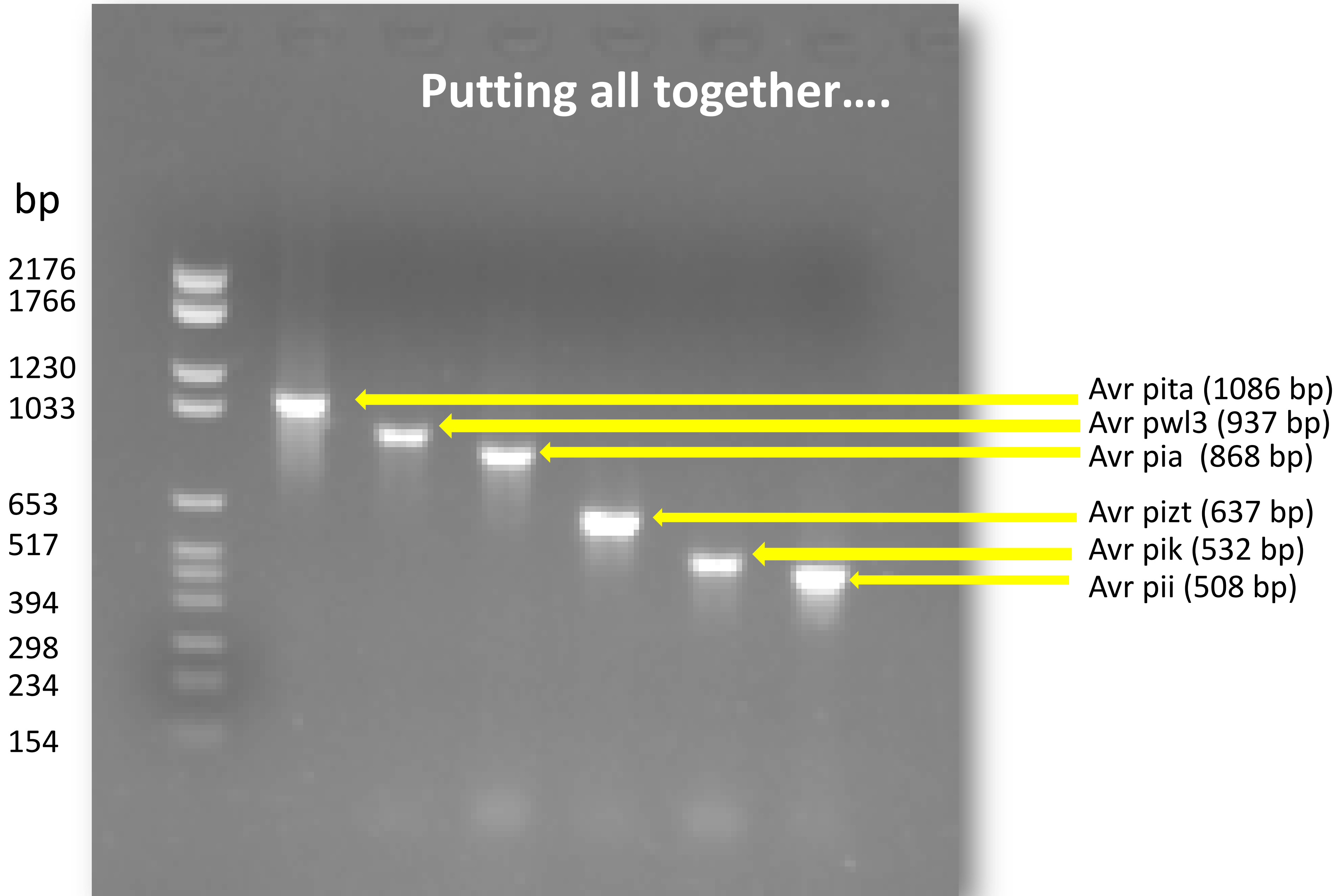
24 isolates tested against 16 varieties each with major R gene

Lopez, unpublished results

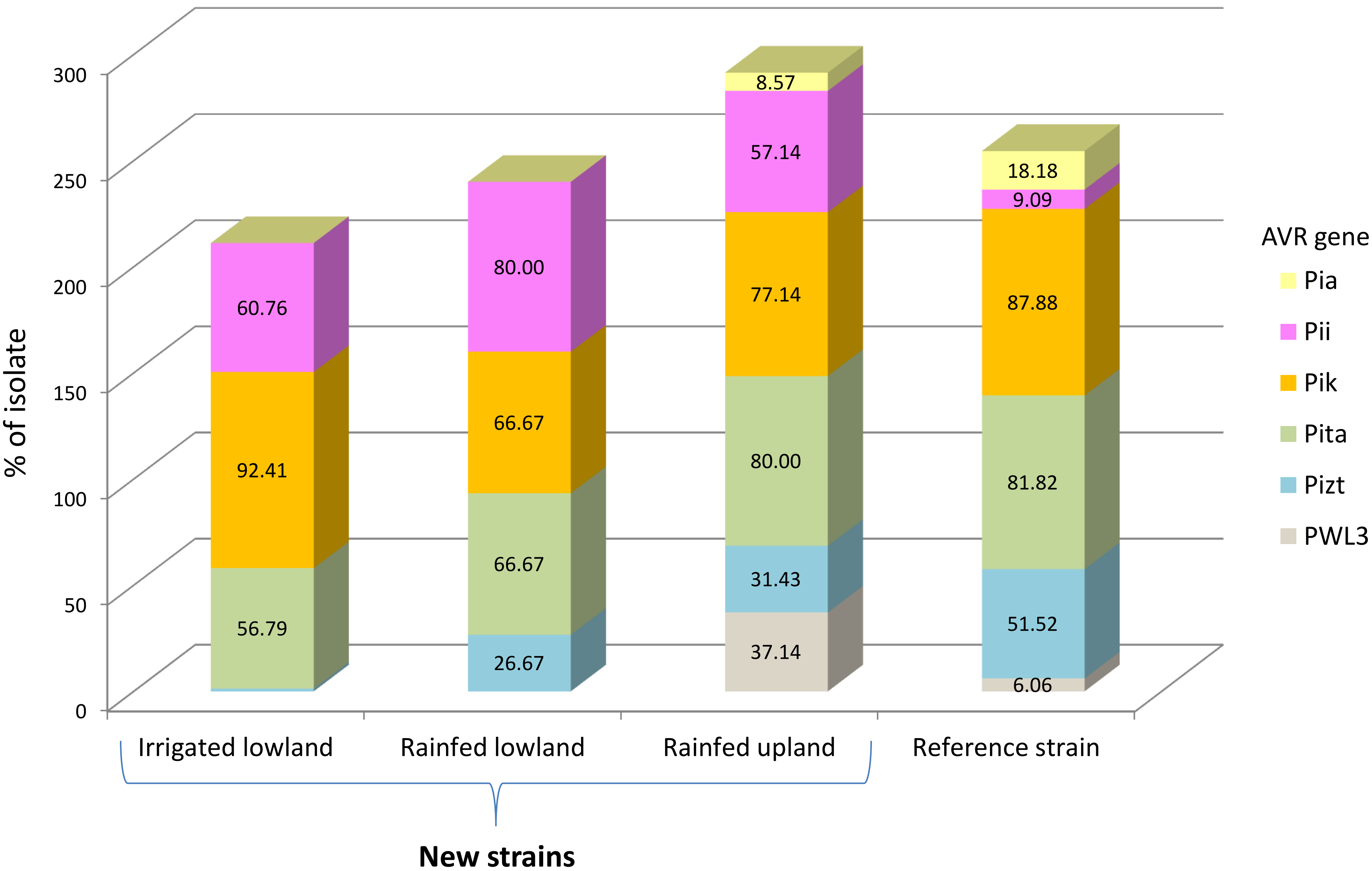
Table 4. Pathogenicity testing of *M. oryzae* isolates against differential rice varieties with their corresponding R genes.

ISOLATE	RICE VARIETIES (R gene/s)															
	Azucena (Pi24)	CO39 (PiCO39)	C101Lac (PiCO39, Pi1, Pi33)	Fukunishiki (Piz, Pish)	C101A51 (PiCO39, Pi2)	Tsuyuake (Pikm)	C101TTP (PiCO39, Pita)	Fujisaka 5 (Pii, Piks)	C104Lac (PiCO39, Pi1)	75-1-127 (Pi9)	C104PKT (PiCO39, Pi3)	Toride 1 (Pizt)	IR1529 (Pi33)	Bala (Pi33)	IR64 (Pi33)	Maratelli
PH0200	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	HS	HR
PH0201	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HR	HS	HR	HS	HR	HS
PH0210	HS	HS	HR	HR	HR	HR	HS	HR	HR	S	HR	S	S	HR	HR	HR
PH0211	?	HR	HR	HR	HR	S	HR	HS	HR	HR	HR	HR	HR	HR	HR	HS
PH0213	HS	HS	HR	HR	HR	HR	HS	HS	HR	HR	HS	?	HR	HR	HR	HS
PH0241	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0242	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	S	HR	HR	HR	HS
PH0248	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0278	HS	HS	HR	HR	HR	HR	S	HS	HR	HR	HS	HR	HR	HR	HR	HS
PH0281	HR	HS	HR	S	HR	HR	S	HS	HR	HR	HS	HR	HR	HR	HR	HS
PH0304	HR	HS	HR	HR	HR	HR	S	HS	HR	HR	HS	HR	HR	HR	HR	HS
PH0318	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0324	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0326	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0328	?	HS	HR	HR	HR	HR	HS	HS	HR	HR	HS	HS	HR	HR	HR	HS
PH0329	S	HS	HR	HR	S	HR	HS	HS	HR	HR	HS	HS	HR	HS	HR	HS
PH0349	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0351	S	HS	HR	HR	HR	HR	HS	HR	HR	HR	HR	HS	HR	HS	HR	HS
PH0358	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0361	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HR	S	HR	HR	HR	HS
PH0383	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0384	HR	HS	HR	HR	S	HR	HS	HR	HR	HR	HR	HS	HR	HR	HR	HS
PH0427	HR	HS	HR	S	HR	HR	HS	HS	HR	HR	HS	HS	HR	HR	HR	HS
PH0432	HR	HS	HR	HR	?	HR	HS	HS	HR	HR	HS	HS	HR	HR	HR	HS

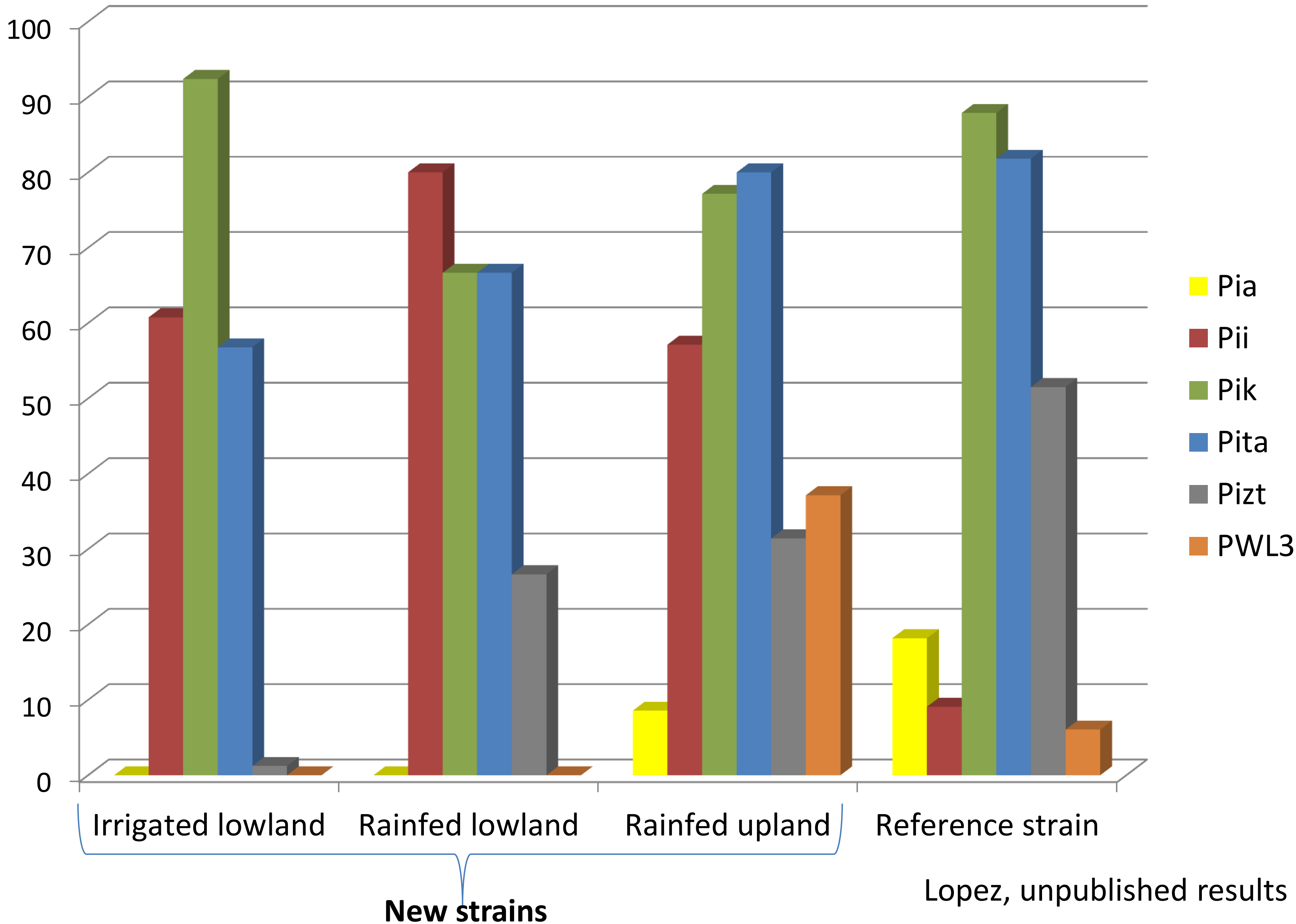
Lopez, unpublished results



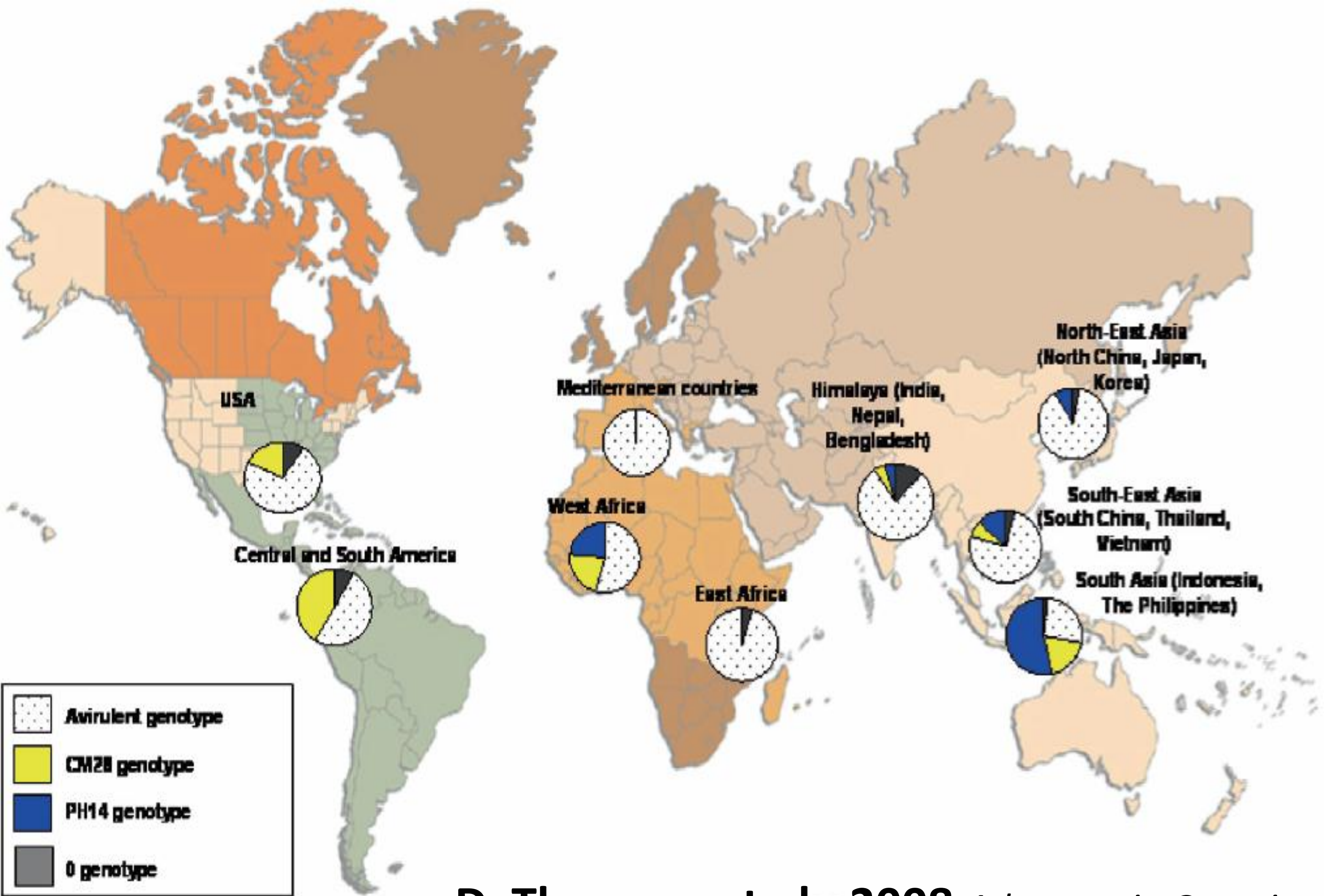
Lopez, unpublished results



Lopez, unpublished results



Lopez, unpublished results



D. Tharreau et al., 2008 *Advances in Genetics, Genomics and Control of Rice Blast Disease*

53 isolates tested for *ACE1* genotype

= 7 (avirulent)

= 2 (undetermined)

= 34 (virulent)

= 10 (virulent)

Lopez, unpublished results

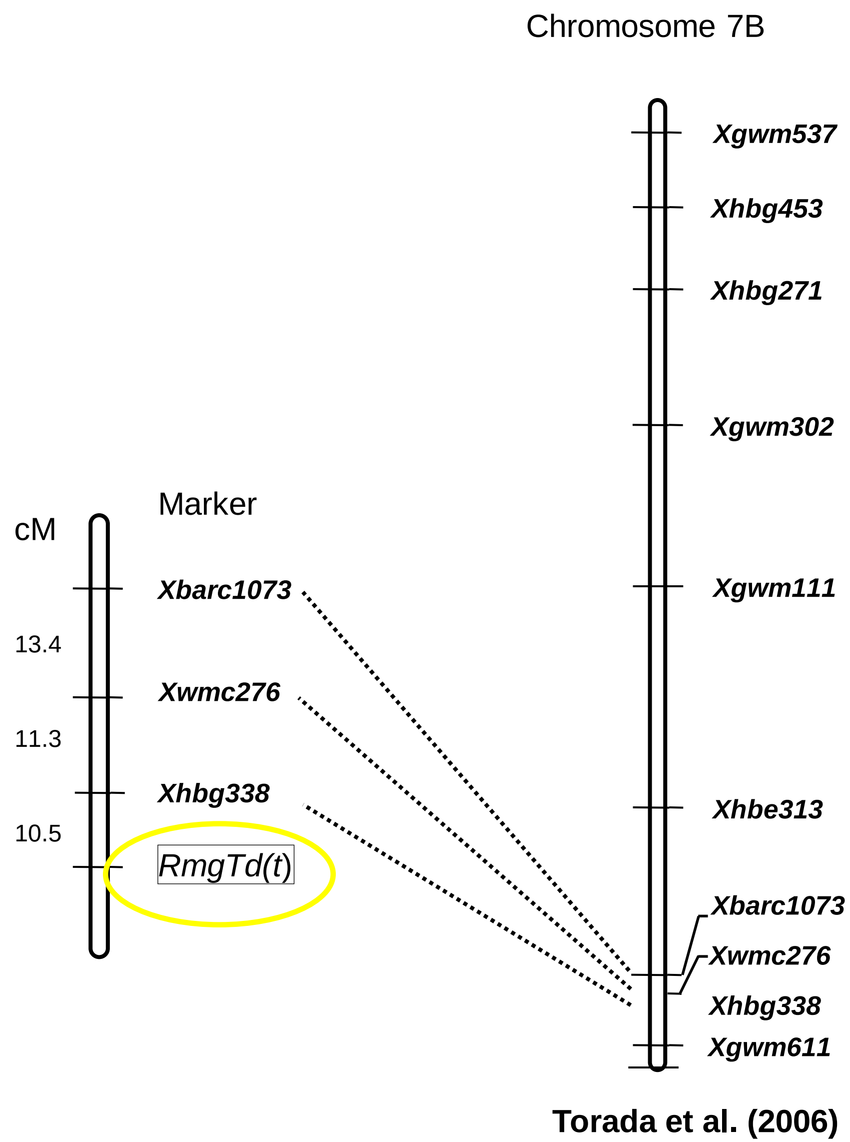
Triticum isolates

which first appeared in 1980’s and caused an outbreak of wheat blast in Brazil

- Highly fertile with any other pathotypes of *M. oryzae*
- Their host – wheat – is easy to handle in the laboratory.

Identification of a hidden resistance gene in tetraploid wheat using laboratory strains of *Pyricularia oryzae* produced by backcrossing

Christian Joseph R. Cumagun, Vu Lan Anh, Trinh Thi Phuong Vy, Yoshihiro Inoue, Hokuto Asano, Gang-Su Hyon, Izumi Chuma, and Yukio Tosa



Linkage map around *RmgTd(t)* constructed using F_3 lines derived from Tat4 x Tat14

Cumagun et al, 2014

Genetic structure of populations of *Rhizoctonia solani* AG-1 IA from rice in China, Japan and the Philippines

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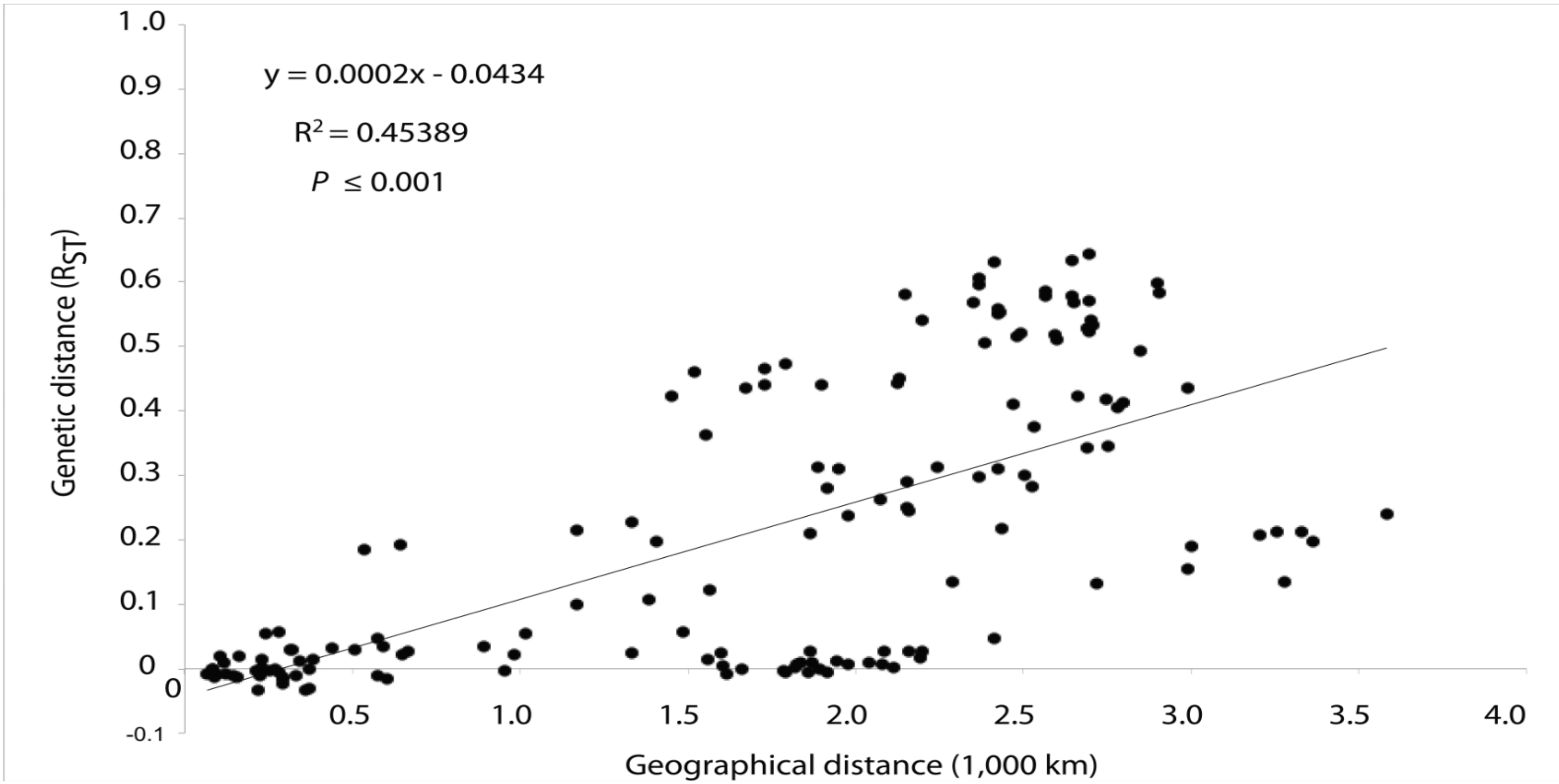
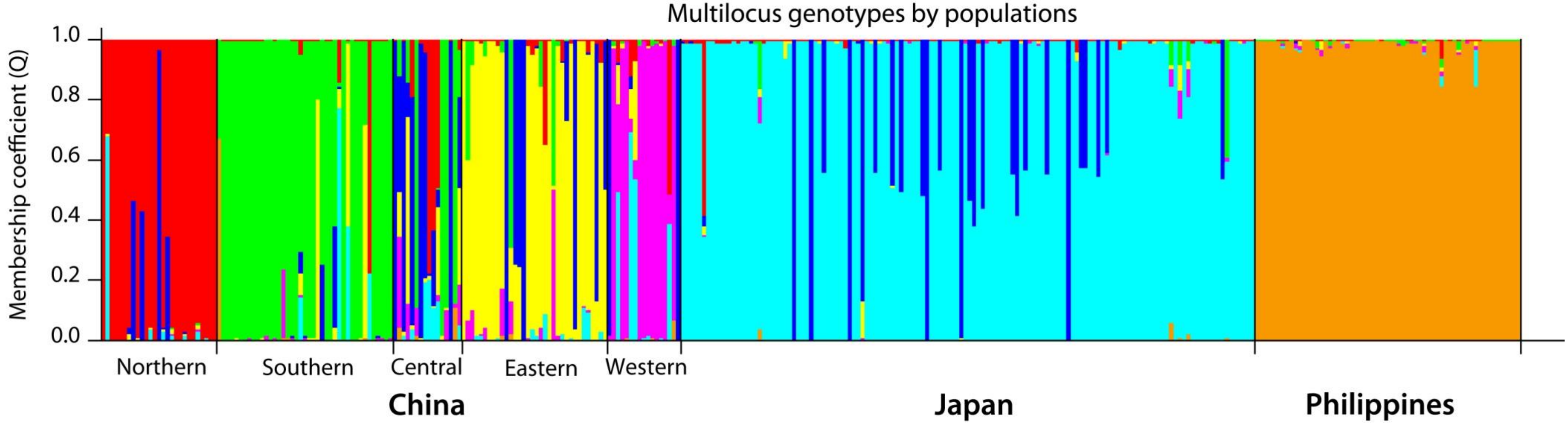
Regression between genetic and geographical distance among pairs of 18 rice-infecting populations of *Rhizoctonia solani* AG-1 IA from China, Japan and the Philippines.



Cumagun et al, unpublished results

Structure inferred membership coefficient for multilocus microsatellite genotypes of *Rhizoctonia solani* AG- 1 IA from rice-infecting population samples from China, Japan and the Philippines.



Given population	Number of genotypes with membership in their given population or in one of the others							Total number of genotypes	Number of admixed genotypes	Admixed proportion
	China					Japan	Philippines			
	Northern	Southern	Central	Eastern	Western					
China										
Northern	23.7	0.0	2.2	0.1	0.0	0.9	0	27	3.3	0.12
Southern	1.0	34.3	0.7	2.4	0.3	1.6	0.7	41	6.7	0.16
Central	2.2	4.1	6.6	1.5	0.8	0.8	0.2	16	9.5	0.59
Eastern	0.7	1.9	6.1	23.7	1.1	0.5	0.1	34	10.3	0.30
Western	0.8	0.1	2.0	0.6	11.2	2.2	0.1	17	5.8	0.34
Japan	1.1	0.8	15.5	0.5	0.4	115.5	0.1	134	18.5	0.14
Philippines	0.1	0.2	0.0	0.1	0.2	0.2	61.2	62	0.9	0.01
							Total	**331**	**54,9**	**0,17**

Cumagun et al, unpublished results

Fumonisin production of *F. verticillioides* and *F. fujikuroi* isolates in the Philippines

Source	Host	No of isolates	Mean fumonisin production (µg/g)		
			FB1	FB2	FB3
Isabela	maize	20	146.75	45.54	9.70
Laguna	maize	16	30.05	10.22	2.12
N. Ecija	rice	7	31.47	5.36	0.52

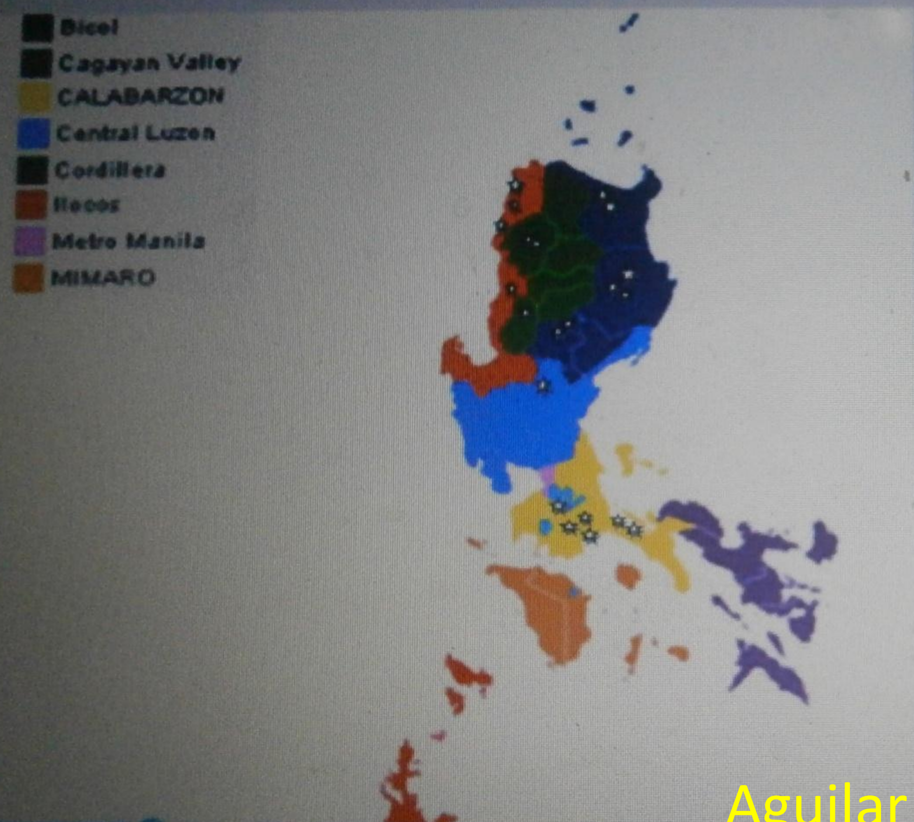
Cumagun et al., 2009

Table 2. Collection sites, morphological identification and aflatoxin production by *Asperigillus* isolates on CAM and HPLC analysis

Yli Matilla, 2015, unpublished results

Isolate code	Collection site	Morphological identification	AFs production on CAM	HPLC analysis of aflatoxins from YES broth				
				G1 ng ml -1 media	B1 ng ml -1 media	G2 ng ml-1 media	B2 ng ml -1 media	Total AFs ng ml -1 media
8P	Soil sample from a field of coconut in Situbo, Tampilisan, Mindanao	*A. parasiticus*	+++	2198.5	1235.6	41.5	30.4	3506
9P	Soil sample from a field of coconut in Situbo, Tampilisan, Mindanao	*A. parasiticus*	+++	1526.6	825.2	26.9	23	2401.7
10P	Soil sample from a field of coconut in Situbo, Tampilisan, Mindanao	*A. parasiticus*	+++	12950.3	5001.3	224.6	146.7	18322.9
18P	Soil sample from a field of maize in New Barili, Tampilisan, Mindanao	*A. flavus*	+	4	3.6	ND	ND	7.6
32P	Soil sample from a field of maize in Garimbara, Visayas	*A. flavus*	+	0.42	1.6	ND	ND	2.02
33P	Soil sample from a field of maize in Garimbara, Visayas	*A. flavus*	+	0.6	1.6	ND	ND	2.2
34P	Soil sample from a field of maize in Garimbara, Visayas	*A. flavus*	+	0.3	1.2	ND	ND	1.5

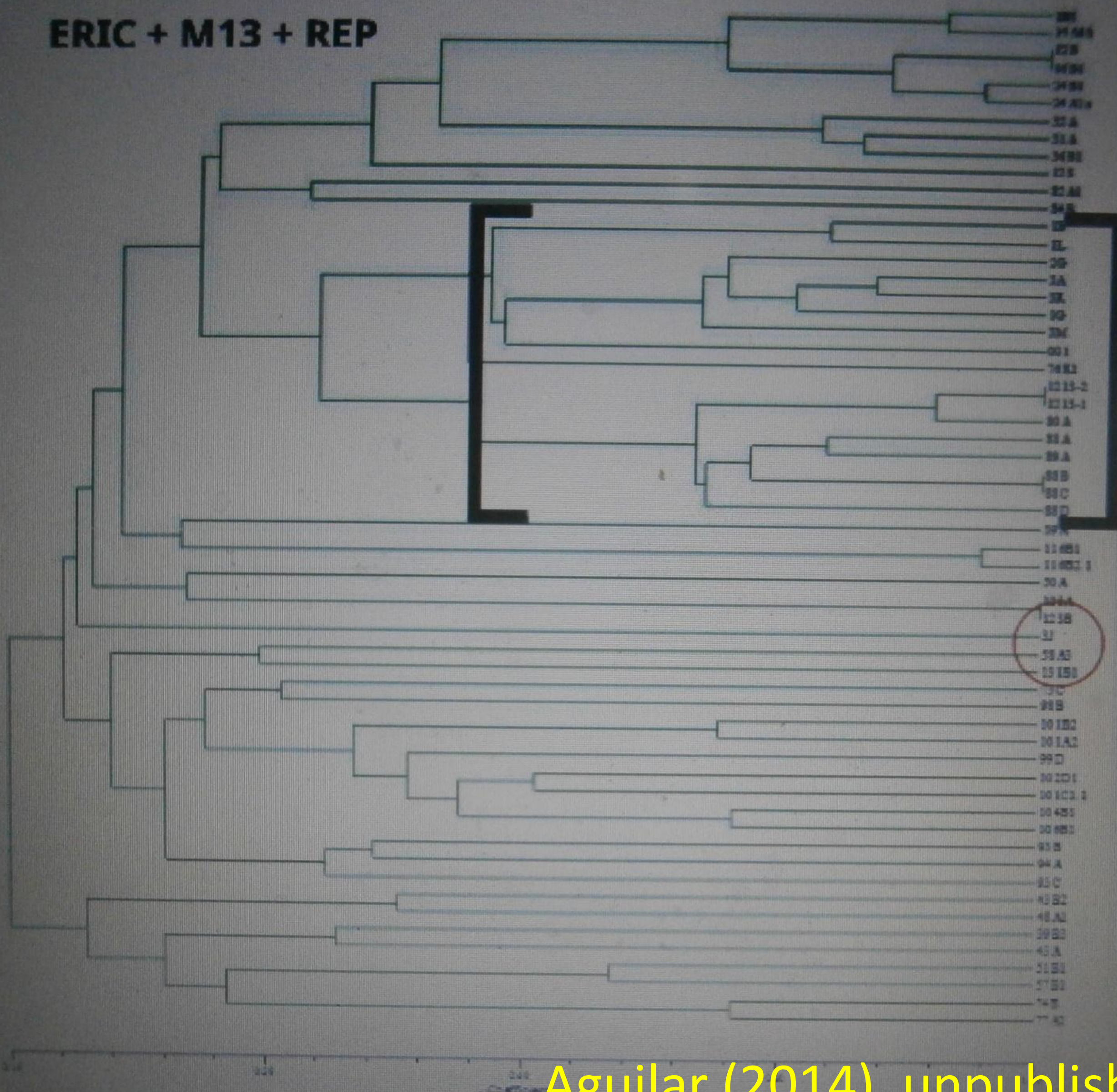
Race 4 in Luzon?



164 isolates were collected from 26 areas covering 12 provinces in 5 regions of Luzon, Philippines

Aguilar (2014). unpublished results

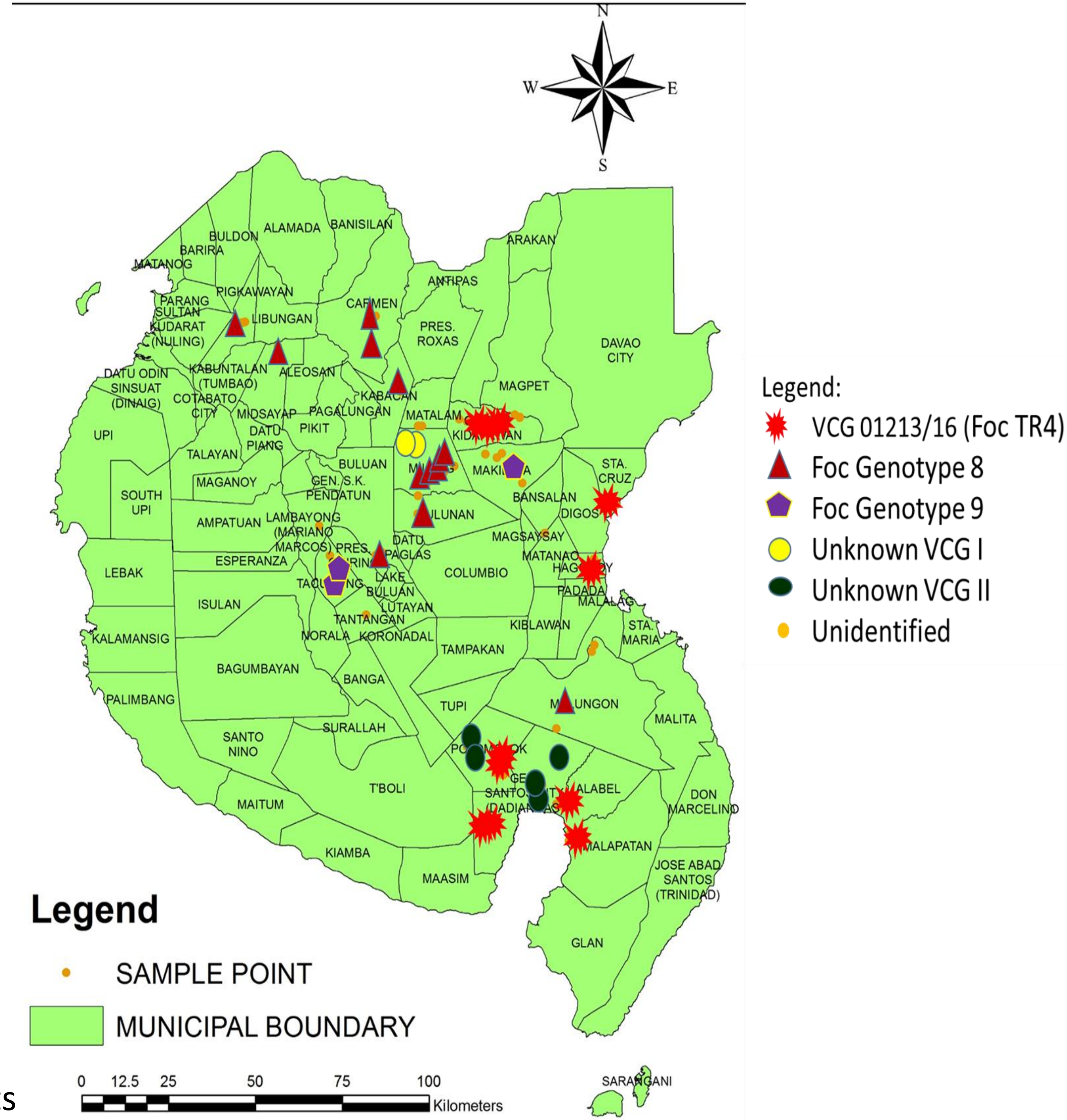
ERIC + M13 + REP



Aguilar (2014). unpublished results

Dendrogram generated from UPGMA cluster analysis using Jaccard Similarity Coefficient based on three primer combinati…

The map of South-Central Mindanao as study area showing the distribution of Foc isolates identified as VCG 01213/16 (Foc TR4), genotype 8 and 9 and 2 unknown VCGs.



Solpot, unpublished results

THE POWER OF THE MEDIA IN BRINGING SCIENCE TO THE PUBLIC

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Conclusions and Future Outlook

- Promoting biodiversity enhances biocontrol research in agriculture. Biodiversity of plant pathogens not only of beneficial fungi should be conserved.
- Rainforests are rich sources of beneficial microbes. Save them before the microbes that are associated with them become extinct.
- Identification of both resistance genes in the host and avirulence genes in the pathogen are important in order for resistance to be effective. Monitoring gene flow of plant pathogens is essential for effective plant disease management.
- The need to focus on *Fusarium* and mycotoxin research in the Philippines.
- The need to train the next generation of mycologists and plant pathologists to sustain food security in the Philippines.

Thank you for your attention