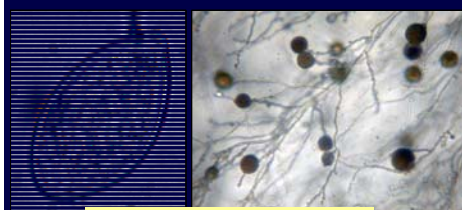
United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine

USDA APHIS

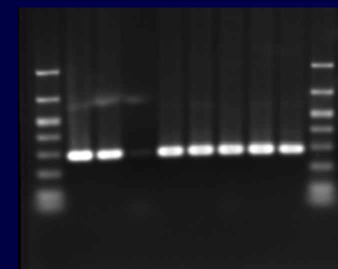
P. capsici

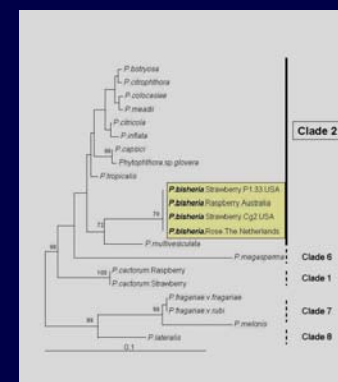


P. ramorum

Development of a Morphological-Phylogenetic Lucid Key for the Identification of Oomycetes: *Phytophthora*

Z. G. Abad, USDA/APHIS/MDL, MD, USA
M. Coffey, World Oomycetes Collection, CA, USA





3rd International *Phytophthora*, *Pythium* and related genera Workshop: Integration of Traditional and Modern Approaches for Investigating the Taxonomy and Evolution of the Oomycetes
Turin – Italy 23 – 24, 2008

MDL

EVOLUTION IN THE TAXONOMY *PHYTOPHTHORA*

THE CLASICAL ERA AND THE MORPHOLOGICAL-SPECIES

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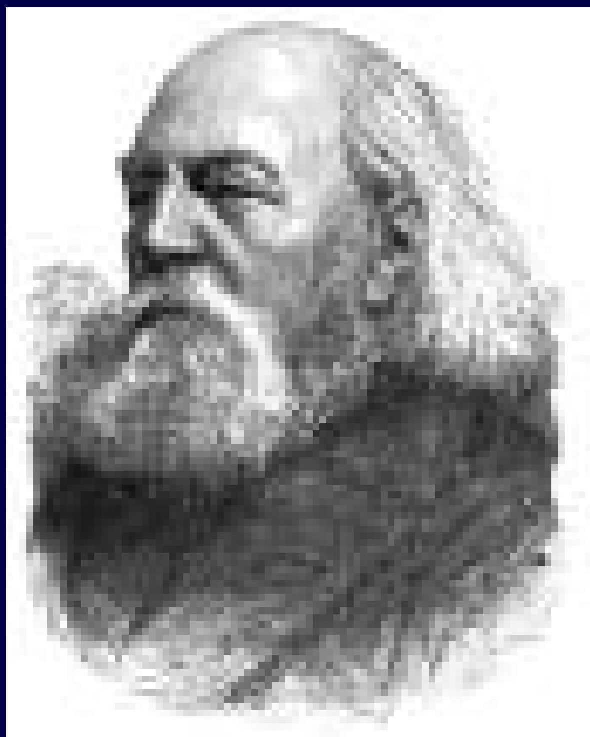
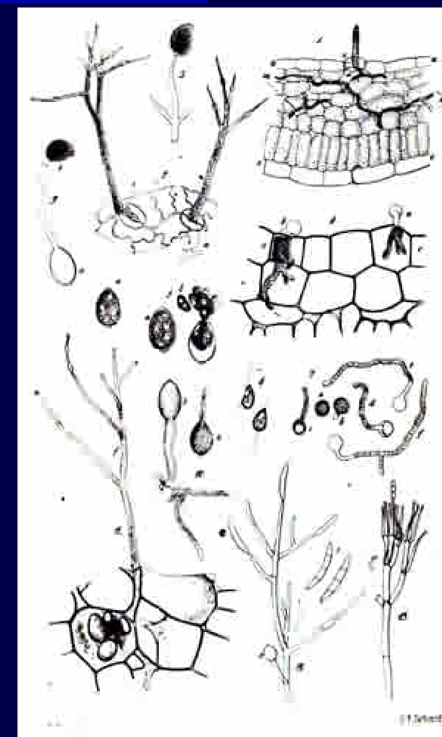
POTATO DISEASE CAUSE 1840´S AND THE PIONEERS OF PLANT PATHOLOGY

1841-1842 Morren,Belgium

1841-1842 Teschemacker, USA





Rev. Berkeley, 1846
The Potato Murrian

Anton de Bary 1861, 1876
Researchers into the nature of the potato fungus *Phytophthora infestans*. J. R. Agric. Soc. England 12:239-269

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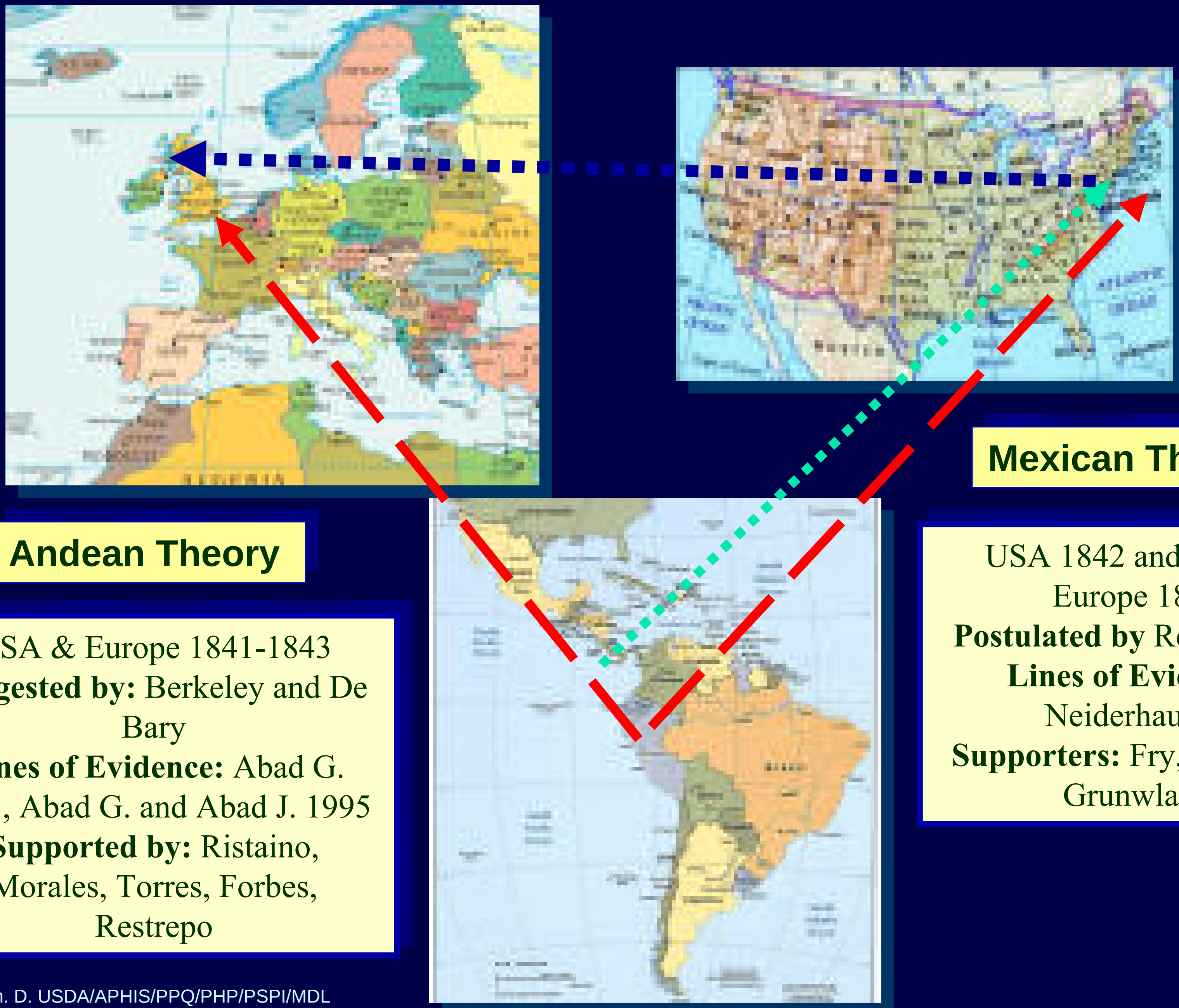
Phytophthora infestans Center of Origen current teories



Andean Theory

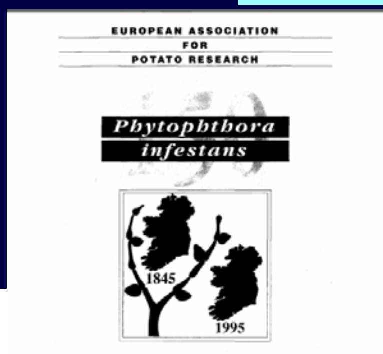
USA & Europe 1841-1843
Suggested by: Berkeley and De Bary
Lines of Evidence: Abad G. 1983, Abad G. and Abad J. 1995
Supported by: Ristaino, Morales, Torres, Forbes, Restrepo

Mexican Theory

USA 1842 and USA to Europe 1845
Postulated by Redick 1928
Lines of Evidence: Neiderhauser.
Supporters: Fry, Goodwin, Grunwland

Jones in 1912, presented the following statements in regard to this topic, **"the details of the introduction of late blight (native upon the wild potato of the Andean regions) in the 1840s from South America into Europe, and subsequent spread in this area, constitute one of the most interesting chapters of the history of plant pathology…**

In 1928, Reddick – Mexican Theory



Historical and scientific evidence that supports the modern theory of the Peruvian Andes as the centre of origin of *Phytophthora infestans*

Z. G. Abad[1], J. A. Abad[1] & C. Ochoa[2]
[1]*Department of Plant Pathology, North Carolina State University, Raleigh, NC 27695-7616, USA.* [2]*International Potato Center (CIP). P. O. Box 1558. Lima-Peru.*

Abstract

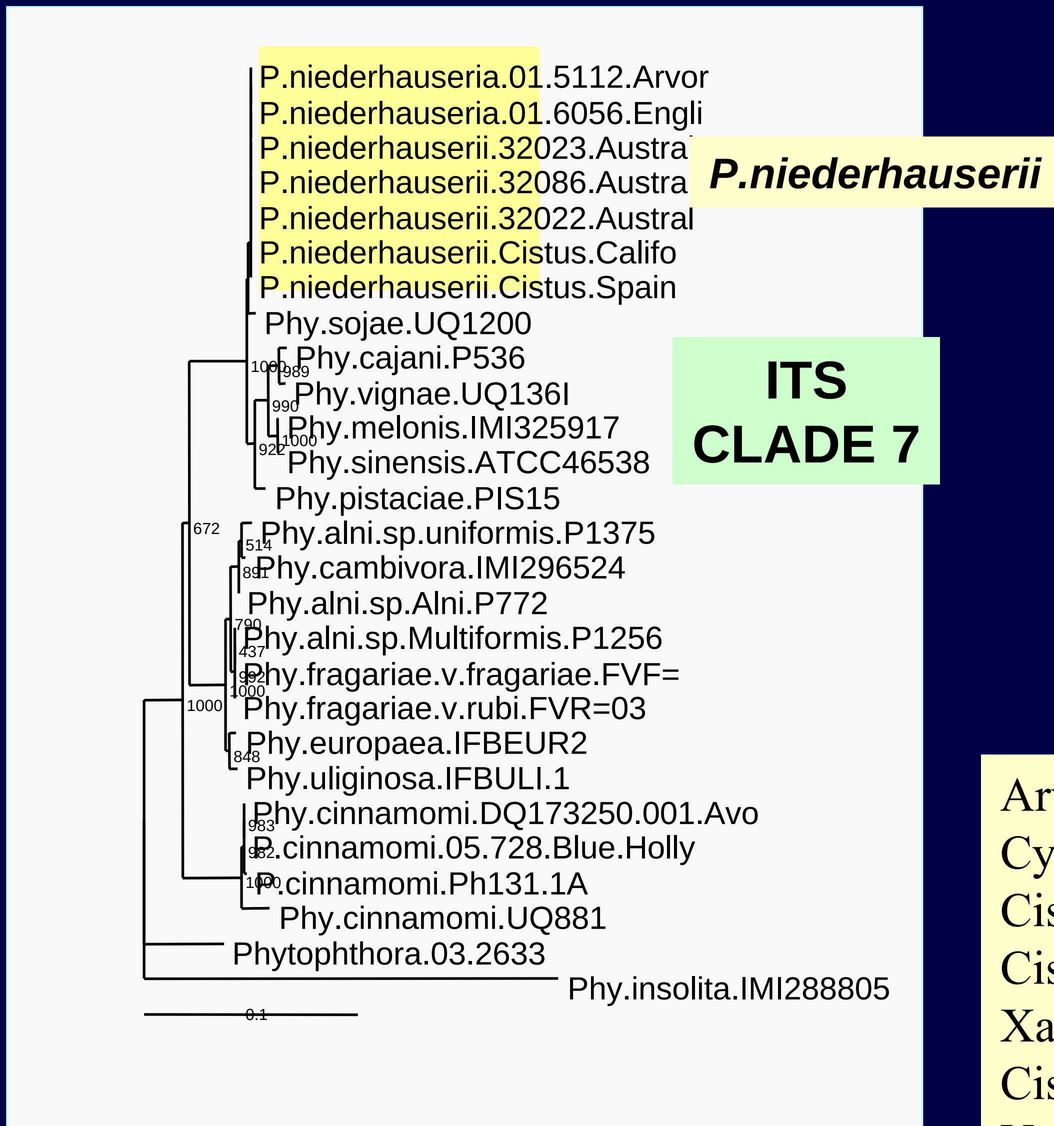
Although present literature suggests that late blight of potatoes is a new disease in Andean countries (first reported in the 1920s), evidence shows that it is much older in that area than it is in Central Mexico. Publications have been found describing the disease in Peru, Bolivia, and Colombia prior to 1845. Our research and that of others in Peru (the centre of origin of potatoes, tomatoes, and pear melon) provides scientific evidence of the Peruvian Andes as the centre of origin of late blight, including: (1) resistance to *Phytophthora infestans* on wild tuber-bearing *Solanum* species, native potatoes and wild tomatoes; (2) the pathogen has a wide host range (members in *Solanaceae* and *Nolanaceae* families), specialized forms e.g., pear melon, race 1,4,10,11; (3) predominance of tomato and pear melon pathotypes in potato isolates from the Andes; (4)

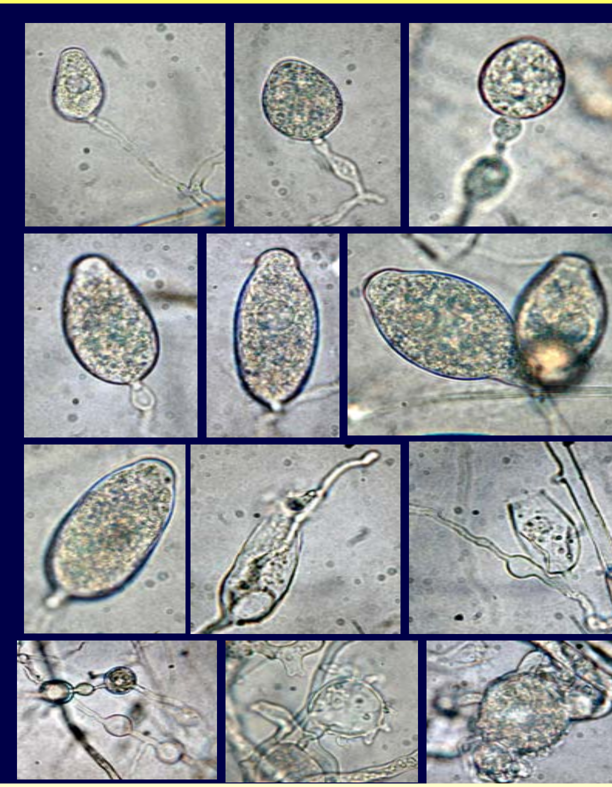
'Lima'
'Péruviennes'
'Cordiliéres'

The importation from
from South America

- Independent South American states [1820 to 1830s]. Peru 1821.
- Introduction of Guano boom
- The advent of the steamships in the late 1830's

Phytophthora niederhauserii Abad ZG & Abad JA to honor John Niederhauser





Arvorbitae, English Yvy, Leyland Cyppress Abad Z.G., Abad J.A., **NC USA**
Cistus , **CA USA** Cheryl Blomquish
Cistus, **Italy** David Cooke
Xanthorrea **Australia**, James Cunnigton
Cistus, **Canary Island** S. Moralejo
Norway M.L. Herrero,

Phytophthora Morphological Taxonomy

- Rosenbaum J. 1917. Studies of the Genus *Phytophthora*. *Proceedings of the National Academy of Sciences of the United States of America* 3: 159-163.
- Tucker, CM 1931. Taxonomy of the genus *Phytophthora* de Bary. Univ. Missouri Agric. Exp. Sta. Bull. 153: 1-208
- Leonian, LH. 1925. Physiological studies on the genus *Phytophthora*. West. Virginia Agric. Expt. Sta. Sci. Paper 11 : 444-498.
- Leonian, LH 1934. Identification of *Phytophthora* species. West Virginia Agriculture Experiment Station Bulletin 262: 2-36
- Frezzi, MJ. 1950. Las especies de *Phytophthora* en la Argentina, Revista de Investigaciones Agrícolas IV: 47–134.
- ❖ Waterhouse GM 1963. Key to the species of *Phytophthora* de Bary. Mycol Pap 92: 22
- ❖ Waterhouse GM 1970. The genus *Phytophthora* de Bary. Mycol Pap 122: 1–59
- Newhook FJ, Waterhouse GM, Stamps DJ. 1978. Tabular key to the species of *Phytophthora* de Bary. Mycol. Pap. 43.
- ❖ Stamps DJ, Waterhouse GM, Newhook FJ, Hall GS. 1990. Revised tabular key to the species of *Phytophthora*. Mycol Pap 162: 28 pp.
- ❖ Erwin O, Ribeiro . 1996. *Phytophthora* Diseases Worldwide. APS. Press. St. Paul, MN.
- Gallegly ME, Hong C. 2008. *Phytophthora*: Identifying Species by Morphology and DNA. APS. Press. St. Paul, MN.

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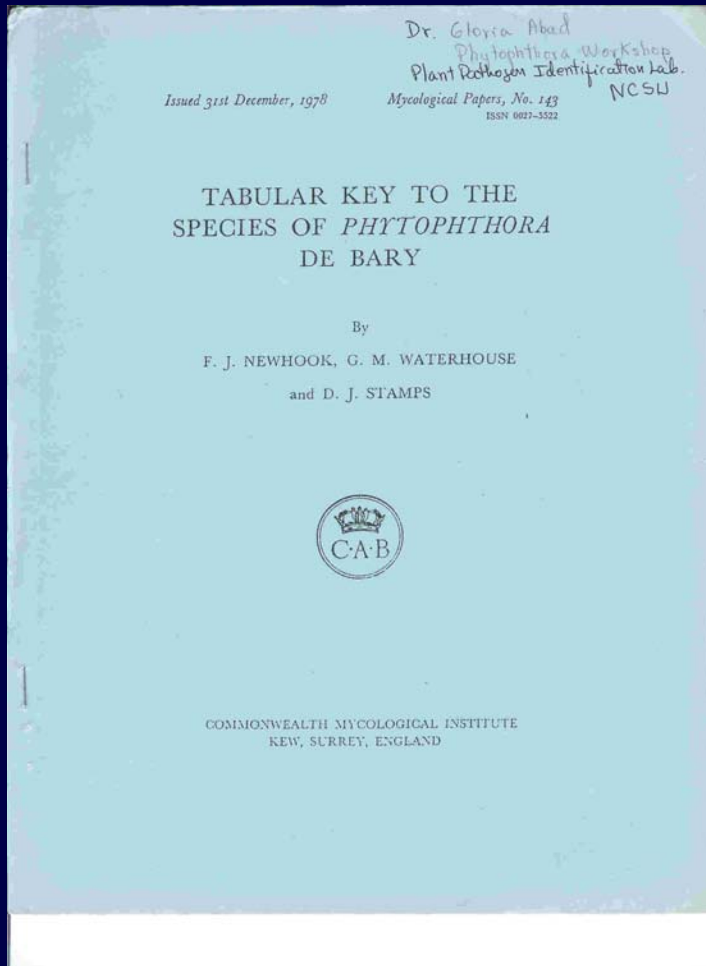
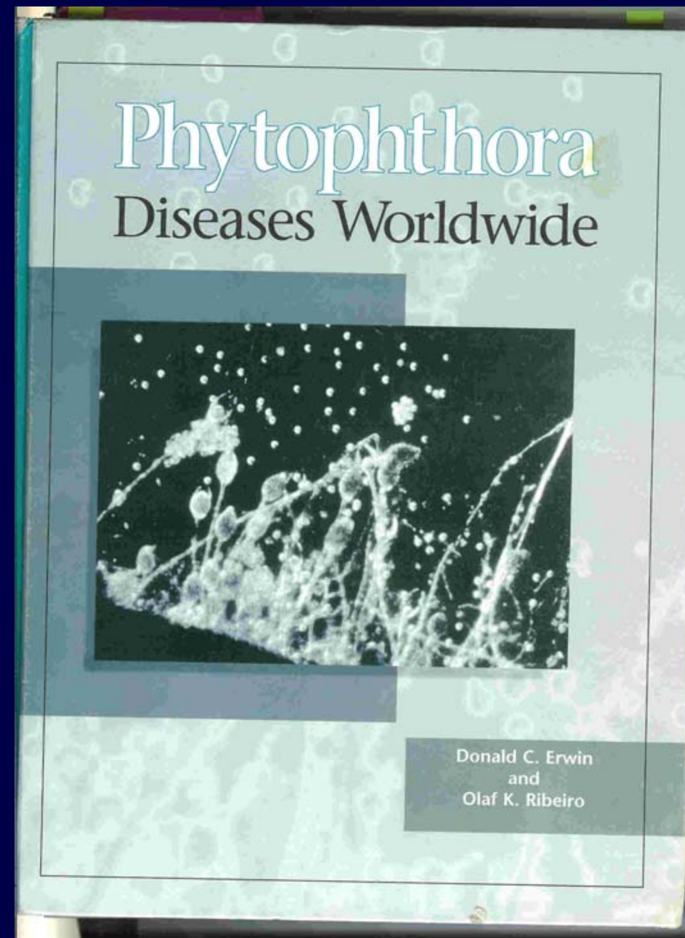


Newhook, Waterhouse, and Stamps. 1978 Tabular Key to the Species of *Phytophthora* De Bary. Commonwealth Mycological Intitute, Kew Surrey, England



Erwin and Ribeiro. 1996. *Phytophthora* Diseases Worldwide. APS. Press.

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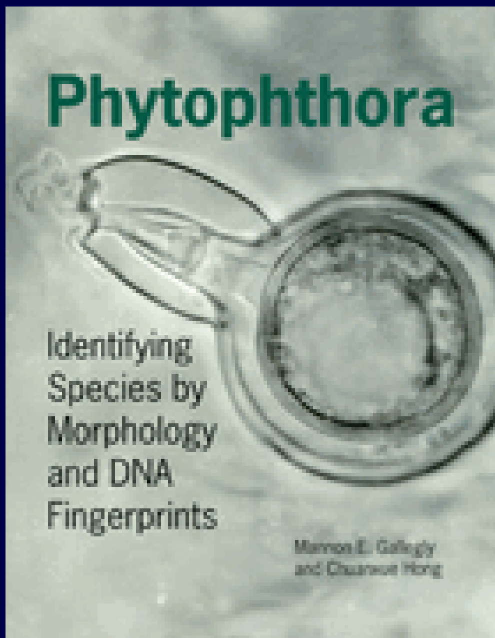
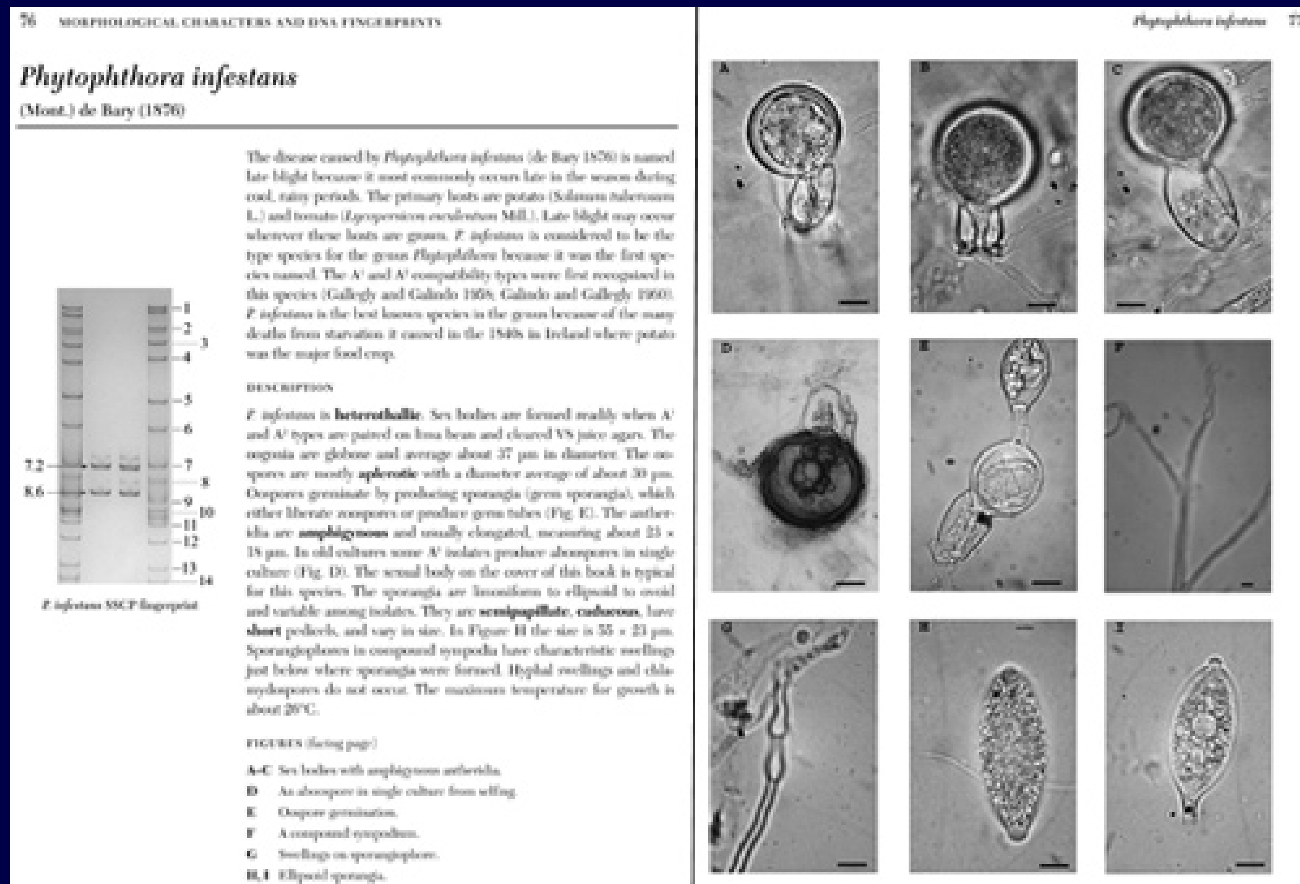


Sixty of the important species and taxons



New dichotomous-like key is presented using minimal morphological characters and the Single Strand Conformational Polymorphism PCR-SSCP DNA fingerprint of the ITS rDNA.

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Morphological features of *Phytophthora*

Asexual phase

sporangiophore

sporangium

chlamydospores

Phytophthora ramorum

P.drechsleri

hyphal swellings

Sexual phase

P.cambivora

oospore

oogonium

antheridium

Colony morphology

P. sp. *morindae*

Temperature growth at 20, 25, 30, 35C

MORPHOLOLGY OF SPORANGIOPHORES

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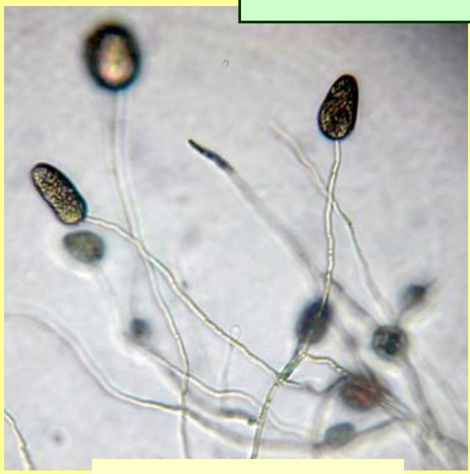
UNBRANCHED



P. erytroseptica

P. sp. kelmania

BRANCHED

P. sp. 3

EXTERNAL PROLIFERATION

P. bisheria

INTERNAL PROLIFERATION

P. lateralis

BOTRYOSE CLUMPS

P.botryosa

UMBELLA TYPE

P.capsici

SYMPLE SYMPODIUM

P.kernoviae

LONG SYMPODIUM

P. ramorum

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Photos by G. Abad

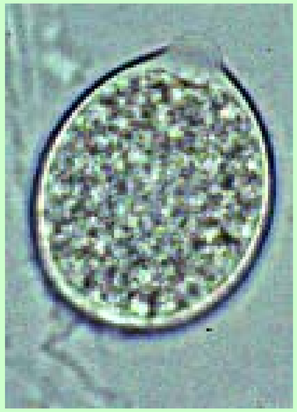
Sporangia shapes

MDL

Globose

P. bohemeria

Globose



P. cactorum

Ovoid

Phytophthora sp. aucubae

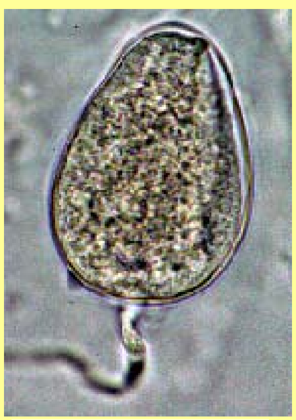
Ellipspoid

P. sp.niederhauserii

Lemoniform

P. capsici

Obpyryform



P. cryptogea

Constricted

P. erytroseptica

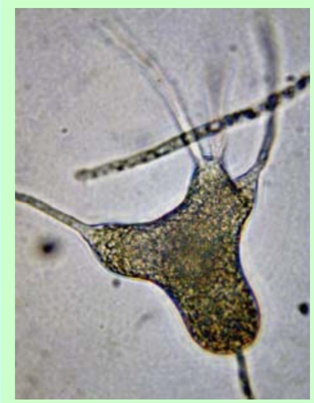
Tapered base

P. tropicalis

Irregular

P. nicotianae

Irregular



P. nicotianae

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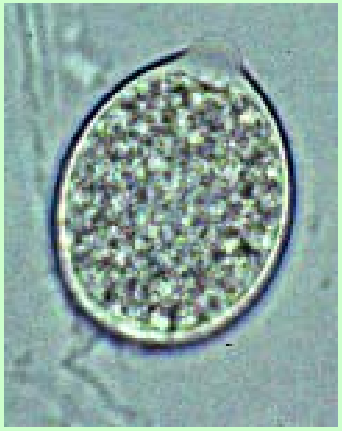
Sporangium, papilla, exit pore and pedicel shapes

Papillate –short pedicell



P. cactorum

P. bohemeria

Semipapillate- Medium pedicel

P. botryosa

Semipapillate- Long pedicel

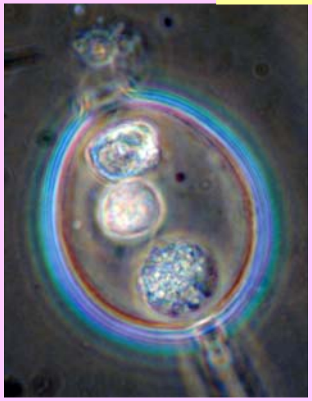
P. capsici

Non-papillate – persistent

P. sp.niederhauserii

Exit pore

Narrow



P. nicotianae

P. bohemeriae

Medium

P. citrophthora

Wide

P. sp. personii

Two papilla

P. capsici

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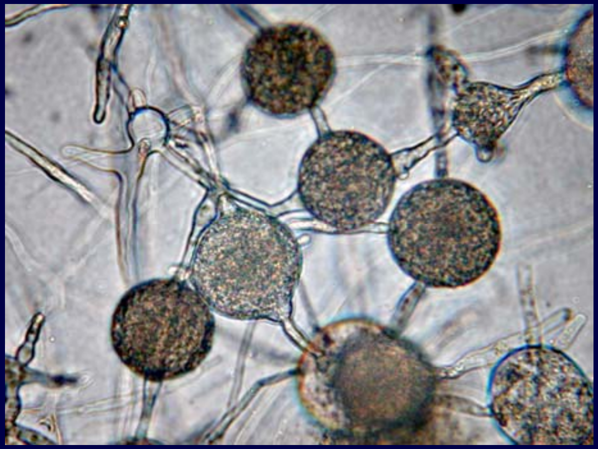
Hyphal swellings

P.drechsleri



P. sp. personii

P. sp. niederhauserii

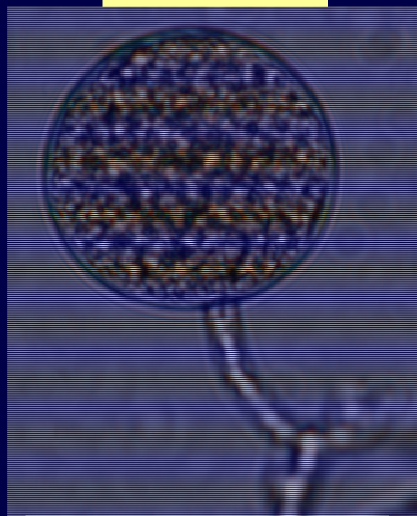
P. sp. kelmania

P. foliorum

Photos by G. Abad

Chlamydosphores

Terminal

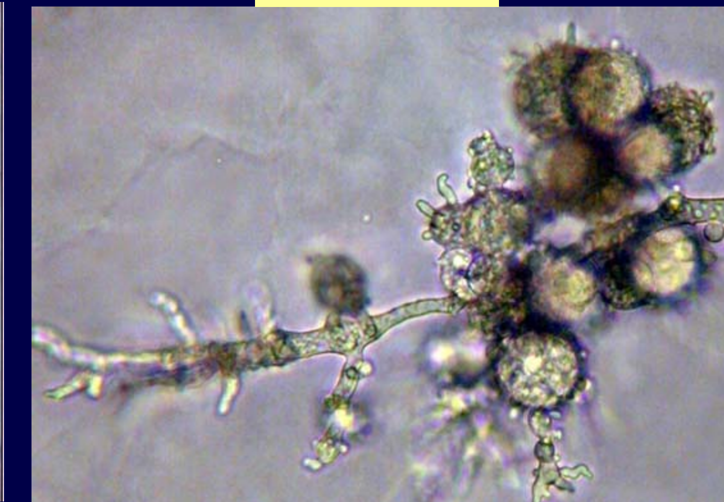


P. tropicalis

Intercalary

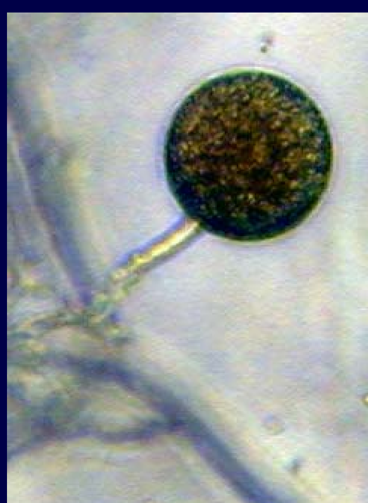
Phytophthora sp. Juniper

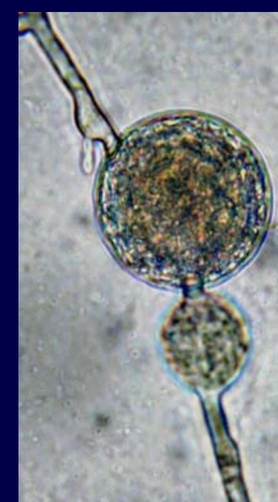
Clustered



P.cinnamomi.

Terminal, lateral, intercalary





P. ramorum

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Photos by G. Abad

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Phytophthora sexual phase

Antheridia

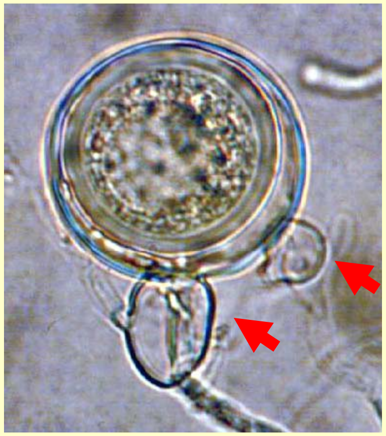
Paragynous

P. cactorum

amphigynous

P. capsici

Paragynous/ amphigynous



P. glovera

Paragynous

P. bisheria

Unusual shapes

P.sp. aucubae

oospores

Plerotic

P. cactorum

Aplerotic

P. capsici

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Morphospecies Groups [Waterhouse (1963), Newhook et al. (1978), Stamps et al. 1990]

GROUP I

Mostly HO

P. cactorum

i.e P. clandestina, P. idaei, P.iranica, P.italica, P.pseudotsugae, P.tentaculata

GROUP II

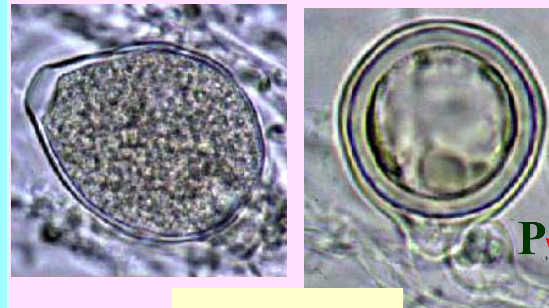
Mostly HT

P. heveae HO

i.e P.boehmeriae, P.botryosa, P.capsici, P.pseudotsugae, P.tentaculata, P. meadii, 6

GROUP III

Mostly HO



P. citricola

i.e P.cyperi, P.cyperi bulbosi, P. inflata, P. lepironiae, P. porri, P. primulae, 2

GROUP IV

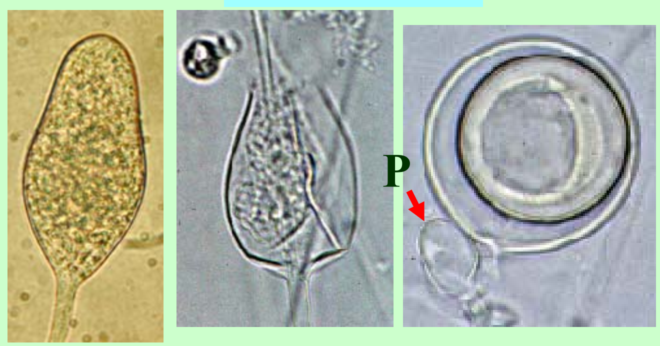
Mostly HT

P. infestans

i.e P. hibernalis HO, *P.ilicis* HO, *P. mirabilis, P. phaseoli* HO, *P. colocasiae, P. eriugena*, HO

GROUP V

Mostly HO



P. megasperma

i.e. P.fragariae v. fragariae, v. rubi P. humicola P.insolita, P. lateralis, P. medicaginis, P. sojae, 3

GROUP VI

Mostly HT

P. cryptogea

i.e P.cambivora, P. cinnamomi, P. drechsleri, P.erythroseptica HO, *P. gonapodyides*

Photos by G. Abad

Problems in morphological ID *of Phytophthora* Species

64 species described to 1994

- variability in morphological characters
- limited no. of morphological characters
- overlapping in morphological characters
- some atypical isolates
- difficulties in esporulation
- lack of expertise for identification

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EVOLUTION IN THE TAXONOMY *PHYTOPHTHORA*

THE MODERN ERA AND THE PHYLOGENETIC - SPECIES

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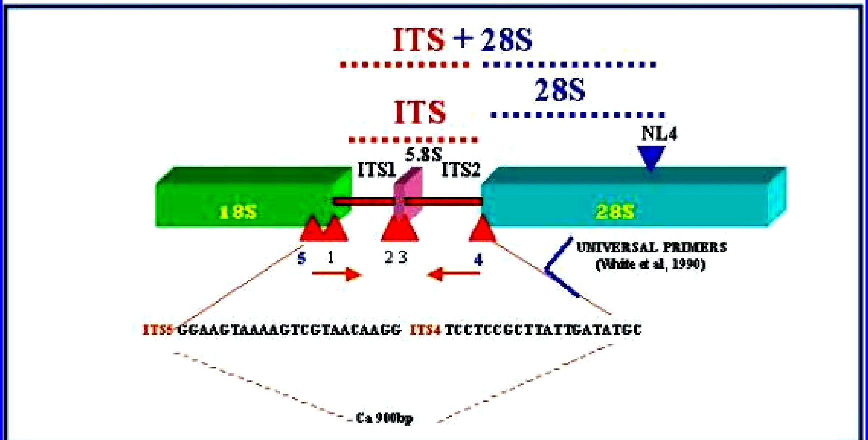
Phytophthora molecular markers

White et al. 1990, Primers– ITS 1,2,3,4,5

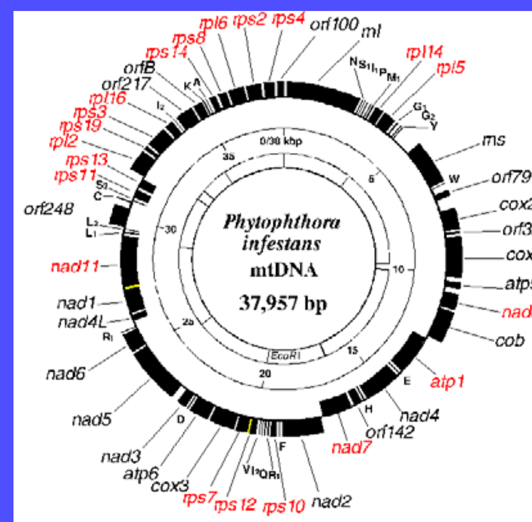


Lee and Taylor 1992- 1993
First phylogeny

Cooke et al 1996 & 1997
Group I – papillated – HO, RFLP
Cooke- et al 2000. phylogeny

Martin and Tooley 2003
mt Cox I sequencing phylogeny

Kroon et al. 2004
Tef
mt Cox II
mt nad11
β- tubulin



Jaime Blair and Michael Coffey. 2007. Seven Nuclear and Mitochandrial Markers

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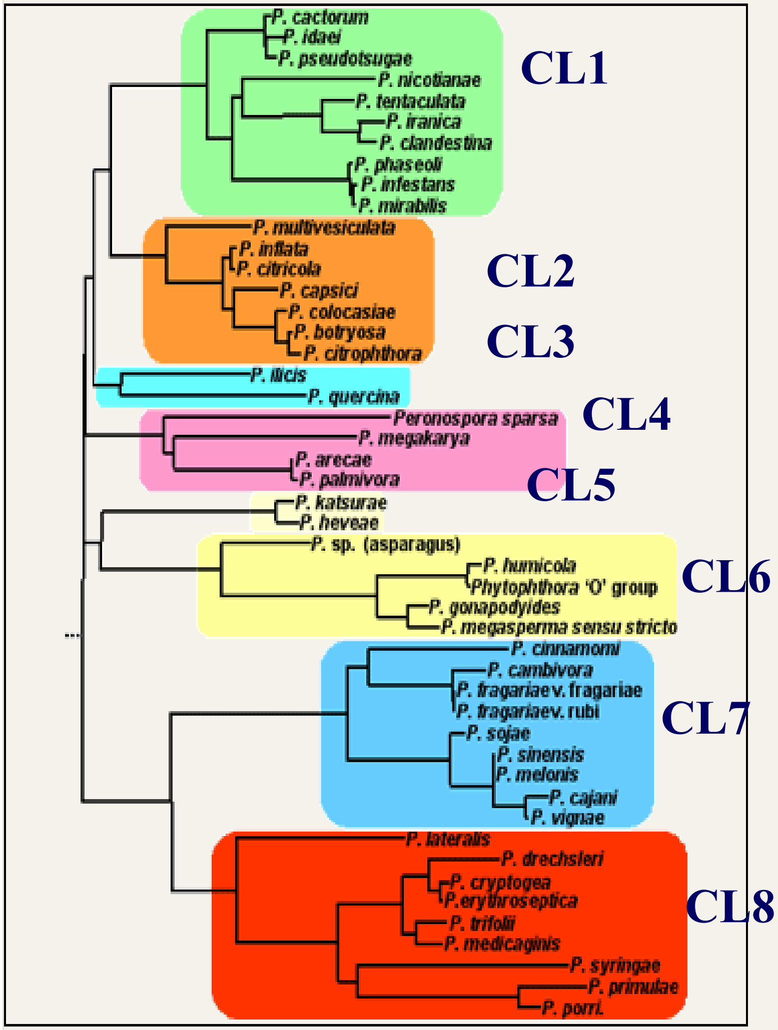
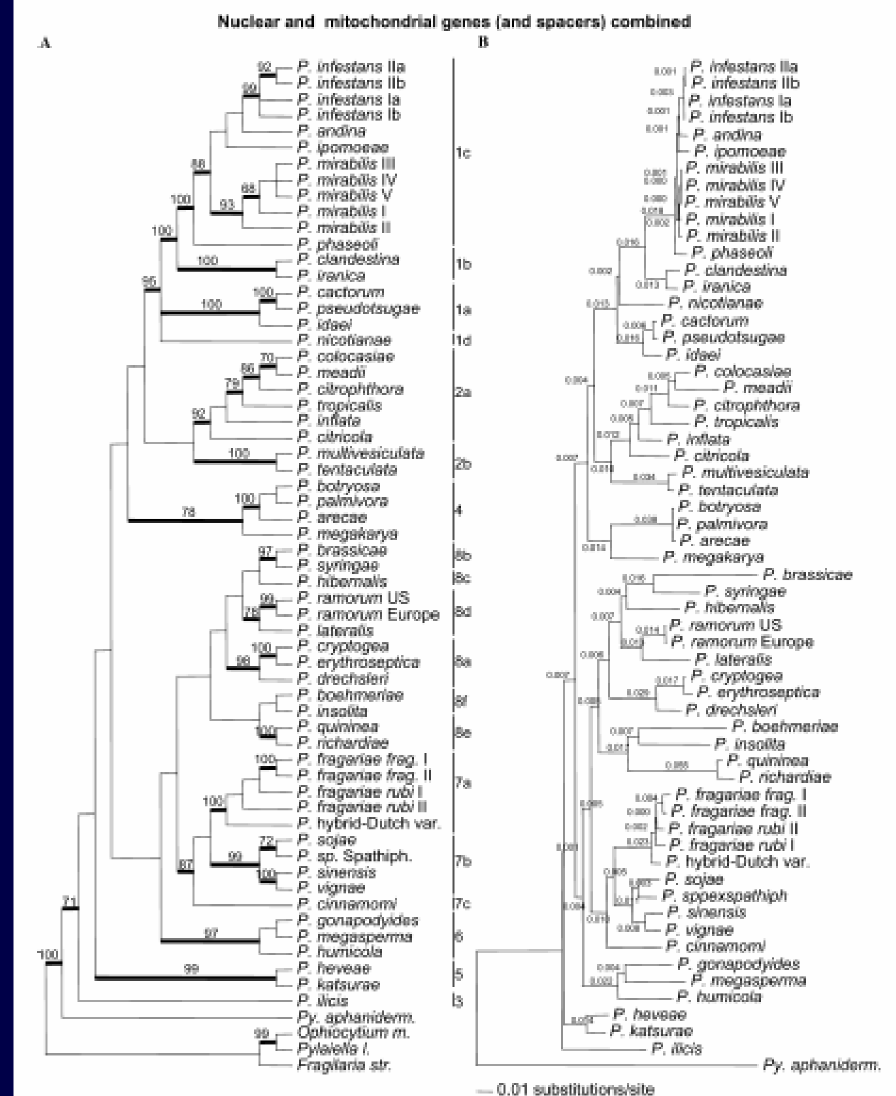
ITS



Cooke et al. 2000. Fungal Genetics And Biology 30, 17-32

TEF α 1 and β- Tubulin



Kroon et al. 2000. Fungal Genetics And Biology 41, 766-782

Photos by G. Abad

A genus-wide phylogeny for *Phytophthora* using seven nuclear loci

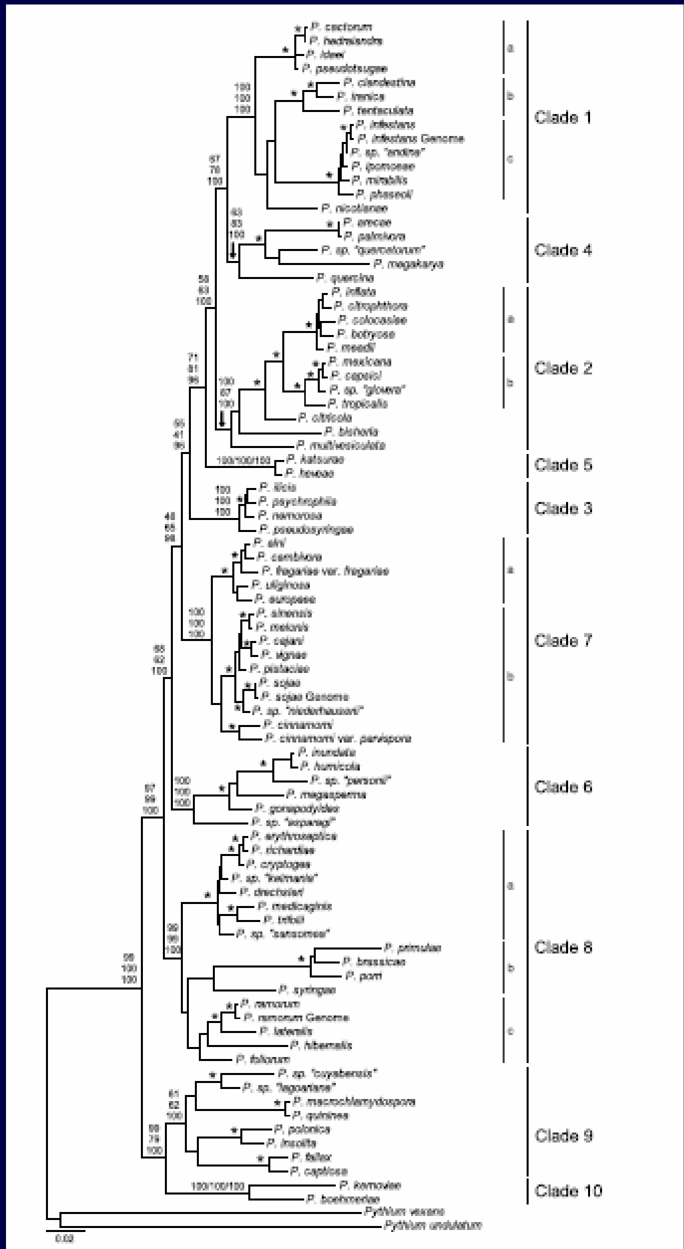


Table 1
Primers used in this study for DNA amplification and sequencing

Locus	Primer name	Primer sequence (5′–3′)	Genomic transcript[a]	Primer coordinates[b]	Ta[c]	Reference
28S Ribosomal DNA	LROR-O	ACCCGCTGAACTYAAGC	X75631[d]	25–41	53	Moncalvo et al. (1995)
	LSUFint[e]	CKTTGACGAAATGGAGCGAT		798–817		This study
	LSURint[e]	TTTCCACACCCTAACACTTGC		880–860		This study
	LR6-O	CGCCAGACGAGCTTACC		1366–1350		Riethmüller et al. (2002)
60S Ribosomal protein L10	60SL10_for	GCTAAGTGTTACCGTTTCCAG	72,378	16–36	53	This study
	60SL10_rev	ACTTCTTGGAGCCCAGCAC		512–493		This study
Beta-tubulin	Btub_F1	GCCAAGTTCTGGGAGGTCATC	72,114	52–72	60	This study
	Btub_F1A	GCCAAGTTCTGGGARGTSAT		52–71		This study
	Btub_F2[e]	CGGTAACAACTGGGCCAAGG		291–310		Kroon et al. (2004)
	Btub_R2[e]	GATCCACTCAACGAAGTACG		1035–1016		This study
	Btub_R1	CCTGGTACTGCTGGTACTCAG		1278–1259		Kroon et al. (2004)
	Btub_R1A	CCTGGTACTGCTGGTAYTCMGA		1278–1258		This study
Elongation factor 1 alpha	EF1A_FL	GGTCACCTGATCTACAAGTGC	71,250	73-93	60	This study
	EF1A_for	TCACGATCGACATTGCCCTG		212–231		Kroon et al. (2004)
	EF1A_R2[e]	TTSACCGACACGTTCTTGAC		917–898		This study
	EF1A_rev	ACGGCTCGAGGATGACCATG		1183–1164		Kroon et al. (2004)
	EF1A_RL	CCTTCTTGTTCACCGACTTG		1297–1278		This study
Enolase	Enl_for	CTTTGACTCGCGTGGCAAC	72,298	36–54	60	This study
	Enl_FY	CAACCCSACCGTYGAGGT		51–68		This study
	Enl_rev	CCTCCTCAATACGMAGAAGC		1288–1269		This study
Heat shock protein 90	HSP90_F1	GCTGGACACGGACAAGAACC	71,510	171–190	62	This study
	HSP90_F1int[e]	CAAGGTGATCCCGGACAAGGC		198–218		This study
	HSP90_F3[e]	ACGCCTCGTTCTACAAGTCG		848–867		This study
	HSP90_F2[e]	ATGGACAACTGCGAGGAGC		1039–1057		This study
	HSP90_R1[e]	ACACCCTTGACRAACGACAG		1091–1072		This study
	HSP90_R2	CGTGTCGTACAGCAGCCAGA		1935–1916		This study
TigA gene fusion protein	Tig_for	TTCGTGGGCGGYAACTGG	71,061	25–42	64[f]	This study
	Tig_FY	TCGTGGGCGGYAAYTGGAA		26-44		This study
	Tig_F2[e]	GCCTACATCACGGAGCARA		424–442		This study
	G3PDH_for[e]	TCGCYATCAACGGMTTCGG		779–797		This study
	Tig_rev[e]	CCGAAKCCGTTGATRGCGA		797–779		This study
	G3PDH_rev	GCCCCACTCRTTGTCRTACCAC		1719–1698		This study

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Fungal Genetics and Biology 45 (2008) 266–277
FUNGAL GENETICS AND BIOLOGY
www.elsevier.com/locate/yfgbi

A multi-locus phylogeny for *Phytophthora* utilizing markers derived from complete genome sequences

Jaime E. Blair [a,*], Michael D. Coffey [b,*], Sook-Young Park [a], David M. Geiser [a], Seogchan Kang [a]

[a] *Department of Plant Pathology, The Pennsylvania State University, University Park, PA 16802, USA*
[b] *Department of Plant Pathology and Microbiology, University of California, Riverside, CA 92521, USA*

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Available online 23 October 2007

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24 Species of *Phytophthora* described after Erwin and Ribeiro (1996)

8/24/08

1998
P. multivesiculata **Ilieva, Man in't Veld, Veenbaas-Rijks & Pieters**
1999
P. quercina Jung

2001
P. tropicalis **Aragaki & Uchida**
P. oryzo-bladis **(Wang and Lu) Ho**
P. pistaceae **Mirabolfathy**
P. polygony **Zheng & Ho**
P. ramorum **Werres, de Cock & Man In't veld**
2002
P. europaea **Hansen & Jung**
P. psichrophila **Jung & Hansen**
P. uliginosa **Jung & Hansen**
P. brassicae **de Cock and Man in't Veld**
P. ipomoeae **Flier & Grünwald**
2003
P. inundata, **Brasier, Sanchez-Hernadez & Kirk**
P. pseudosyringae **Jung & Delatour**
2004
P. alni **Brasier & Kirk**
P. inundata, **Brasier, Sanchez-Hernadez & Kirk**
P. hedraiandra **de Cock & Man in't Veld**
P. polygony **Zheng & Ho**

2005
P. kernoviae **Brasier, Beales & Kirk**
2006
P. captiosa **Dick & Dobbie**
P. fallax **Dick & Dobbie**
P.foliorum **Donahoo & Lamour**
P.polonica **Belbahri, Melgarejo & Leford**
2007
P. alticola **Maseko, Coutinho & MJ Wingf.**
P. austrocedrae **Gresl. & Hansen**
P. frigida **Maseko, Coutinho & MJ Wingf. (2007)**
P. siskiyouensis **Reeser & EM Hansen (2007)**
2008
P. bisheria **Abad ZG, Abad JA & Louws**
P. gallica **T Jung T & J Nechwatal**
P. irrigata **C Hong & M Gallegly (2008)**
P. parsiana Mostowfizadeh, Cooke & Banihashemi
P. pinifolia **AJ. Durán, Gryzenh. & MJ Wingf.**
P. quercetorum **Balci & Balci**

Phytophthora ‘taxons’ in process for official description

Many, many!! species in progress for official descriptions. Some examples….

13 species in progress for official description

- ***P*. sp. *andina* Forbes et al.**
- ***P. sp. asparagi* Cooke *et al***
- ***P.* taxon ‘cranberry’ Oudemans et al.**
- ***P. sp. glovera* Abad & Shew**
- ***P. sp. kelmania* Abad ZG & Abad JA**
- ***P. sp. morindae* Abad ZG & Nelson S**
- ***P.* sp. *niederhauserii* Abad ZG & Abad JA**
- ***P. sp. pelgrandis* Nirenberg & Gerlarch**
- ***P.* sp. *personii* Abad ZG et al.**
- ***P. sp. quercetorum* Balci & Balci**
- **P. sp. fragaefolia Shirai K & Shinmura**
- **P. sp. hungarica Belbahri,L., Lefort,F., Calmin,G. and Oszako,T.**
- **P. sp. sylvatica Belbahri,L., Lefort,F., Calmin,G. and Oszako,T.**

16 putative new species

MIKE COFFEY’S GROUP

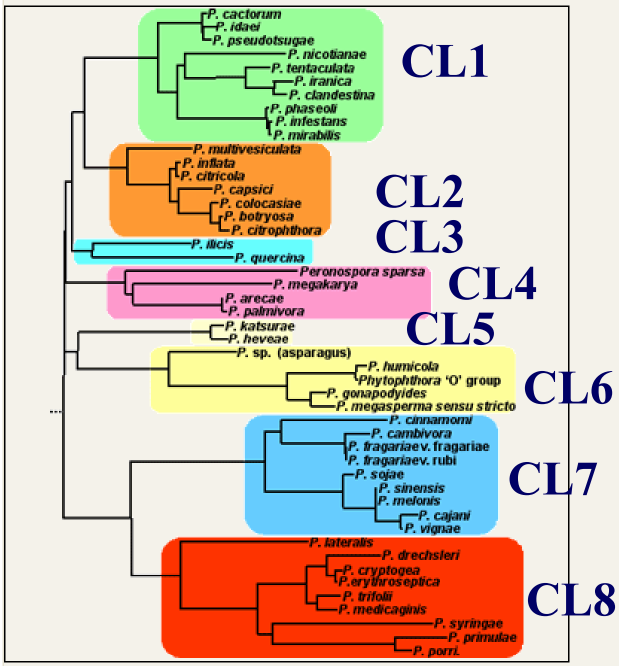
- ***P.* sp. *carica***
- ***P.* sp. *cuyabensis***
- ***P.* sp. *erwinii***
- **P. sp. *lagoariana***
- **Phytophthora sp. *novaeguinee***
- ***P.* sp. oregonsis**
- **P. sp. sansomea**
- ***P.* sp. *sulawesiensis***
- ***P.* sp. *zentmeyerii***

CLIVE BRASIER GROUP

Many putative new species in *P. megasperma* complex

DAVID COOKE (4), GLORIA ABAD (2)

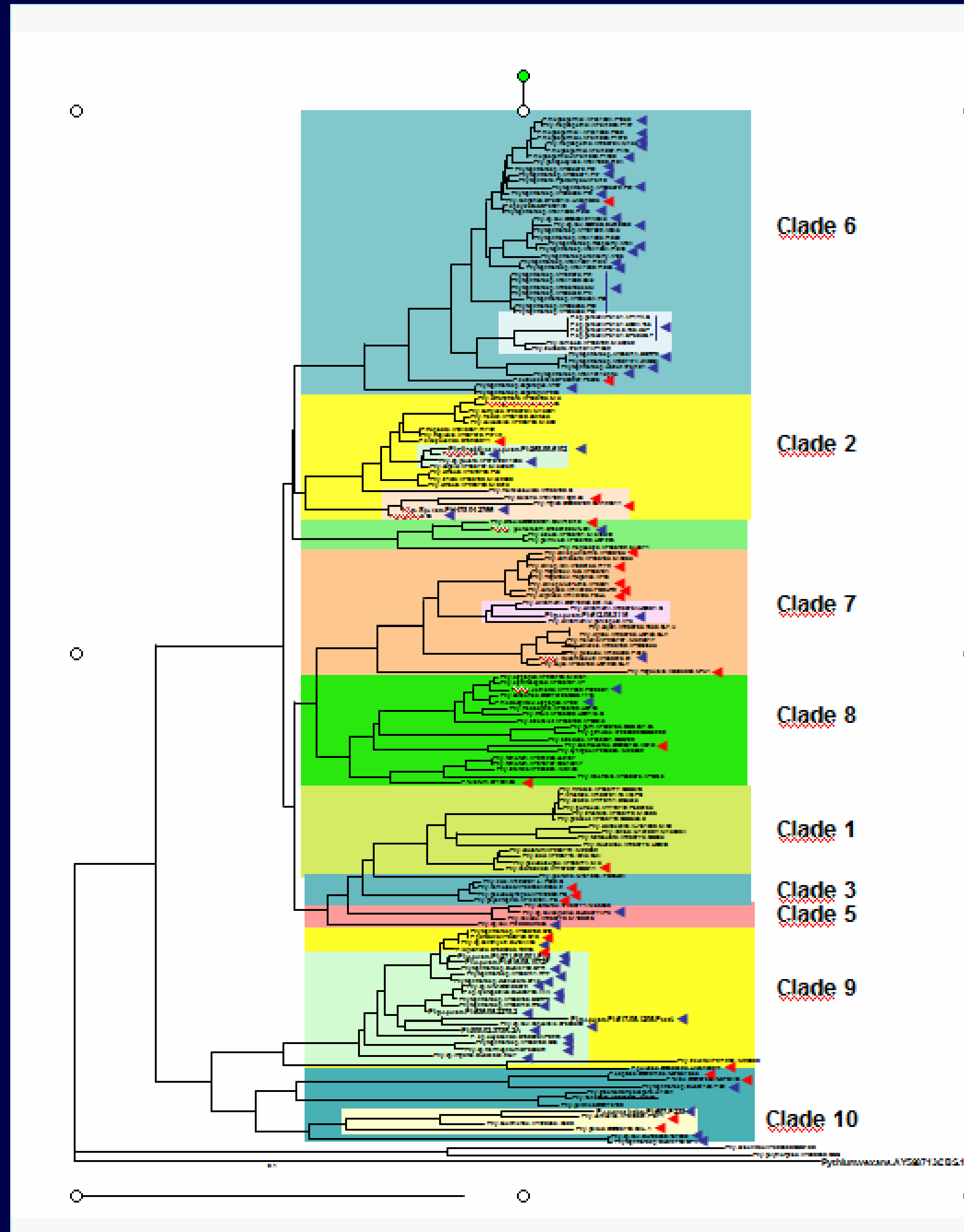
Six putative new species in *P. insolita* complex



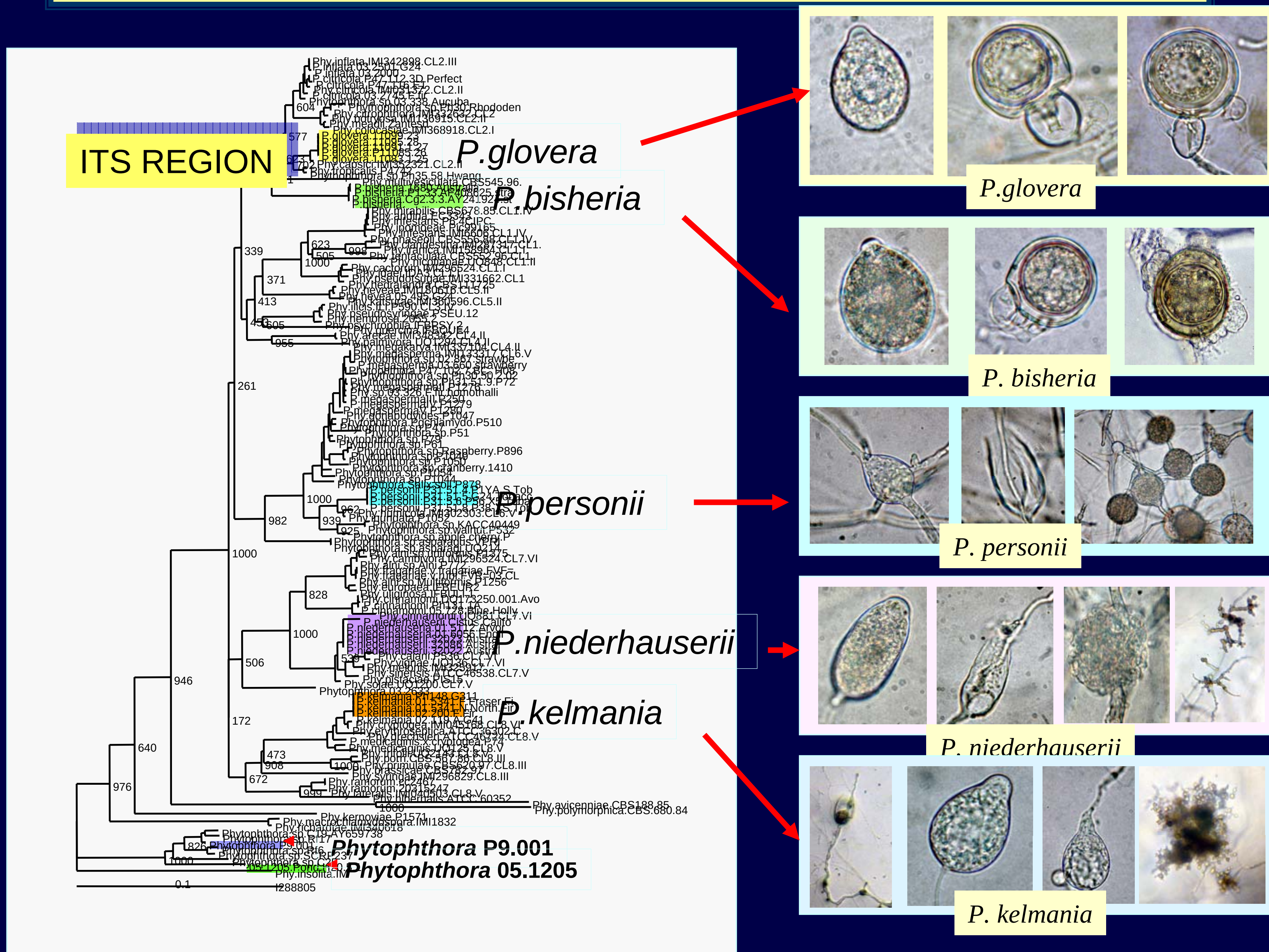
References

Cooke, D. E. L., Drenth, A., Duncan, J. M., Wagels, G. and Brasier, C. M. (2000) A molecular phylogeny of *Phytophthora* and related Oomycetes. *Fungal Genetics and Biology* 30, 17-32

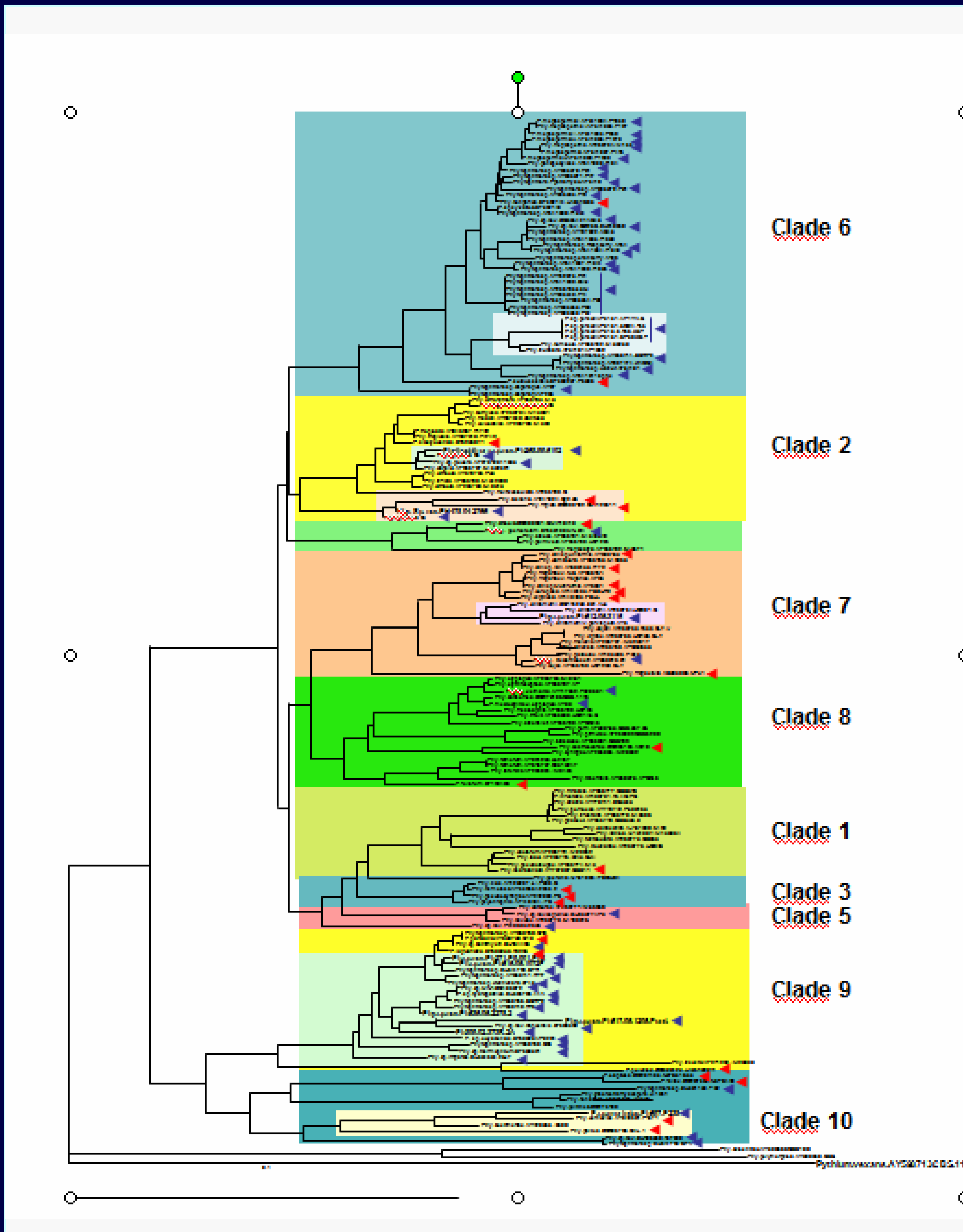
Cooke et al. 2000. Fungal Genetics And Biology 30, 17-32



Phylogram of *Phytopthora* species resulted from Neighborgh-Joining (NJ) analysis (1000bs) of the ITS region.



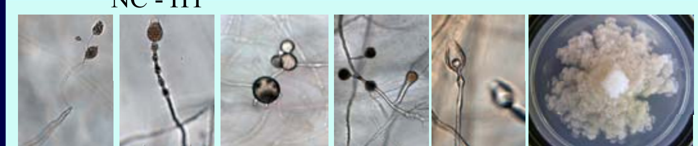
ABAD ET AL OTHER PUTATIVE NEW SPECIES



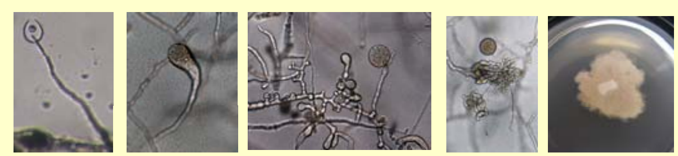
Phy. sp. caroliniana Ph268.99.6102 from strawberry NC- HO

Phy. sp. pseudobisheria Ph478.04.2766 Azalea NC- HO

Phy. sp. proliferanta Ph517 05.1205 Pond H20 NC - HT



Phy. sp. catenulata Ph536 05.2278 Irrigation Pond, NC - HT



***Phytophthora* sp. nov. 2** Ph271.09.001 Soil Ecuador - HT

***Phy.* sp. nov. 1**Ph309 02.373.B.2A Irrigation Pond, NC - HT

Phytophthora sp. *morindae* Abad ZG & Nelson S

Fig. 1) Fruit symptoms in an early stage (demonstrates that green fruits are attacked before they are ripe).
Fig. 2) All symptoms types: black flags, veinal necrosis. fruit rot, fruit mummification, leaf spot, leaf blight, stem blight.
Fig. 3) Effect of the disease at a local farm (massive defoliation and fruit drop).
Fig. 4) Foliar blight can cause normal green leaves to turn black in less than one week after infection. Location: Leilani Estates, Island of Hawaii.

Phytophthora morindae **Abad & Nelson**
-Nelson SC, Abad ZG. 200_. *Phytophthora morindae*, a new species causing Black Flag on Noni (*Morinda citrifolia* L) in Hawaii. (To be submitted to Mycological Research)

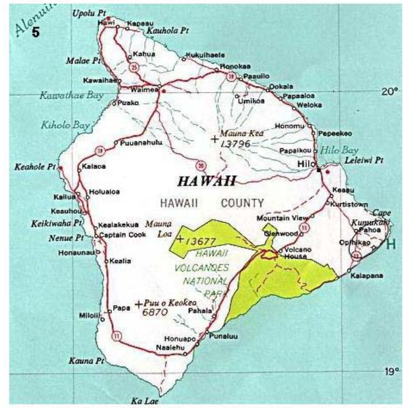
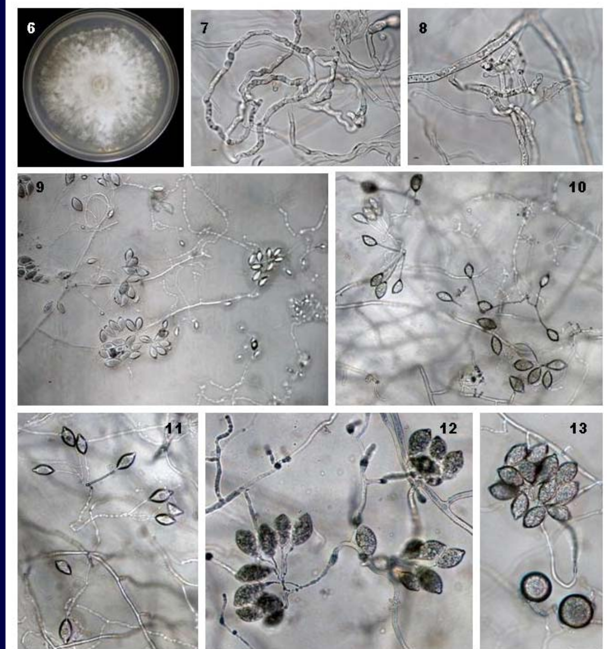
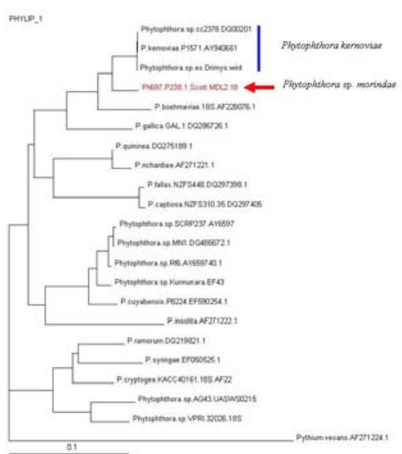
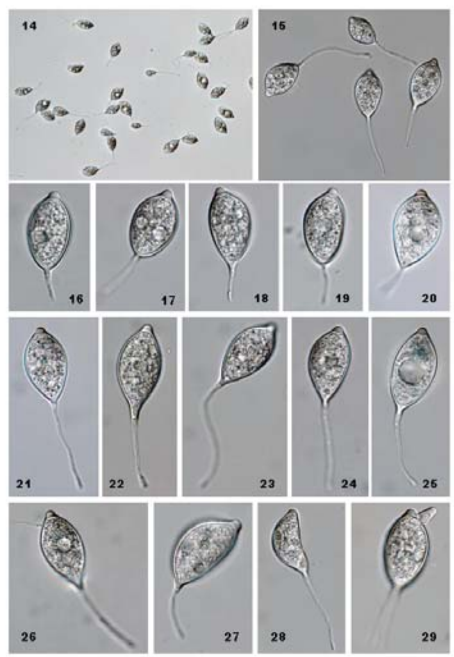
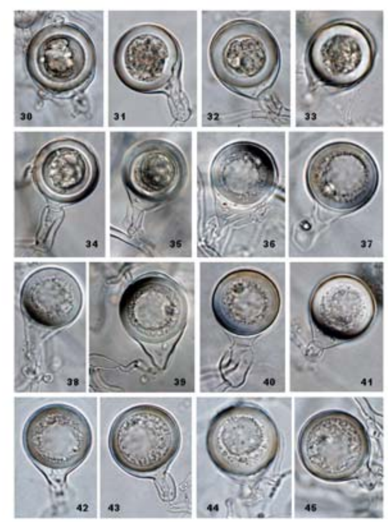


Fig 5 – Ellipse showing the location in which *Phytophthora morindae* is causing the black flag disease of *Morinda citrifolia* in Hawaii.









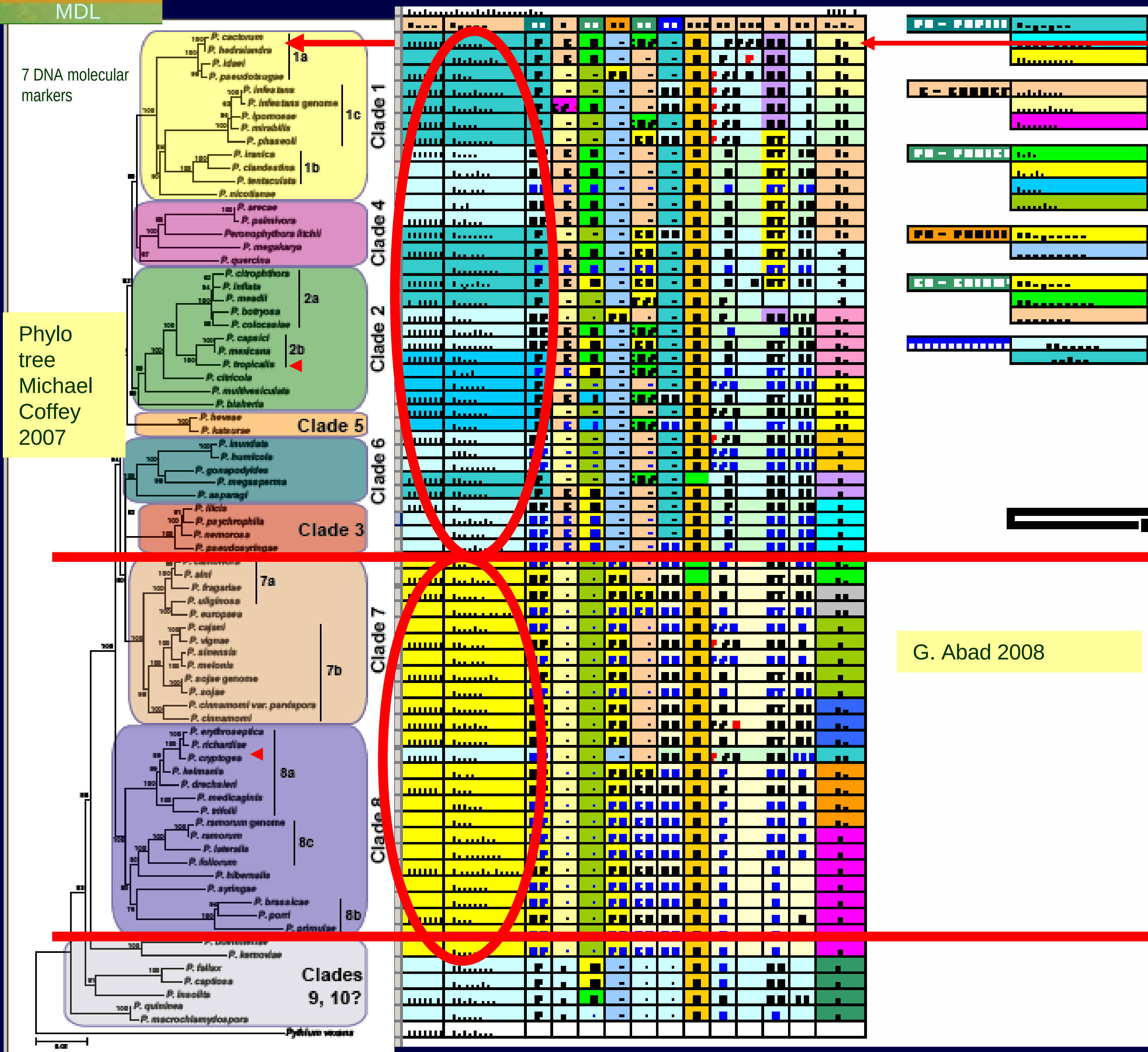
G. Abad, Ph. D. USDA/APHIS/PPQ/PHP/PSPI/MDL

INTEGRATING MORPHOLOGICAL AND MOLECULAR FOR A UNIFIED TAXONOMY OF *PHYTOPHTHORA*

MDL

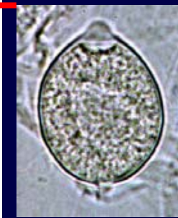
7 DNA molecular markers

Phylo tree Michael Coffey 2007



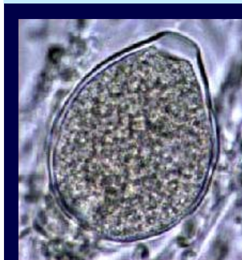
G. Abad 2008

PAPILLATE



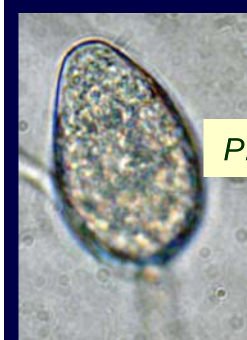
P. cactorum

SEMIPAPILLATE



P. citricola

NON-PAPILLATE

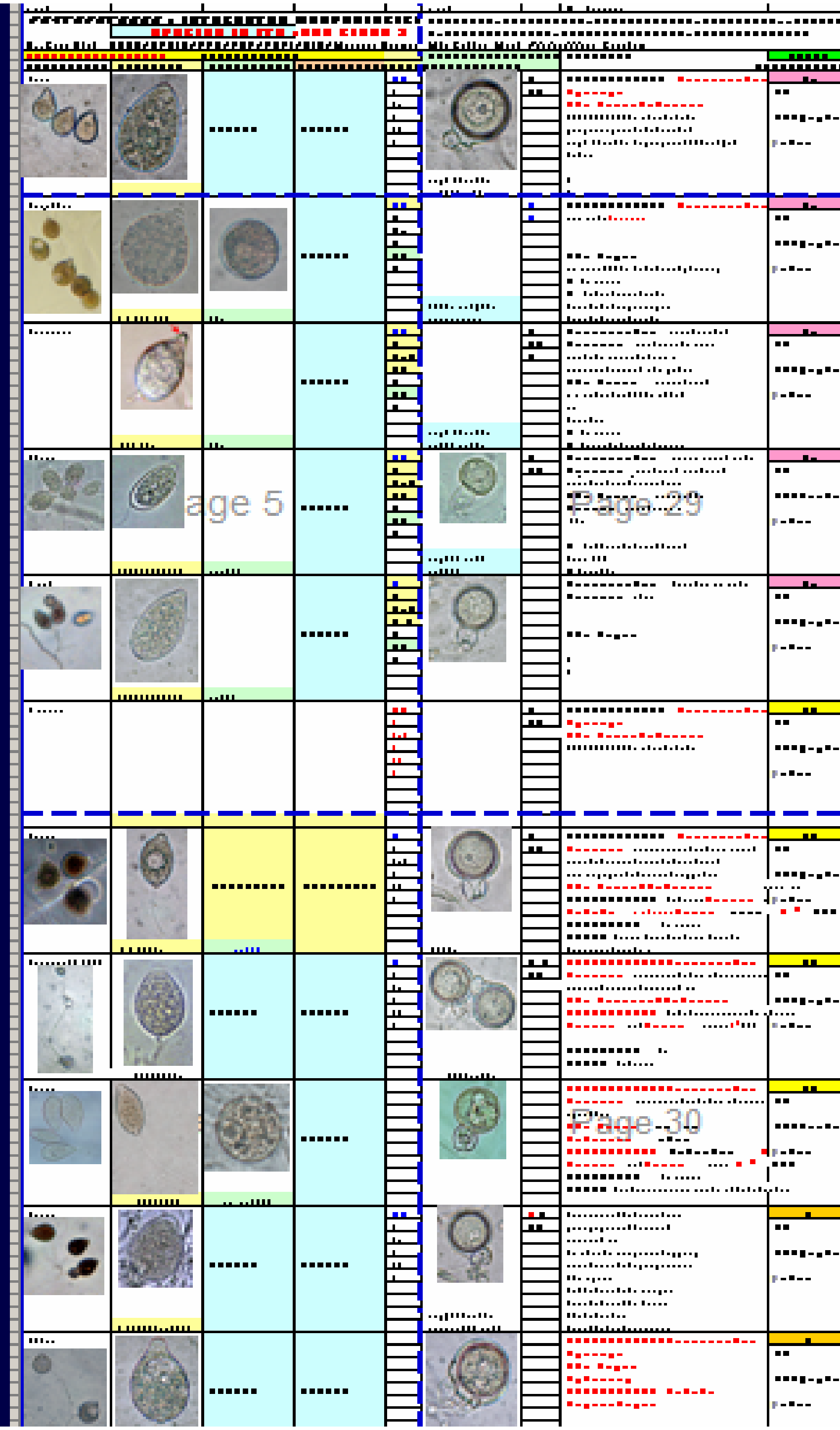


P. erytroseptica

SEMIPAPILLATE

INTEGRATED MORPHOLOGICAL/PHYLOGENTIC KEY-2008

Phytophthora species in CLADE 2



G. Abad, Ph. D. USDA/APHIS/PPQ/PHP/PSPI/MDL

USDA APHIS MDL

INTEGRATED MORPHOLOGICAL/PHYLOGENTIC KEY-2007

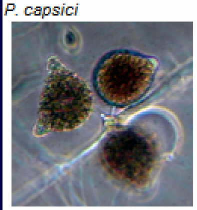
Clade 2

PHYTOPHTHORA: INTEGRATED MORPHOLOGICAL/PHYLOGENETIC KEY

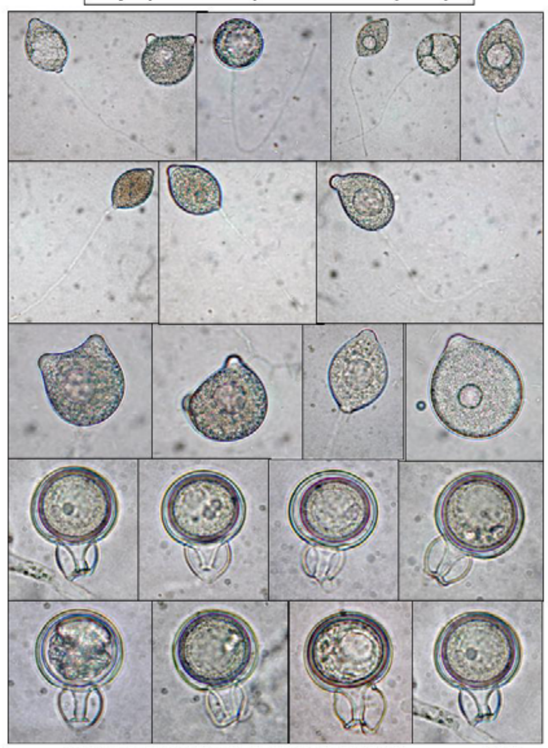
SPECIES IN ITS rDNA CLADE 2

Z..Gloria Abad USDA/APHIS/MDL, Mike Coffey World *Phytophthora* Collection

LEGENDS: P = PAPILLATE, SP = SEMIPAPILLATE, C = CADUCOUS (+ OR -), Pe = PEDICEL (S = SMALL, M = MEDIUM L = LONG), Pr = PROLIFERATION (+ OR -), Ch = CHLAMYDOSPORES (+, -, +/-), Hs = HYPHAL SWELLINGS (+, -, +/-),

ASEXUAL STAGE					SEXUAL STAGE: OOGONIA, ANTHERIDIA, OOSPORES		COMMENTS	CLADE
SPORANGIOPHPORE	SPORANGIA	CHLAMYDOSPORES	HYPHAL SWELLINGS	LEGEND		LEGEND		NCBI ACCESSION #
P. capsici 	 30-60 x 25-35 um	NOT COMMON rare, 16-30 µm	NOT COMMON	P C + Pe L Pr - Ch +/- Hs +/-	 25-35 um	A HT II	**ASEXUAL STAGE:** Sporangiophore simple sympodia, and sympodia. Sporangia papillate, variable in shape, mostly ovoid to ellipsoid, others globose, obturbinate. Many with two or more papillae. Caducous with long pedicels Chlamydospores & Hyphal swellings not common **SEXUAL STAGE:** Hetherotallic. Oogonia smooth. Antheridia amphigynous. Oospore plerotic. T°: 35C **DISTRIBUTION:** Cosmopolitan **HOSTS:** Capsicum, Carica, Citrullus, Cucumis, Cucurbita, Lycopersicon.	2b ITS TEF 1 alpha β-tubulin

Phytophthora capsici Leonian (1922)



USDA APHIS MDL

INTEGRATED MORPHOLOGICAL/PHYLOGENTIC KEY-2007

Clade 8c

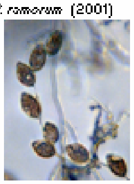
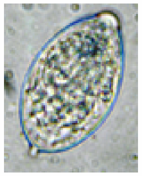
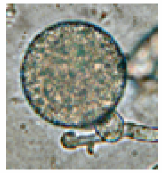
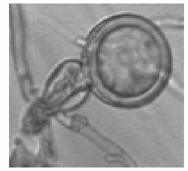
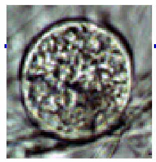
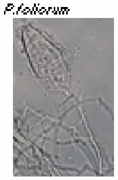
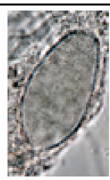
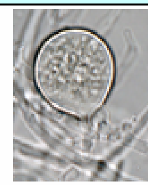
PHYTOPHTHORA : INTEGRATED MORPHOLOGICAL/MOLECULAR KEY

SPECIES IN ITS rDNA CLADE 8

Z..Gloria Abad USDA/APHIS/PPQ/PHP/PSPI/NIS/Molecular Diagnostics Laboratory

LEGENDS: P = PAPILLATE, SP = SEMIPAPILLATE, C = CADUCOUS, Pe = PEDICELL, Pr = PROLIFERATION, Ch = CHLAMYDOSPORES, Hs = HYPHAL SWELLINGS

Mike Coffey World *Phytophthora* Collection

SPORANGIOPHPORE	SPORANGIA	CHLAMYDOSPORES	HYPHAL SWELLINGS		SEXUAL STAGE: OOGONIA, ANTHERIDIA, OOSPORES		COMMENTS	CLADE AND GPD ACCESION #s
P. ramorum (2001) 	 20-32x40-80 (24x52) µm	 22-72 (av. 53.8) µm	ABSENT	SP C + Pe S Pr - Ch + Hs -	 Oog: 28-38 (31.2) µm	HT A	**ASEXUAL STAGE: Sporangiophore** single or sympodial. **Sporangia** semipapillated, caducous, with short pedicel, ellipsoid, spindle-shaped or elongate-ovoid, semipapillate with narrow indistinct papilla. **Chlamydospores** abundant on agar intercalar, terminal and lateral. **Hyphal Swellings** absent. **SEXUAL STAGE:** **D:** Europe, North America (Canada, USA: WA, OR, CA). **H:** Sudden Oak Dead, At least 26 genera in 17 families, including Rhododendron spp. (Ericaceae).	Clade 8c ITS B-TUB TEF COXI COXII
P. lateralis 			ABSENT	NP C - Pe - Pr + Ch + Hs +	ABSENT in most isolates	P HO V	**ASEXUAL STAGE: Sporangiophore** **Sporangia** Nonpapillate **Chlamydospores** many lateral sessile **SEXUAL STAGE:** sex bodies absent in most isolates. **D:** Northwestern North America. **H:** Chamaecyparis, Douglas fir. Root rot.	Clade 8c ITS B-TUB TEF COXI COXII
P. foliorum 		ABSENT					**ASEXUAL STAGE: Sporangiophore** **Sporangia** **Chlamydospores** **Hyphal Swellings** **SEXUAL STAGE:** **D:** **H:**	Clade 8c ITS B-TUB TEF COXI COXII
P. hibernalis 		ABSENT	ABSENT				**ASEXUAL STAGE: Sporangiophore** **Sporangia** **Chlamydospores** **Hyphal Swellings** **SEXUAL STAGE:** **D:** **H:**	Clade 8c ITS B-TUB TEF COXI COXII

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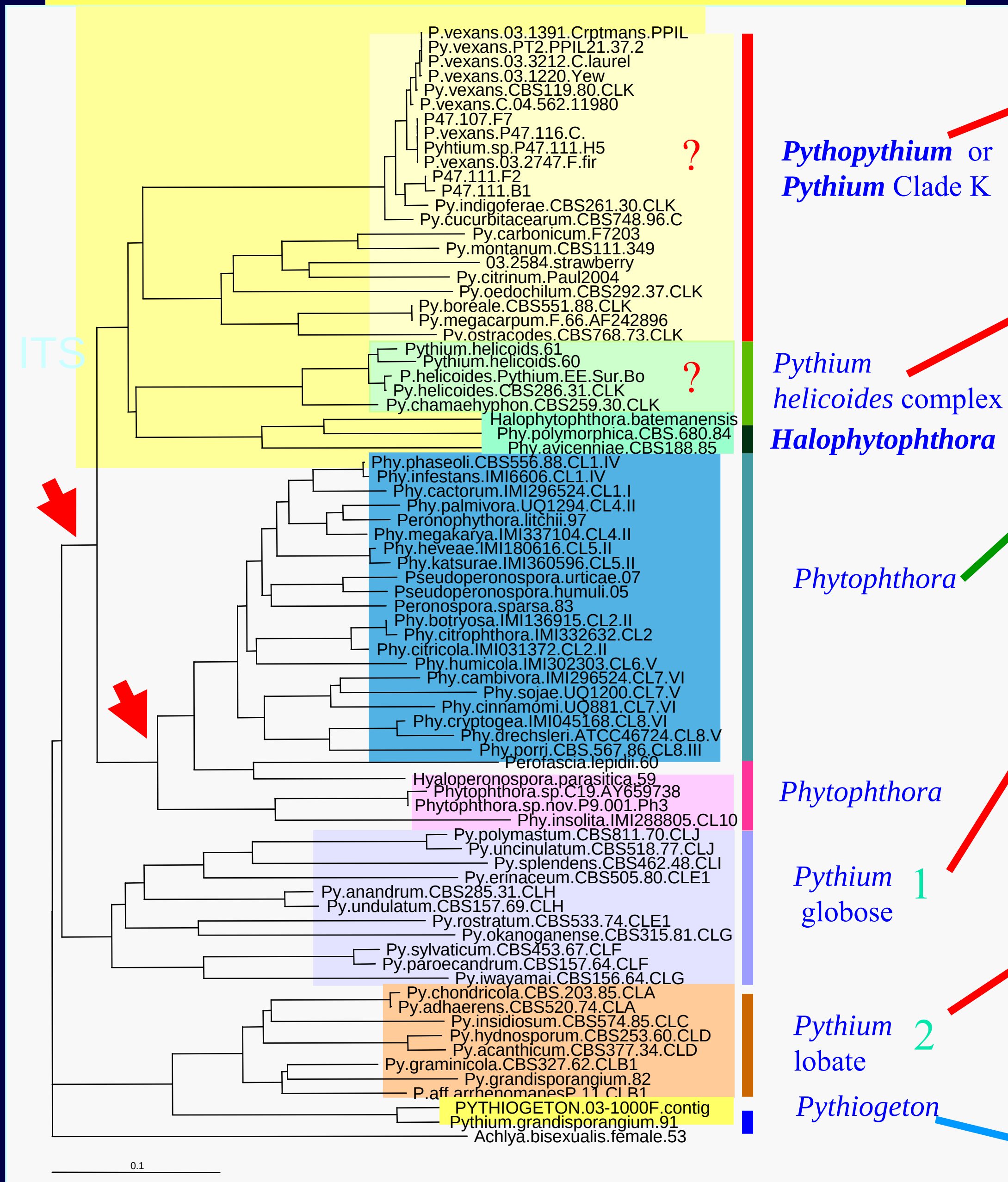
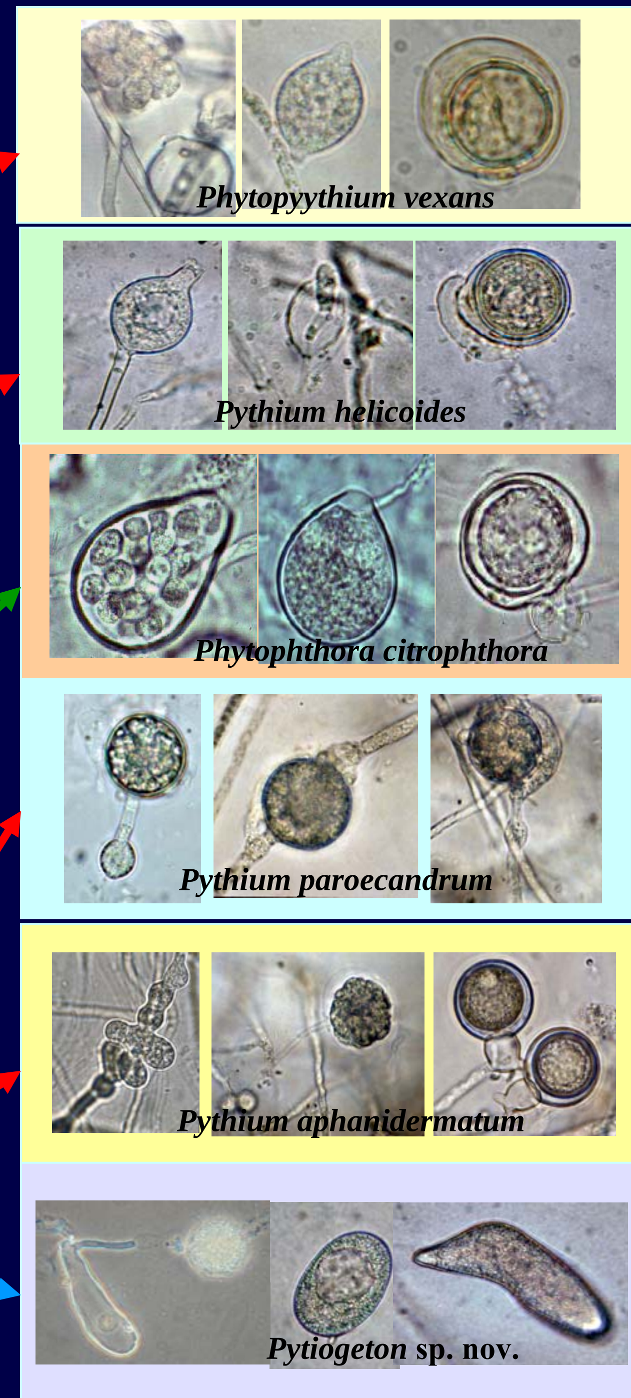
Peronosporaceae family and some phylogenetic groups





Gloria Abad, Ph.D. USDA/APHIS/PPQ/PSPI/NIS/MDL

MDL

CENTRE FOR BIOLOGICAL INFORMATION TECHNOLOGY
THE UNIVERSITY OF QUEENSLAND - AUSTRALIA

LUCID KEY
OOMYCETES- *PHYTOPHTHORA*
By Gloria Abad and Michael Coffey

FUTURE

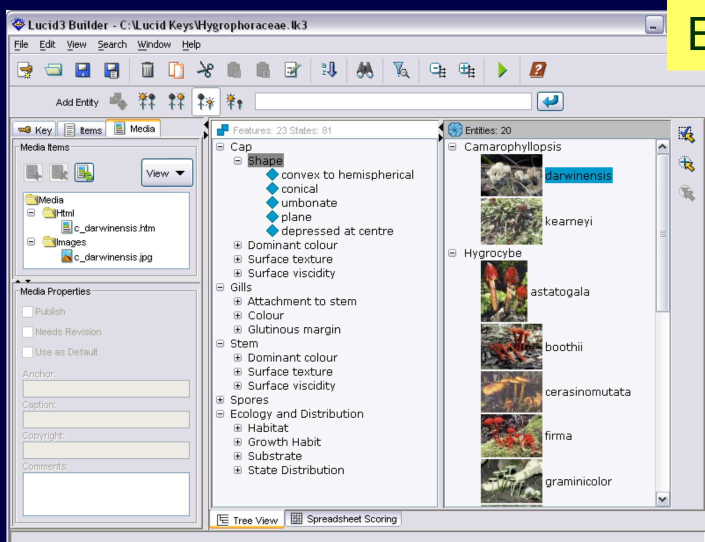
PYTHIUM

PYTHIOGETON

PHYTOPYTHIUM nov. gen

LUCID CENTRE LISENCE TO Z.G.ABAD USDA/MDL 2008 SOFTWARE

EXAMPLES



Lucid Keys Hygrophoraceae

Urban bee species of the San Francisco Bay area

G. Abad, Ph. D. USDA/APHIS/PPQ/PHP/PSPI/MDL