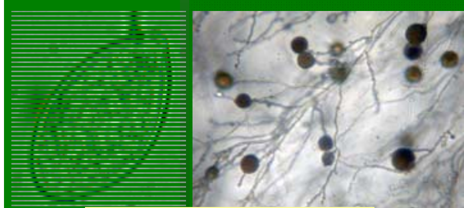
United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine

USDA APHIS

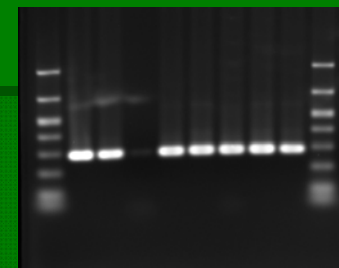
P. capsici

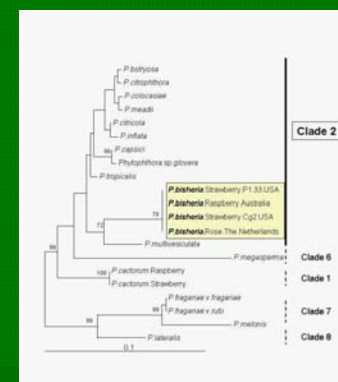


P. ramorum

Methods for identification of *Phytophthora* species.

Gloria Abad, Ph. D.
Lead Scientist
USDA/APHIS/PPUSDA/APHIS/PPQ/PHP/PSPI
MOLECULAR DIAGNOSTICS LABORATORY





WORKSHOP: Fighting *Phytophthora*: How to Detect, Investigate, and Manage *Phytophthora*. July 26 2008
APS Cenntennial Meeting 2008

USDA APHIS
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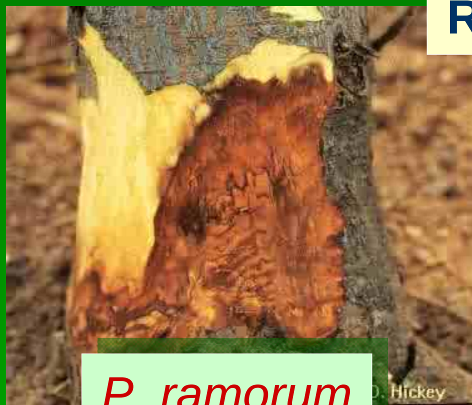
Diseases caused by *Phytophthora*

88 spp. 7/25/08

Root, Crown, Collar Rots, Stem canker, Wilts

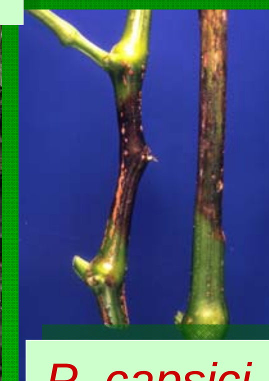


P. ramorum

P. cinnamomi

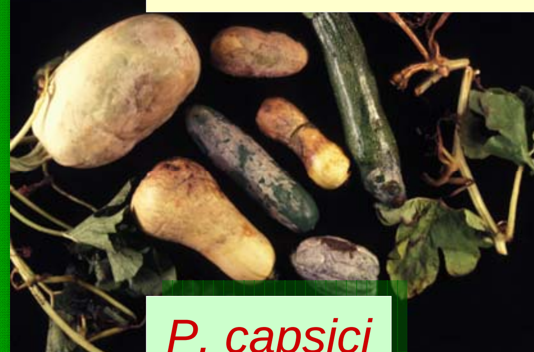
Leaf and Stem Blights

P. infestans

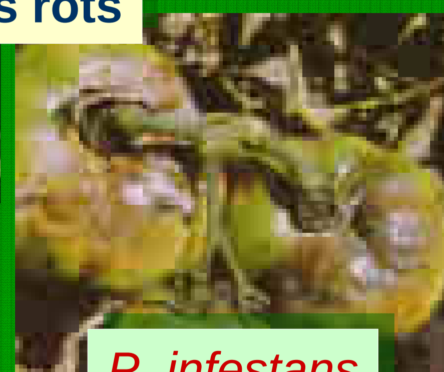


P. capsici

Fruit, and Tubers rots



P. capsici



P. infestans

Photos: Mostly from the internet

Phytophthora pinifolia AJ. Durán, Gryzenh. & MJ Wingf. (2008)

MDL

Perfect stage
Not Known

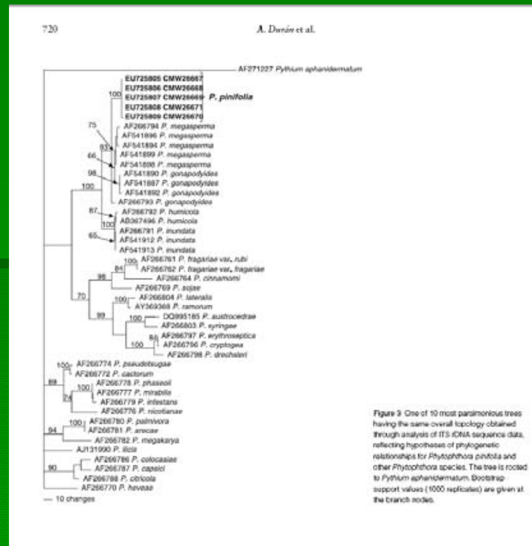
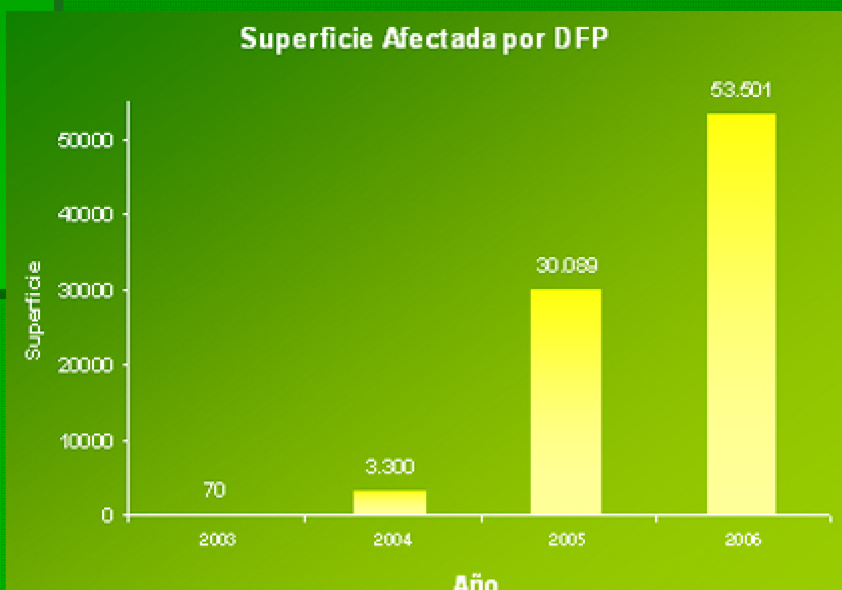


Figure 3 One of 10 most parsimonious trees having the same overall topology obtained through analysis of ITS rDNA sequence data, reflecting hypotheses of phylogenetic relationships for *Phytophthora pinifolia* and other *Phytophthora* species. The tree is rooted to *Pythium aphanidermatum*. Bootstrap support values (1000 replicates) are given at the branch nodes.



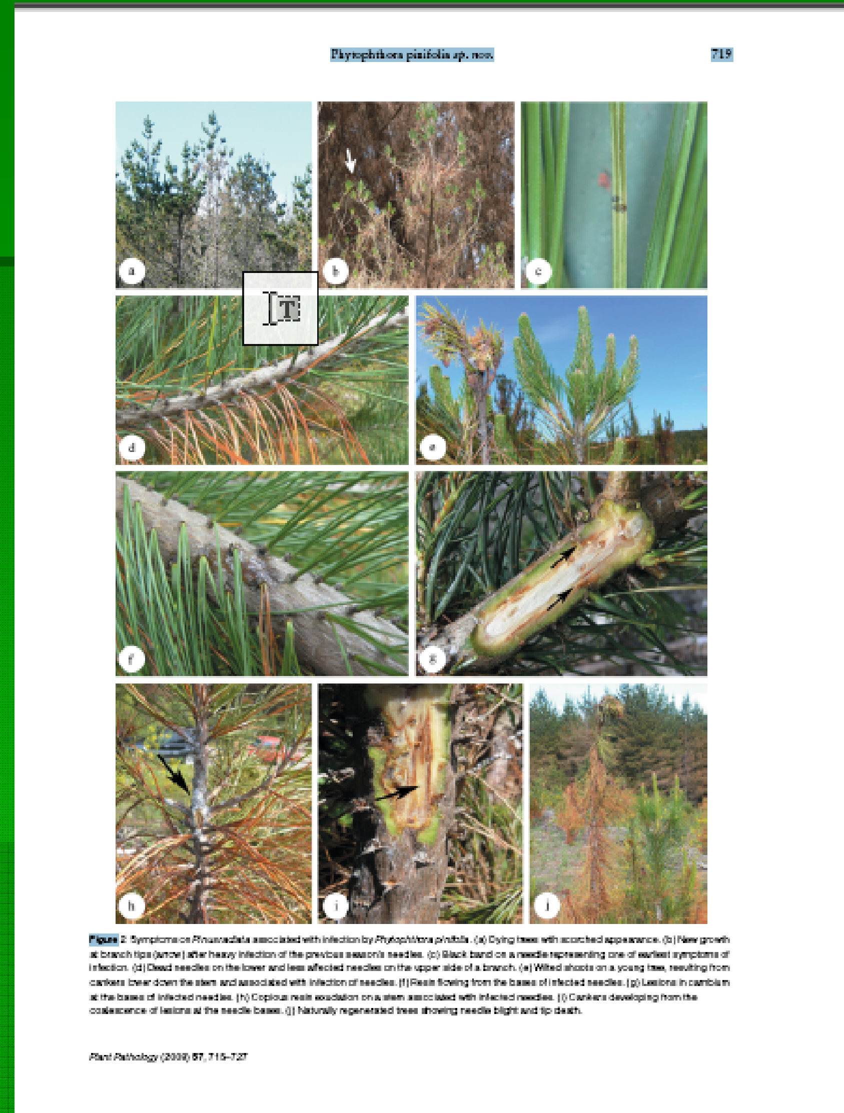


Figure 2 Symptoms on *Pinus radiata* associated with infection by *Phytophthora pinifolia*. (a) Dying trees with scorched appearance. (b) New growth at branch tips (arrow) after heavy infection of the previous season's needles. (c) Black band on a needle representing one of earliest symptoms of infection. (d) Dead needles on the lower and less affected needles on the upper side of a branch. (e) Wilted shoots on a young tree, resulting from cankers lower down the stem and associated with infection of needles. (f) Resin flowing from the bases of infected needles. (g) Lesions in cambium at the bases of infected needles. (h) Copious resin exudation on a stem associated with infected needles. (i) Cankers developing from the coalescence of lesions at the needle bases. (j) Naturally regenerated trees showing needle blight and tip death.

Plant Pathology (2008) 57, 715–727

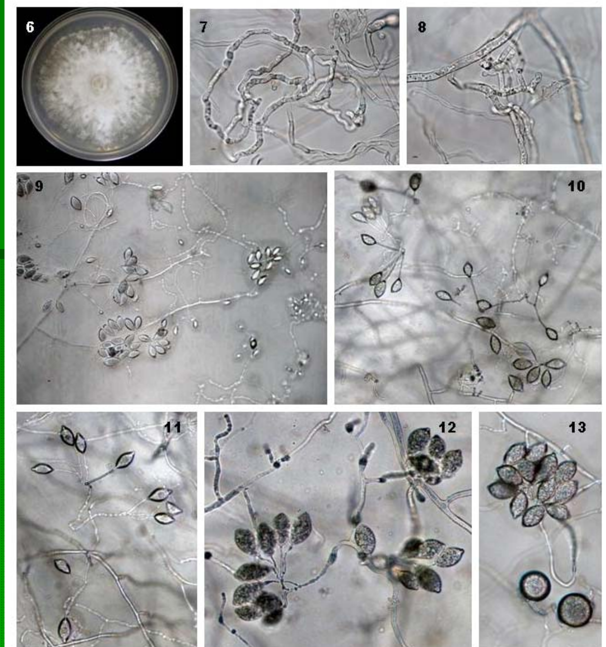
Durán A, Gryzenhout M, Slippers B, Ahumada R, Rotella A, Flores F, Wingfield BD, Wingfield MJ. 2008. *Phytophthora pinifolia* sp. nov. associated with a serious needle disease of *Pinus radiata* in Chile. Plant Pathology 57: 715-727.

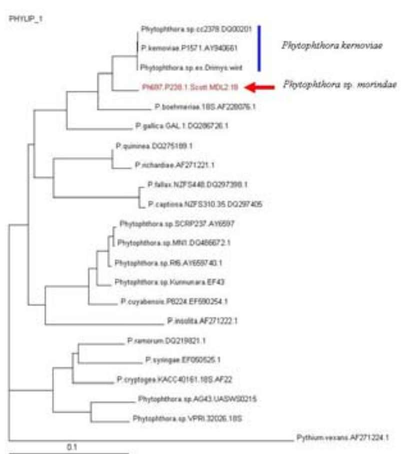
Phytophthora sp. *morindae* Abad ZG & Nelson S

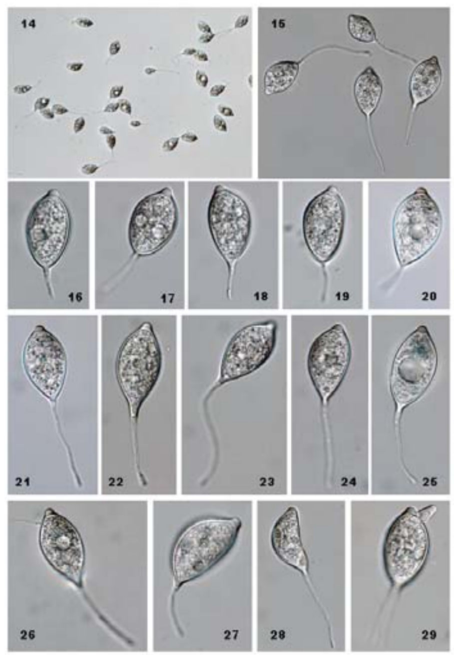
Fig. 1) Fruit symptoms in an early stage (demonstrates that green fruits are attacked before they are ripe).
Fig. 2) All symptoms types: black flags, veinal necrosis, fruit rot, fruit mummification, leaf spot, leaf blight, stem blight.
Fig. 3) Effect of the disease at a local farm (massive defoliation 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.

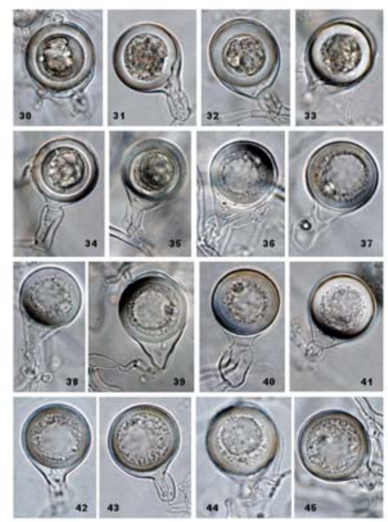
Phytophthora morindae **Abad & Nelson**
-Nelson SC, Abad ZG. 200.. *Phytophthora morindae*, a new species causing Black Flag on Noni (*Morinda citrifolia* L.) in Hawaii. (To be submitted to Mycological Research)

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





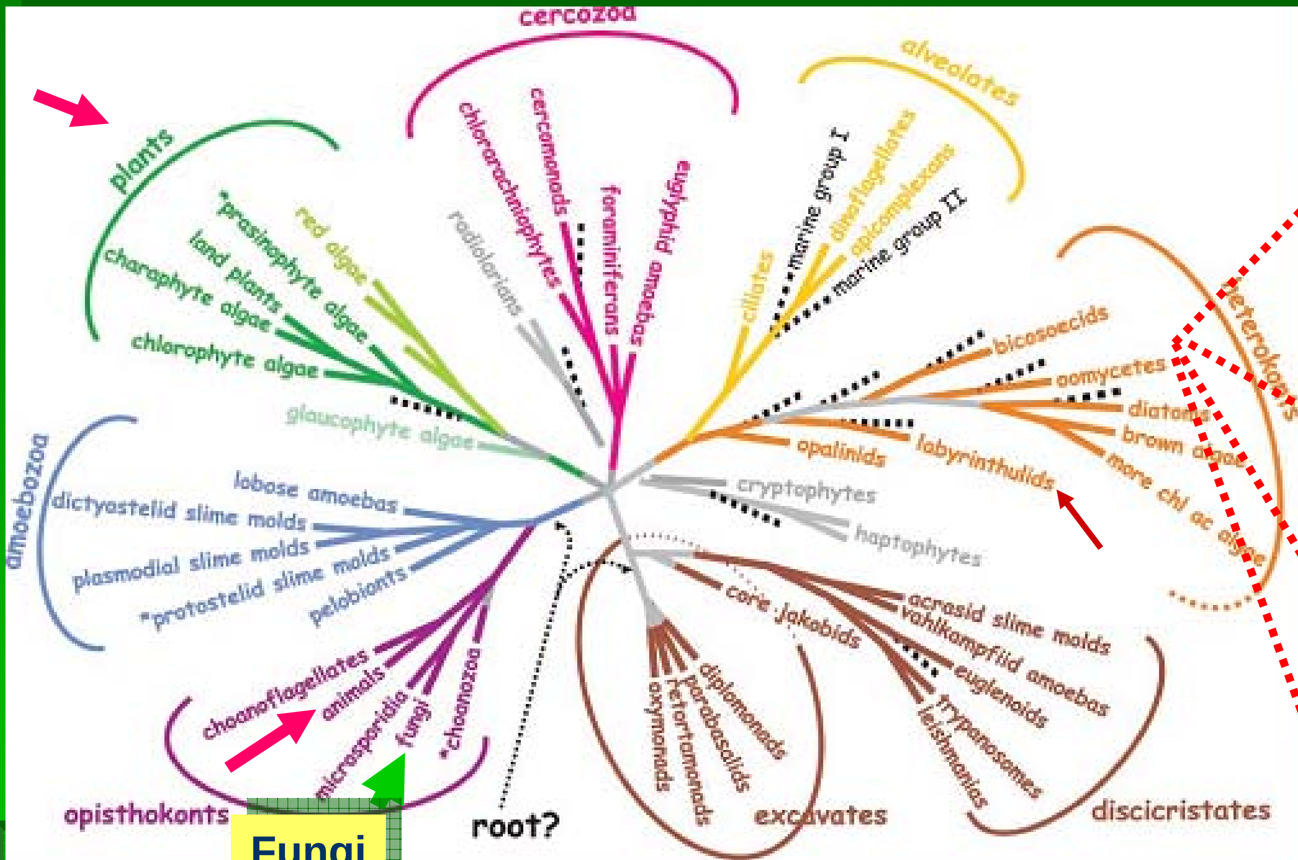




MDL

The Phylogenetic position of Straminipiles and Fungi in relation to other Eucaryotes

Phylogenetic tree from Baldauf et al, 2003 *Science* 300:1703-1706



Fungi


Fusarium


Rhizoctonia


Colletotrichum

Straminipiles


Phytophthora


Pythium


Pythiogeton


Peronospora

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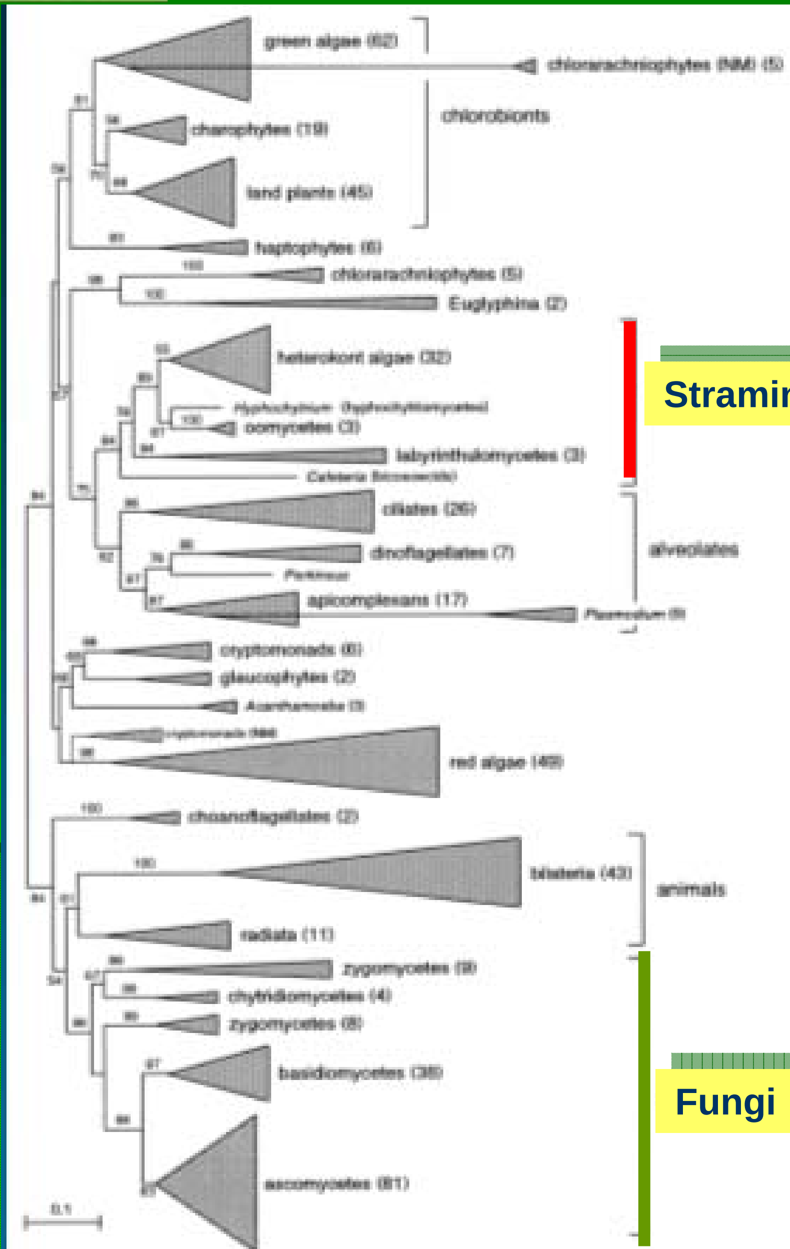
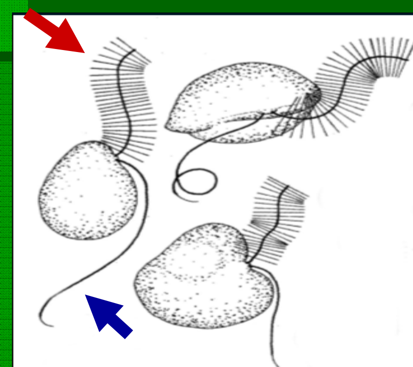
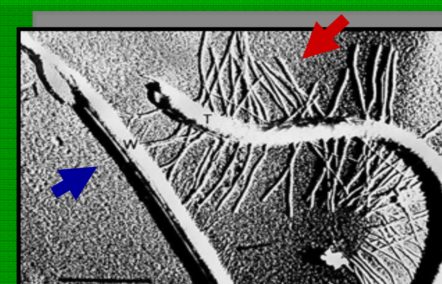
MDL



Phylogenetic Relationships of Straminipiles and Fungi with other Organisms

SSU rRNA Evolutionary Tree
From Van de Peer et al J. Mol. Evol, **2000** 2000

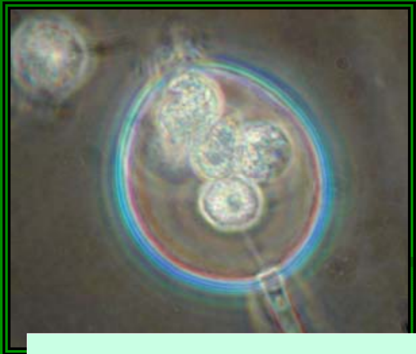




Additional characters that differentiate straminipiles to true fungi

Trait	Oomycetes	Fungi
Cell wall composition	β-1,3 and β-1,6 glucans; cellulose	Chitin
Storage reserves	β-1,3 glucans (Mycolaminarin)	Glycogen
Somatic Cells	Coenocytic	Mostly septate
Somatic nuclei	Diploid	Haploid
Mitochondrial cristae	Tubular	Flat

TAXONOMIC POSITION



Phytophthora

Pythium

Pythiogeton

Kingdom: Straminipila (Dick 2001)

- **Phylum:** Heterokonta
- **Sub-Phylum:** Peronosporomycotina
- **Class:** Peronosporomycetes (OOMYCETES)

  800 SPECIES (3 subclasses)
- **Subclass:** Peronosporomycetidae

  Order: Peronosporales (Waterhouse, 1973)
- **Order:** Pythiales? (Dick et.al 1984)
- **Family:** Pythiaceae (10 genera)
- **Genus :** *Phytophthora* (87sp.), *Pythium* (160sp.)

Family: Pythiogenaceae fam. nov. (2 genera) (Volglmayir et al 1999)

Genus : *Pythiogeton* (9 sp.), *Medusoides* (1 sp.) (gen. nov.)

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

Taxonomy of *Phytophthora* Species

- The Era of Morphological species
- The Era of Phylogenetic species
- A new era of Morphological/Phylogenetic Species?

MDL

EVOLUTION IN THE TAXONOMY *PHYTOPHTHORA*

THE CLASICAL ERA AND THE MORPHOLOGICAL-SPECIES

MDL

The marvelous potato

1500´s

1700´s

The Potato Disease

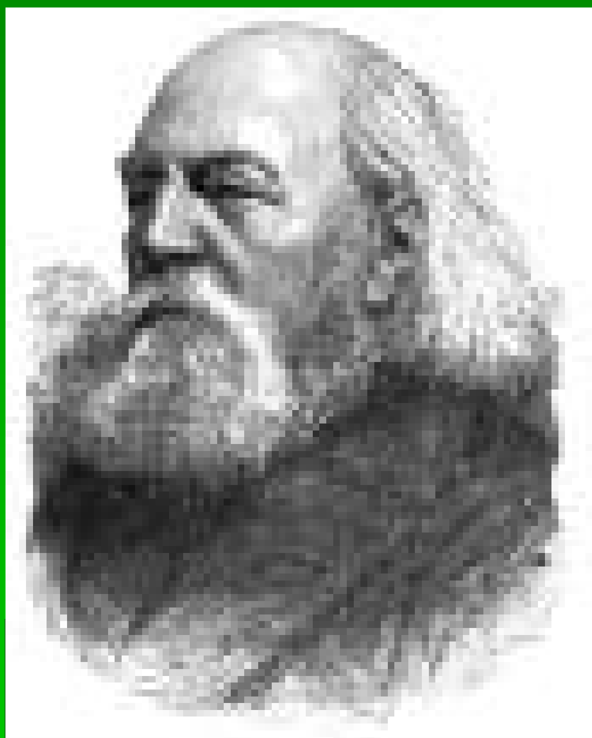
1840´s

Which was the cause of the disease?

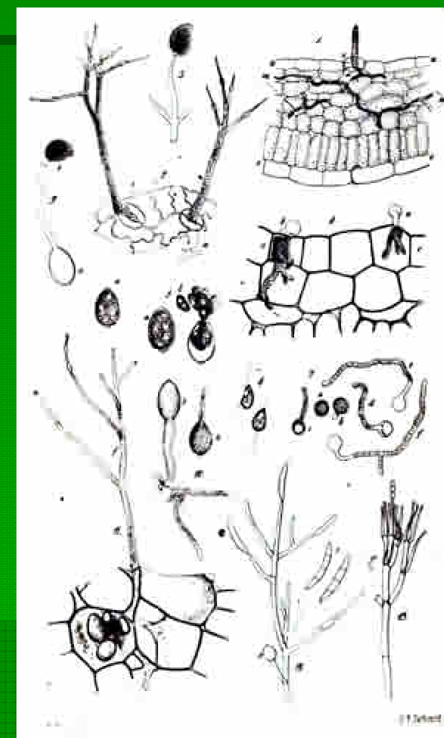
Where the Disease came From?

MDL

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



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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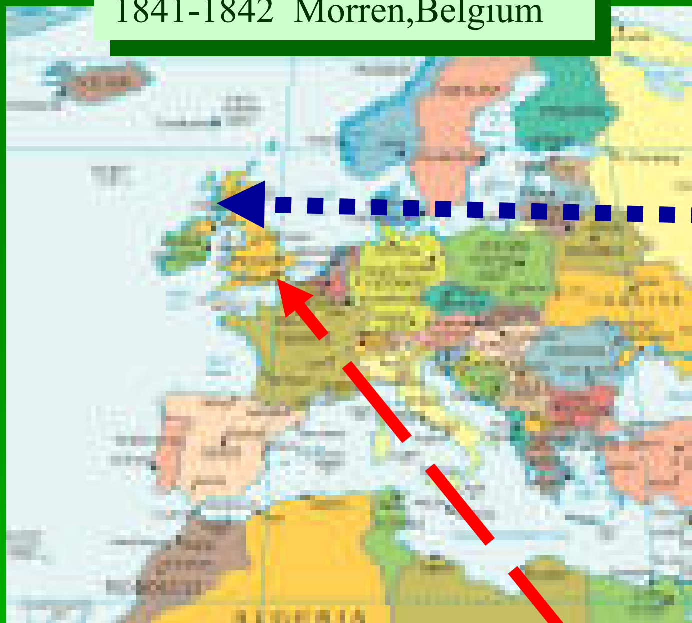
Phytophthora infestans Center of Origen current teories

1841-1842 Morren,Belgium



1841-1842 Teschemacker, USA

Mexican Theory

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

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

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.
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- 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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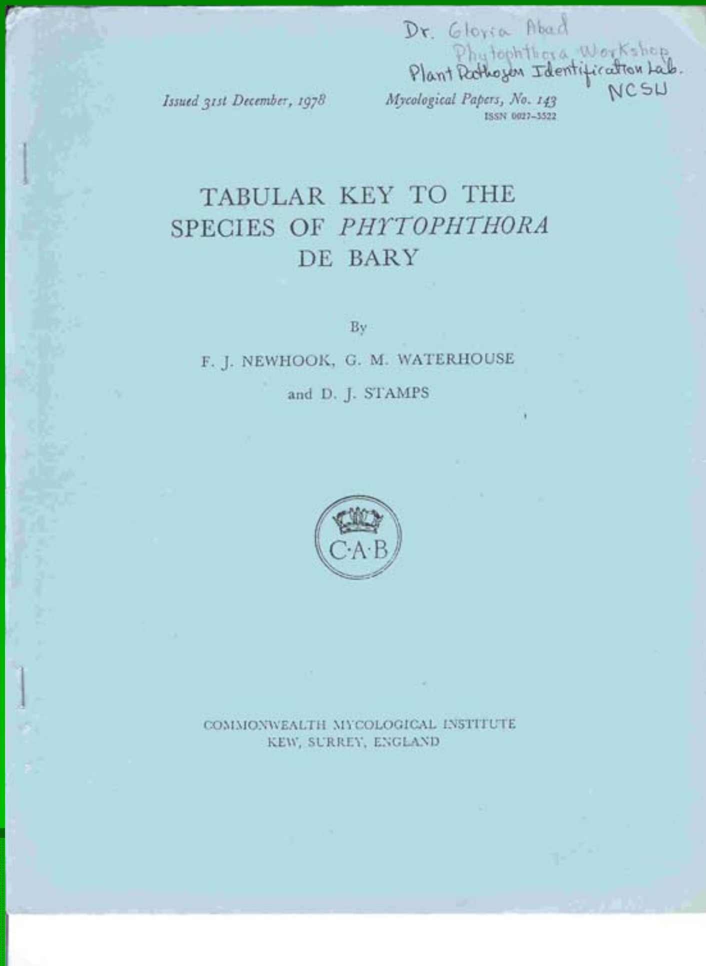

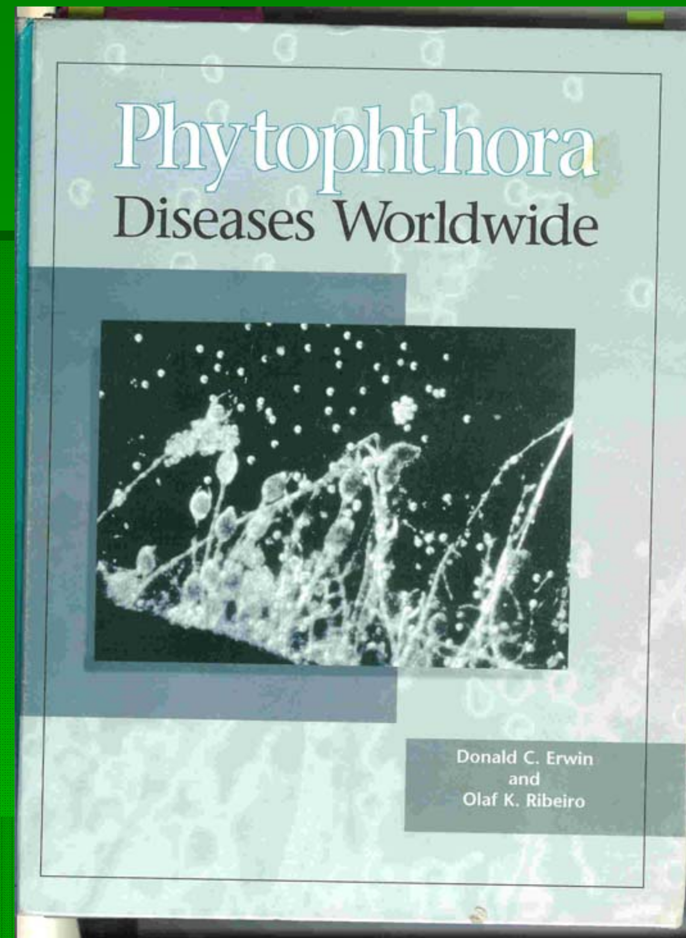

Newhook, Waterhouse, and Stamps. 1978
Tabular Key to the Species of *Phytophthora* De Bary. Commonwealth Mycological Intitute, Kew Surrey, England

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

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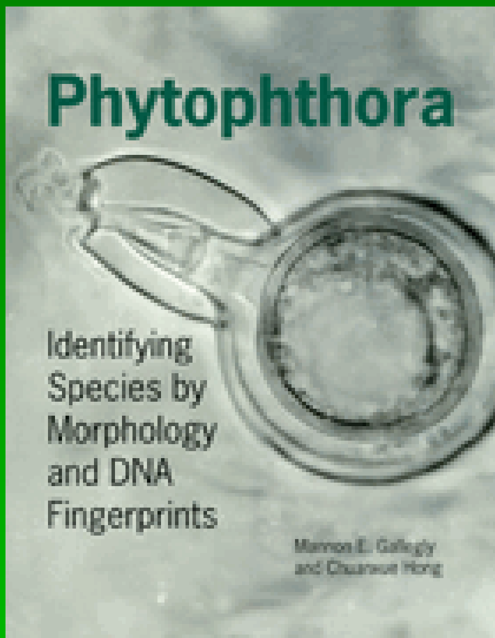
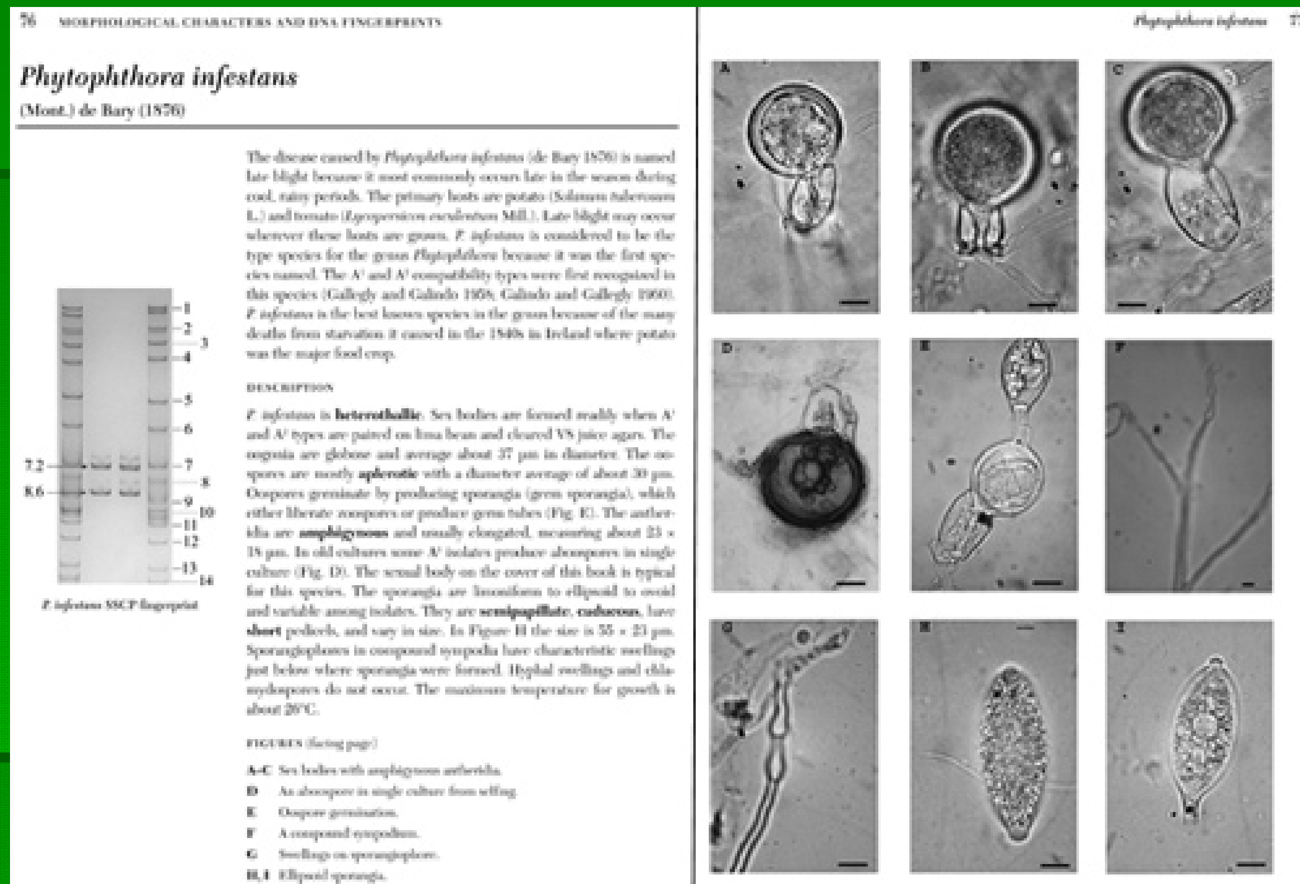
The 64 *Phytophthora* morphospecies presented at Erwin and Ribeiro's Book (1996)

P. arecae (1913)	P. fragariae v. oryzobladis (1978)	P. megasperma (1931)
P. boehmeriae (1927)	P. fragariae v. rubi (1993)	P. melonis (1976)
P. botryosa (1969)	P. gonapodyides (1927)	P. mexicana (1923)
P. cactorum (1886)	P. heveae (1929)	P. mirabilis (1985)
P. cajani (1978)	P. hibernalis (1925)	P. nicotianae (1896)
P. cambivora (1927)	P. humicola (1985)	P. palmivora v. palmivora (1919)
P. capsici (1922)	P. idaei (1995)	P. palmivora v. heterocysta (1983)
P. cinnamomi (1922)	P. ilicis (1957)	P. phaseoli (1889)
P. cinnamomi v. parvispora (1993)	P. infestans (1876)	P. porri (1931)
P. citricola (1927)	P. inflata (1949)	P. primulae (1952)
P. citrophthora (1925)	P. insolita (1980)	P. pseudotsugae (1983)
P. clandestina (1985)	P. iranica (1971)	P. quininea (1947)
P. colocasiae (1900)	P. italica (1996)	P. richardiae (1927)
P. cryptogea (1919)	P. japonica (1974)	P. sinensis (1982)
P. cyperi (1935)	P. katsurae (1979)	P. sojae (1958)
P. cyperi - bulbosi (1953)	P. lateralis (1942)	P. syringae (1909)
P. drechsleri (1931)	P. lepironiae (1919)	P. tentaculata (1993)
P. eriugena (1977)	P. macrochlamydospora (1991)	P. trifolii (1991)
P. erythroseptica v. erytroseptica (1913)	P. meadii (1918)	P. undulata (1989)
P. erythroseptica v. pisi (1959)	P. medicaginis (1991)	P. verrucosa (1940)
P. fragariae v. fragariae (1940)	P. megakarya (1979)	P. vignae (1957)

UNCULTURABLE SPECIES





76 MORPHOLOGICAL CHARACTERS AND DNA FINGERPRINTS

Phytophthora infestans

(Mont.) de Bary (1876)

The disease caused by *Phytophthora infestans* (de Bary 1876) is named late blight because it most commonly occurs late in the season during cool, rainy periods. The primary hosts are potato (*Solanum tuberosum* L.) and tomato (*Lycopersicon esculentum* Mill.). Late blight may occur wherever these hosts are grown. *P. infestans* is considered to be the type species for the genus *Phytophthora* because it was the first species named. The A^1 and A^2 compatibility types were first recognized in this species (Gallegly and Galindo 1958; Galindo and Gallegly 1960). *P. infestans* is the best known species in the genus because of the many deaths from starvation it caused in the 1840s in Ireland where potato was the major food crop.

DESCRIPTION

P. infestans SSCP fingerprint

Phytophthora infestans 77

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.

MDL

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

Photos by G. Abad

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MORPHOLOLGY OF SPORANGIOPHORES

UNBRANCHED

P. erytroseptica

P. sp. kelmania

BRANCHED

P. sp. 3

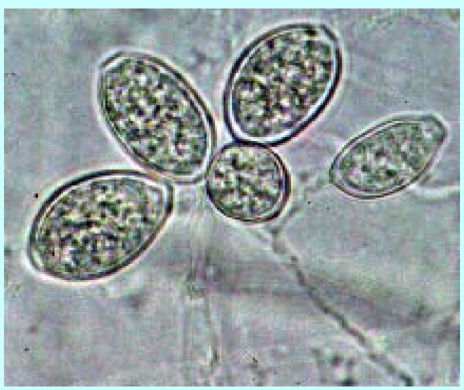
EXTERNAL PROLIFERATION

P. bisheria

INTERNAL PROLIFERATION

P. lateralis

BOTRYOSE CLUMPS



P.botryosa

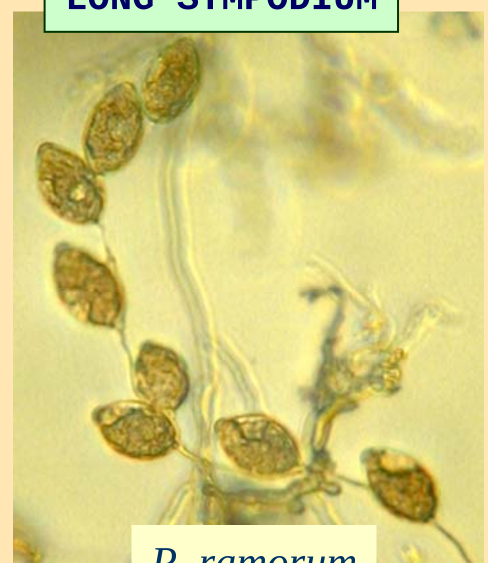
UMBELLA TYPE

P.capsici

SYMPLE SYMPODIUM

P.kernoviae

LONG SYMPODIUM



P. ramorum

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

Photos by G. Abad

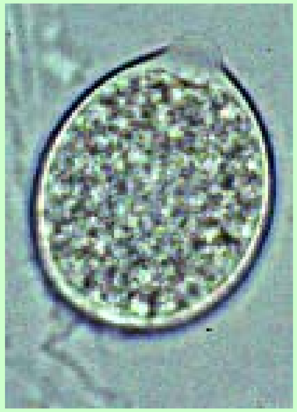
Sporangia shapes

MDL

Globose

P. bohemeria

Globose



P. cactorum

Ovoid

Phytophthora sp. aucubae

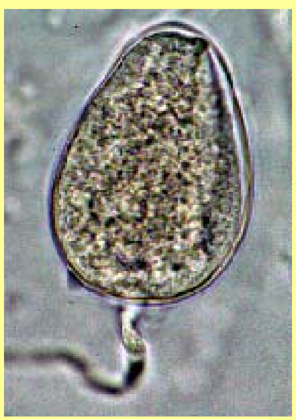
Ellipspoid

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

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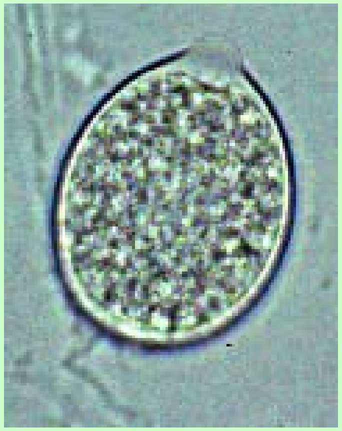
Papillate –short pedicell



P. cactorum

P. bohemeria

Semipapillate- Medium pedicel

P. botryosa

Semipapillate- Long pedicel

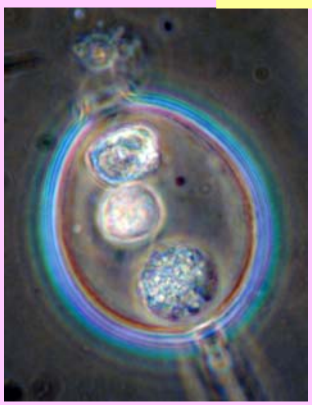
P. capsici

Non-papillate – persistent

P. sp.niederhauserii

Exit pore

Narrow



P. nicotianae

P. bohemeriae

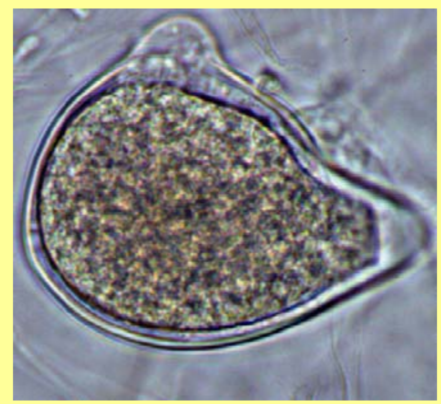
Medium

P. citrophthora

Wide

P. sp. personii

Two papilla



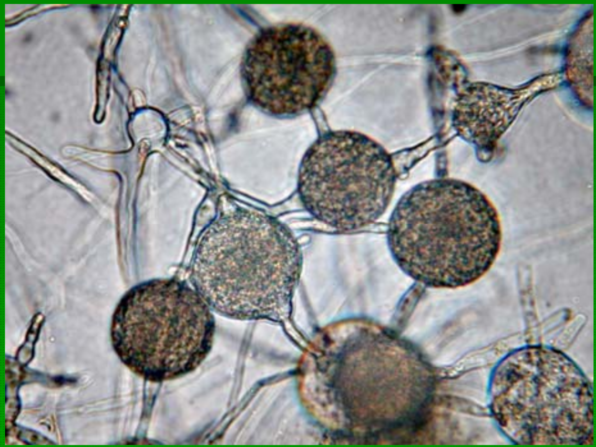
P. capsici

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

Photos by G. Abad

Hyphal swellings

P.drechsleri



P. sp. personii

P. sp. niederhauserii

P. sp. kelmania

P. foliorum

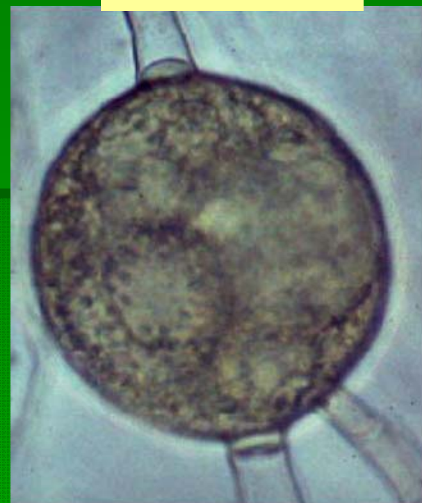
MDL

Chlamydosphores

Terminal

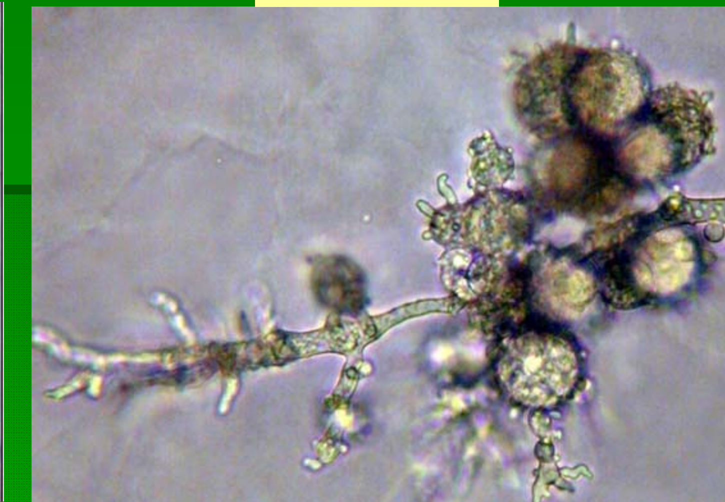
P. tropicalis

Intercalary



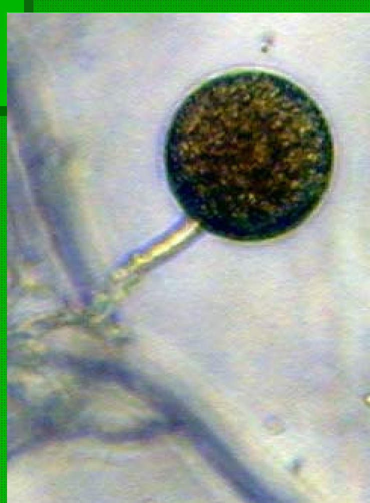
Phytophthora sp. Juniper

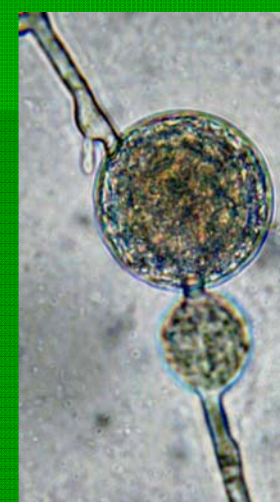
Clustered



P.cinnamomi.

Terminal, lateral, intercalary

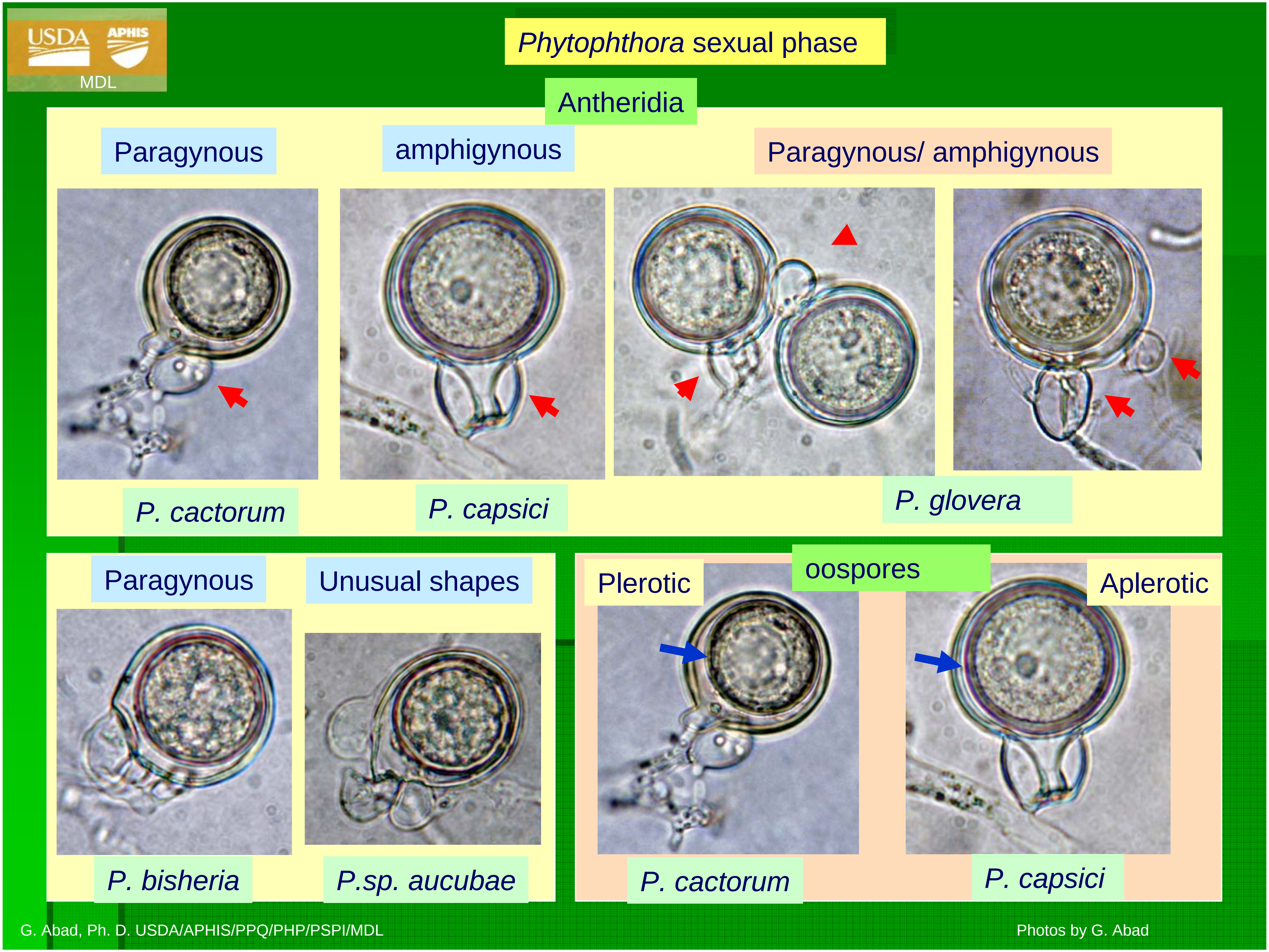




P. ramorum

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

Photos by G. Abad


USDA APHIS
MDL
Phytophthora sexual phase
Antheridia
Paragynous
amphigynous
Paragynous/ amphigynous
P. cactorum
P. capsici
P. glovera
Paragynous
Unusual shapes
oospores
Plerotic
Aplerotic
P. bisheria
P.sp. aucubae
P. cactorum
P. capsici
G. Abad, Ph. D. USDA/APHIS/PPQ/PHP/PSPI/MDL
Photos by G. Abad

USDA APHIS MDL

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

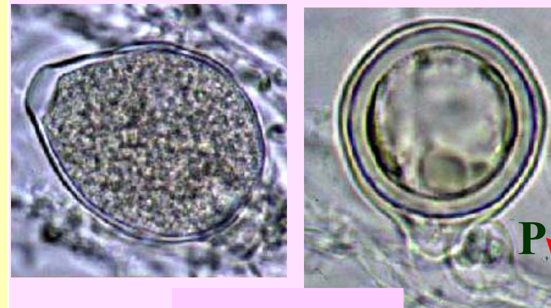
Mostly HT

P. heveae HO

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

GROUP III

Mostly HO

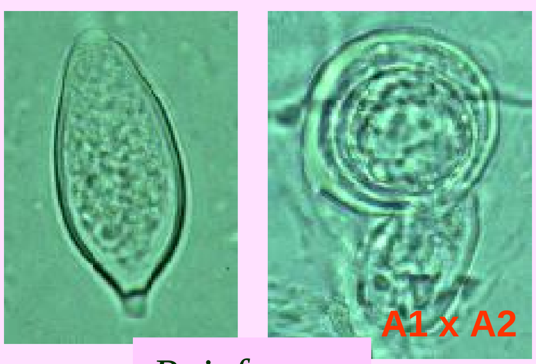


P. citricola

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

GROUP IV

Mostly HT

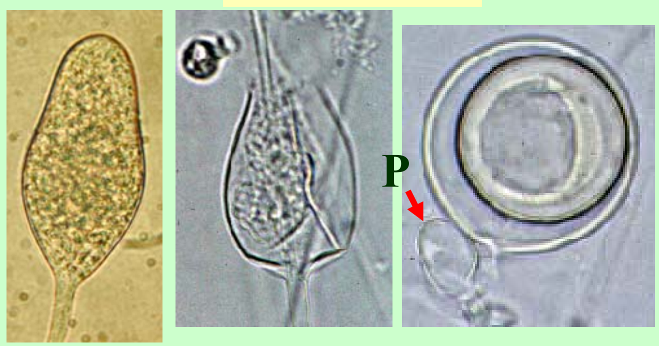


P. infestans

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*

Problems in morphological ID *of Phytophthora* Species

88 species described to 7/25/08

- variability in morphological characters
- limited no. of morphological characters
- overlapping in morphological characters
- Some atypical isolates
- Difficulties in sporulation
- Lack of expertise for identification
- The need of molecular characterization

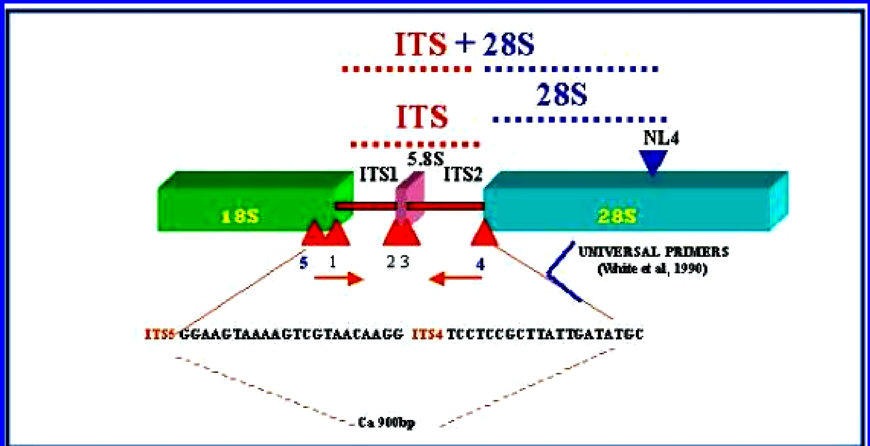
MDL

EVOLUTION IN THE TAXONOMY *PHYTOPHTHORA*

THE MODERN ERA AND THE PHYLOGENETIC - SPECIES

Phytophthora molecular markers

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

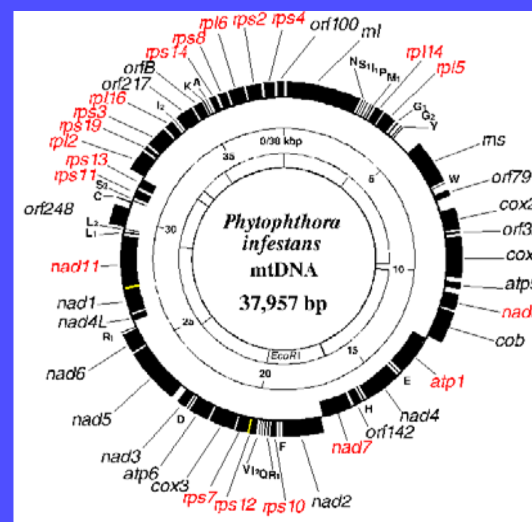


Lee and Taylor 1992- 1993
First phylogeny

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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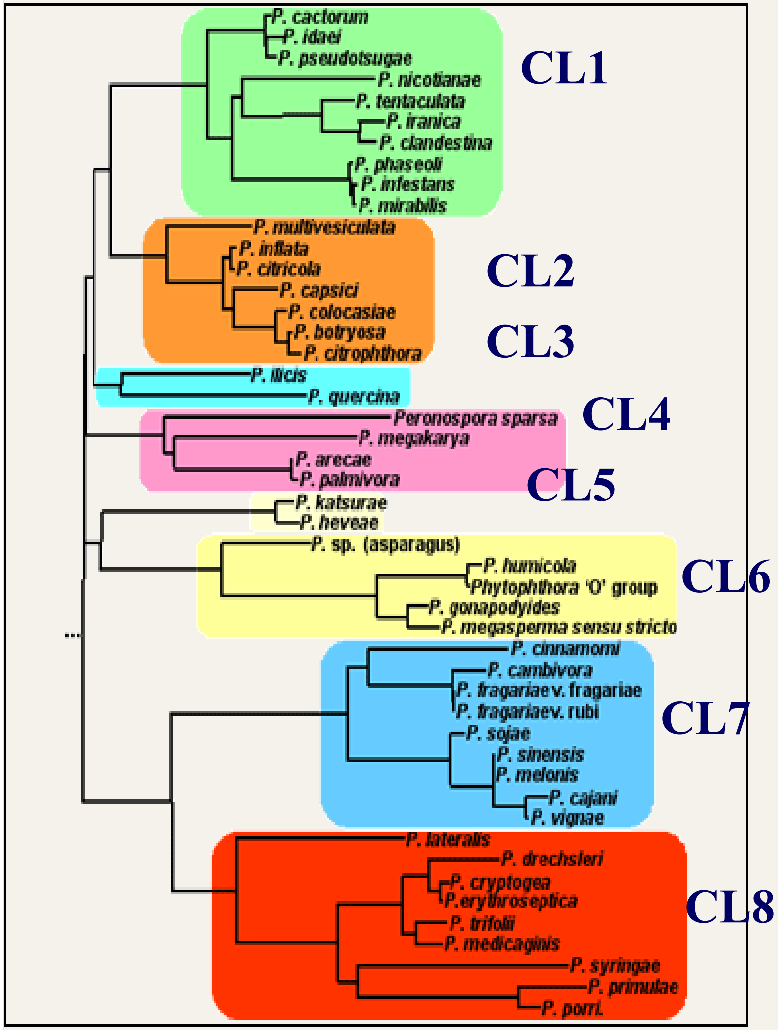
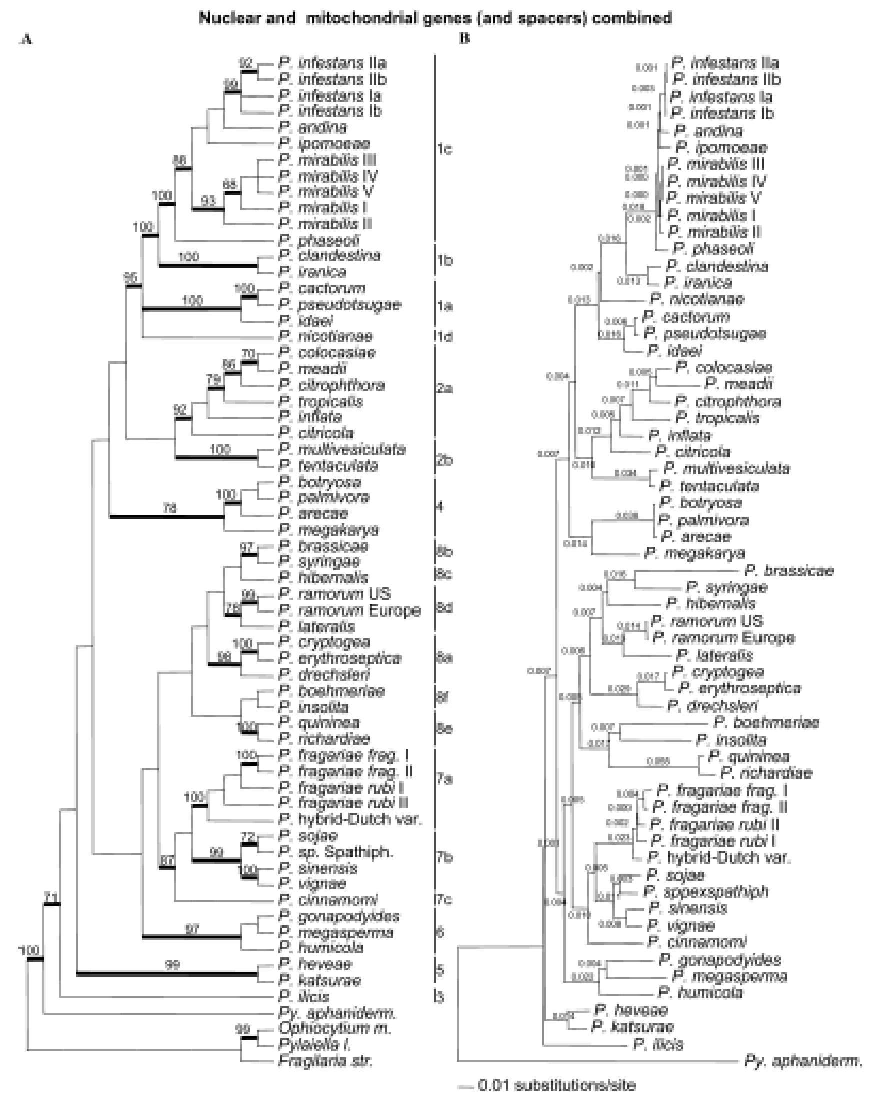
ITS



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

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

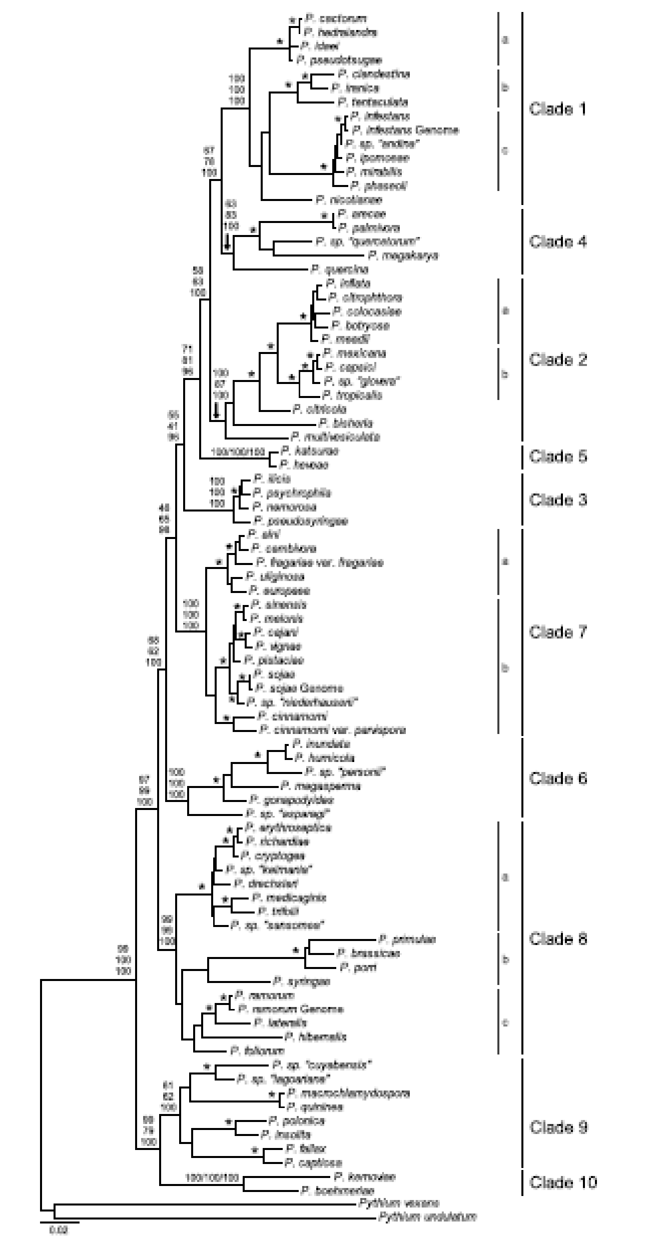

Table 1
Primers used in this study for DNA amplification and sequencing

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

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Available online 23 October 2007

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

7/25/08

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**

MDL

Phytophthora 'taxons' in process for official description

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

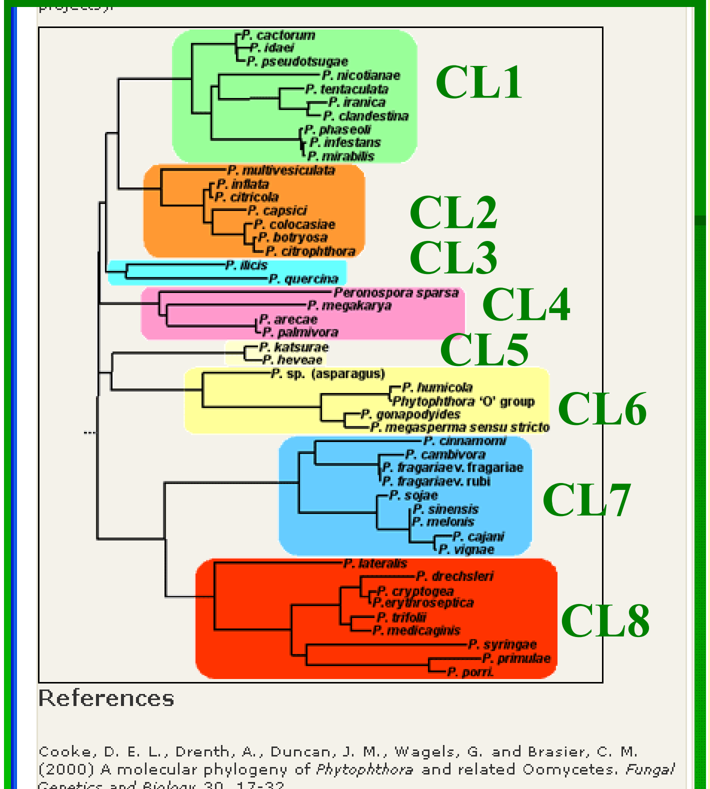
- ***P.*** **sp.** ***carica***
- ***P.*** **sp.** ***cuyabensis***
- ***P.*** **sp.** ***erwinii***
- **P. sp.** ***lagoariana***
- **Phytophthora sp.** ***novaeguinee***
- ***P.*** **sp. oregonsis**
- **P. sp. sansomea**
- ***P.*** **sp.** ***sulawesiensis***
- ***P.*** **sp.** ***zentmeyerii***

CLIVE BRASIER GROUP

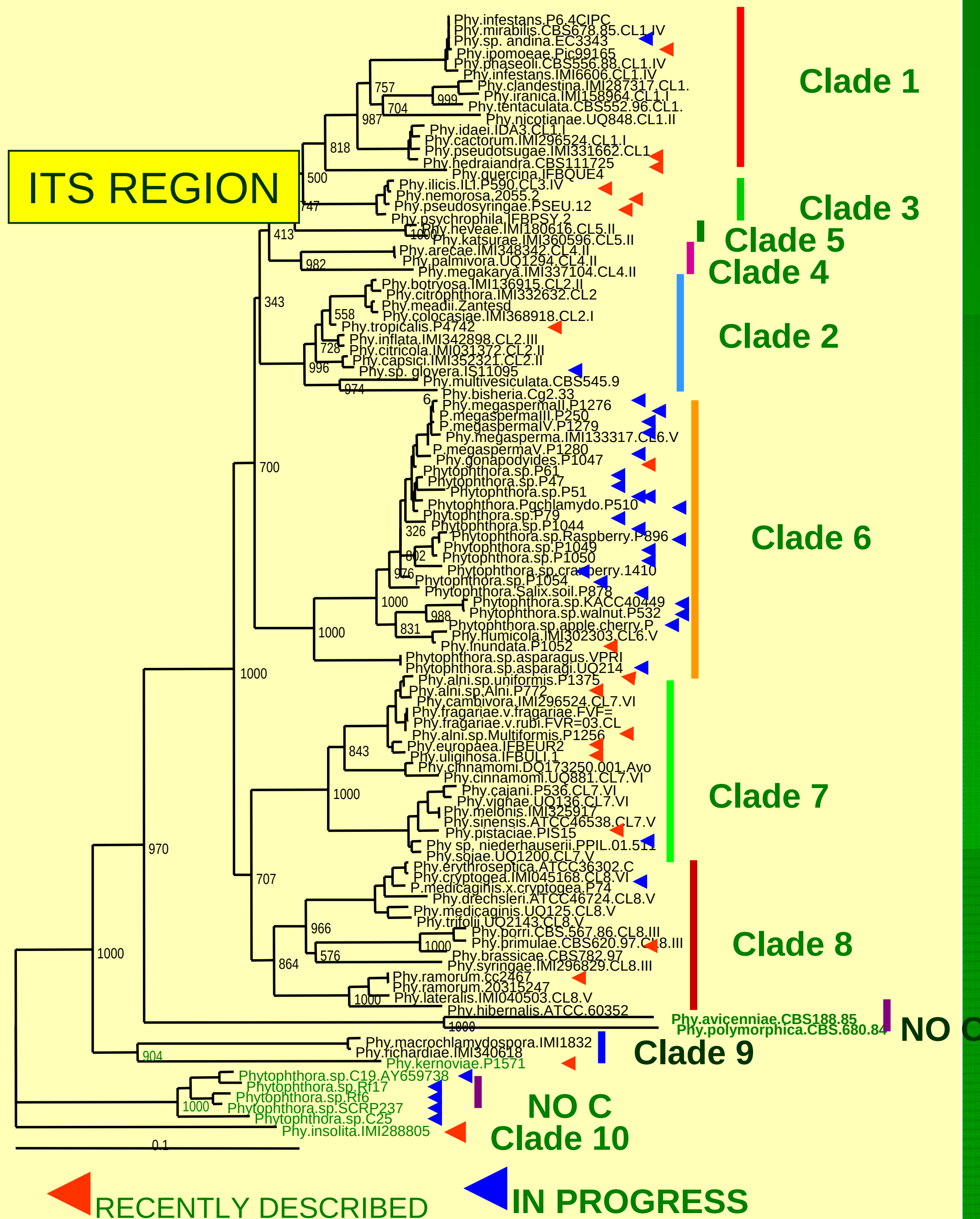
Five putative new species in ***P. megasperma*** **complex**

DAVID COOKE (4), GLORIA ABAD (2)

Six putative new species in ***P. insolita*** **complex**



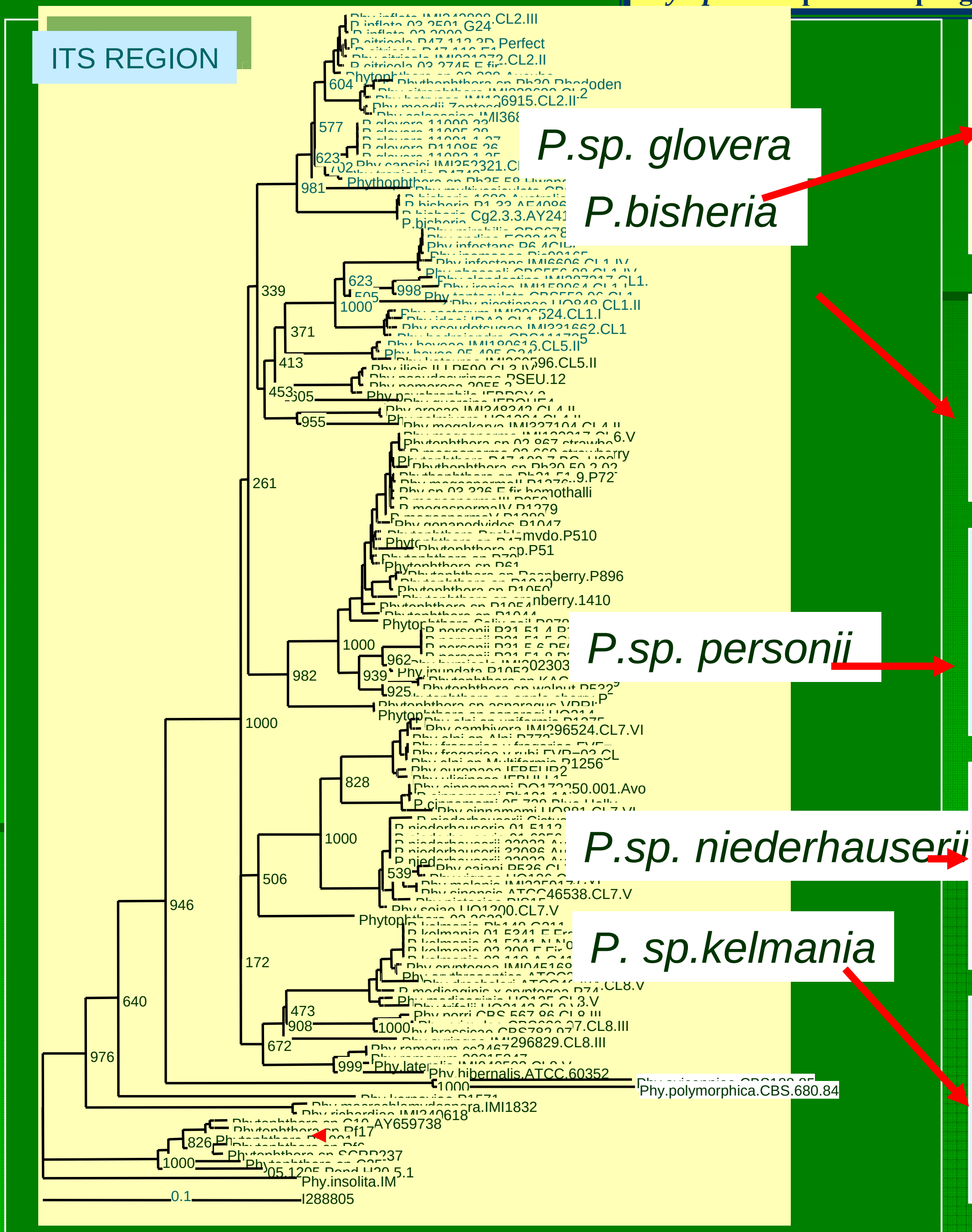
Cooke et al. 2000. Fungal Genetics And Biology 30, 17-32

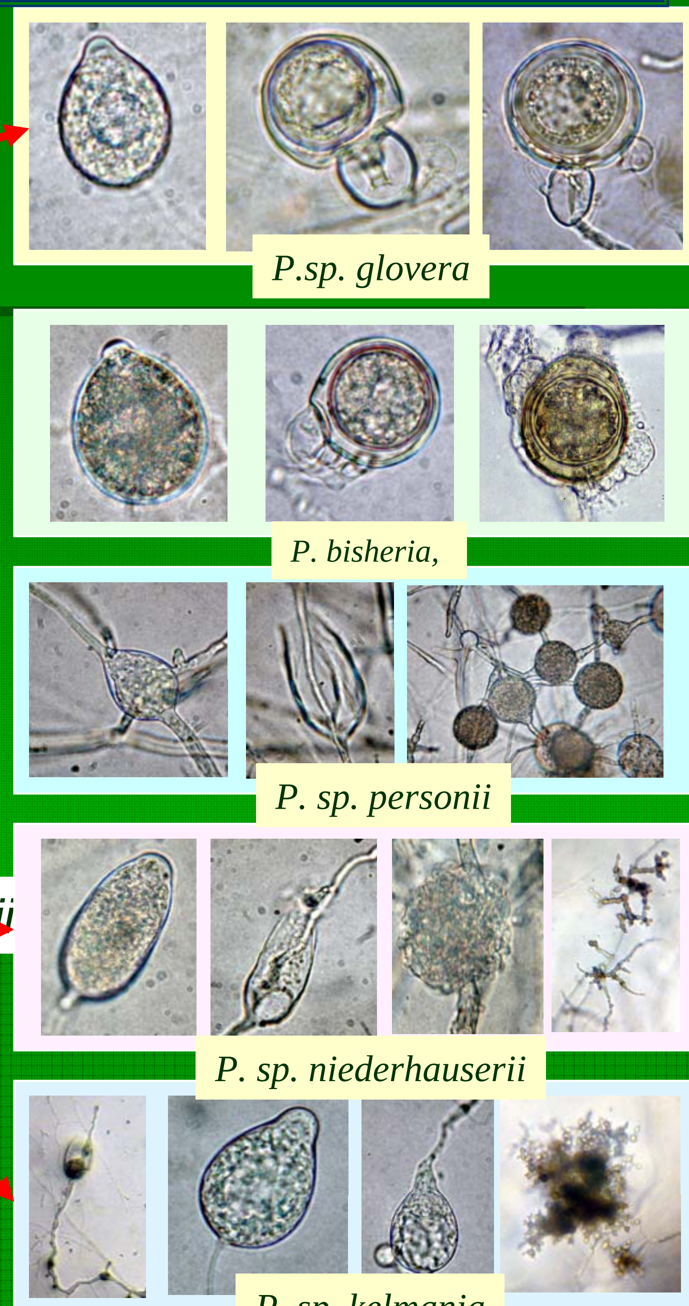


G. Abad, Ph. D. USDA/APHIS/PPQ/PHP/PSPI/MDL

Gloria Abad, Ph.D.

Phytopthora species in progress of drescription in the group of G. Abad





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

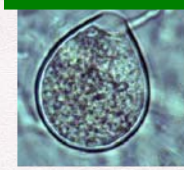
G. Abad 2004

PAPILLATED

NON-PAPILLATED (1)

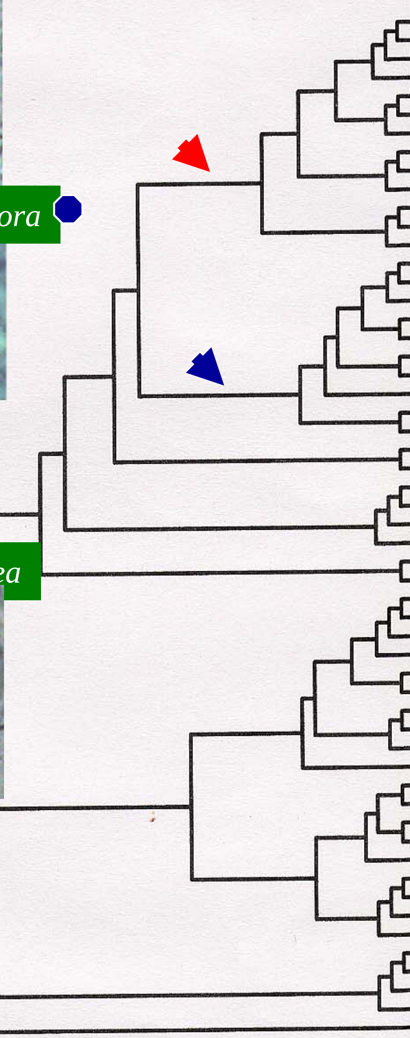
P. cactorum

P. citrophthora



P. cryptogea

ITS



PHYTOPHTHORA SPECIES	ANAMORPH PA	C	PE	PR	CH	HS	TELEO AN	H	GROUP GR	CO
P. clandestina	P	C/-	S	-	-	HS	P/A	HO	I	1
P. iranica	P	-	-	-	CH/-	-	P/A	HO	I	1
P. tentaculata	P	-	-	-	CH	HS	P/A	HT	I	1
P. nicotianae	P	-	-	-	CH	HS	A	HT	II	1
P. mirabilis	SP	C	S	-	-	-	A	HT	IV	1
P. phaseoli	SP	C	S	-	-	-	A	HO HT	IV	1
P. infestans	SP	C	S	-	-	-	A	HT	IV	1
P. cactorum	P	C	S	-	CH/-	-	P	HO	I	1
P. idaei	P	-	-	PR	-	-	P/A	HO	I	1
P. pseudotsugae	P	-	-	-	-	HS	P/A	HO	I	1
P. palmivora	P	C	S	-	CH	-	A	HT	II	4
P. areace	P	C	M	-	CH	-	A	HT	II	4
P. megakaria	P	C	M	-	CH	-	A	HT	II	4
P. citrophthora	SP	-	-	-	CH/-	-	U	U	II	2
P. botryosa	P	C	S	-	CH/-	-	A	HT	II	2
P. colocasiae	SP	C	M	-	CH	-	A	HT	IV	2
P. citricola	SP	-	-	-	-	-	P/A	HO	III	2
P. inflata	SP	-	-	PR	-	-	P	HO	III	2
P. glovera	SP	-	-	-	-	-	P/A	HO	III	NI
P. capsici	P	C	L	-	-	HS	A	HT	II	2
P. tropicalis	P	C	L	-	CH/-	HS	A	HT	II	NI
P. multivesiculata	SP	-	-	PR		HS	A	HO	IV	2
P. bisheria	SP	-	-	-	-	-	P	HO	III	NI
P. ilicis	SP	C	M	-	-	-	P	HO	IV	3
P. quercina	P	-	-	-	CH	-	P	HO	I	3
P. gonapoydes	NP	-	-	PR	-	HS	A	HT	VI	6
P. megasperma	NP	-	-	PR	-	HS	P/A	HO	V	6
P. humicola	NP	-	-	PR	-	HS	P/A	HO	V	6
Phytophthora sp. Asp.	ND	ND	ND	ND	ND	ND	ND	ND	ND	6
P. heveae	P	C	M	-	-	-	A	HO	II	5
P. katsurae	P	-	-	-	CH/-	-	A	HO	II	5
P. cryptogea	NP	-	-	PR	-	HS	A	HT	VI	8
P. erytroseptica	NP	-	-	PR	-	HS	A	HT	VI	8
P. kelmania	NP	-	-	PR	CH	HS	U	U	VI	NI
P. drechsleri	NP	-	-	PR	CH	HS	A	HT	VI	8
P. medicaginis	NP	-	-	PR	CH/-	HS	P/A	HO	V	8
P. trifolii	NP	-	-	PR	-	HS	P/A	HO	V	8
P. porri	SP	-	-	-	-	HS	P/A	HO	III	8
P. primulae	SP	-	-	-	-	-	P	HO	III	8
P. syringae	SP	-	-	-	-	HS	P/A	HO	III	8
P. lateralis	NP	-	-	PR	CH	HS	P	HO	V	8
P. vignae	NP	-	-	PR	CH	HS	A	HT	VI	7
P. cajani	NP	-	-	PR	-	HS	A	HT	VI	7
P. melonis	NP	-	-	PR	-	HS	A	HT	VI	7
P. sinensis	NP	-	-	PR	-	HS	A	HT	VI	7
P. sojae	NP	-	-	PR	CH	HS	P/A	HO	V	7
P. fragariae.var.fragariae	NP	-	-	PR	-	HS	P/A	HO	V	7
P. fragariae.var.rubi	NP	-	-	PR	-	HS	P/A	HO	V	7
P. cambivora	NP	-	-	PR	-	HS	A	HT	VI	7
P. cinnamomi	NP	-	-	PR	CH	HS	A	HT	VI	7
P. macrochlamydospora	NP	-	-	PR	CH	HS	U	U		NC
P. richardiae	NP	-	-	PR	-	HS	P/A	HO	VI	NC
P. insolita	NP	-	-	PR	CH	HS	U	U	V	NC
P. bohemariae	P	C	S	-	CH	-	A	HO	II	NI

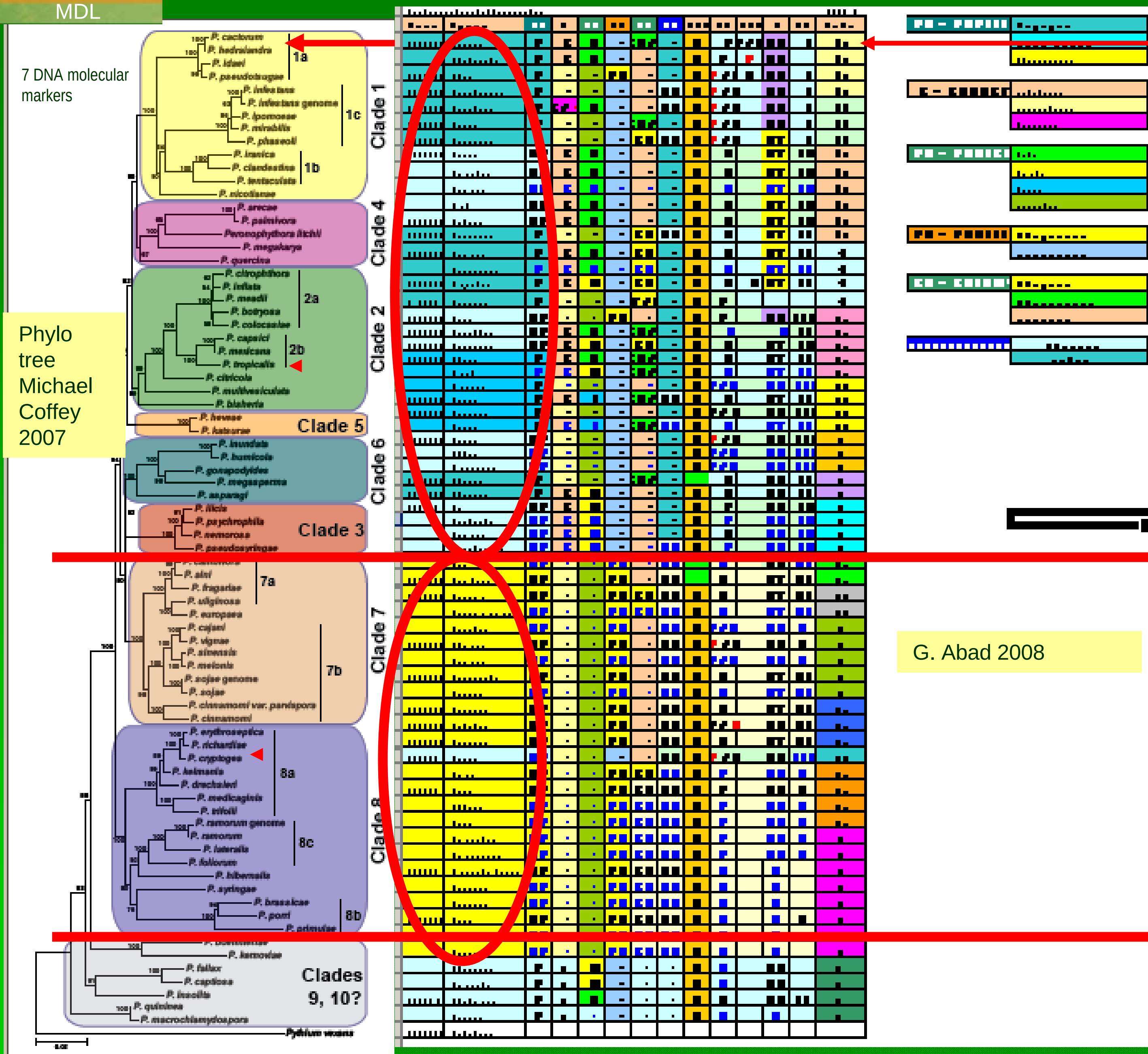
CONSPICUOUSLY PAPILLATED SPECIES
SEMIPAPILLATED SPECIES
NON PAPILLATED SPECIES

SPORANGIUM PA= PAPILLA (p = papillate, SP=semipapillate, NP=no papillate
C= CADUCITY (C=caducous, - = persistent)
PE= PEDICEL (L=long pedicel, M = medium pedicle, S= short pedicel)
PR= PROLIFERATION (PR=proliferating, - = non proliferating)
CH = CHLAMYDOSPORES PRESENT
HS = HYPHAE SWELLINGS PRESENT
TELEOMORPH: AN = ANTHERIDIA (A = amphigynous, P= paragynous)
H=HOMOTHALLISM (HO= homothallic, HE = heterothallic)

Clade 1
Clade 4
Clade 2
Clade 3
Clade 6
Clade 5
Clade 8
Clade 7

MDL

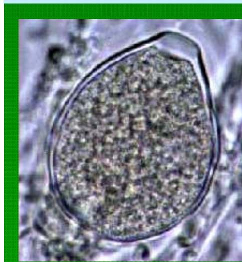
INTEGRATING MORPHOLOGICAL AND MOLECULAR FOR A UNIFIED TAXONOMY OF *PHYTOPHTHORA*



PAPILLATE

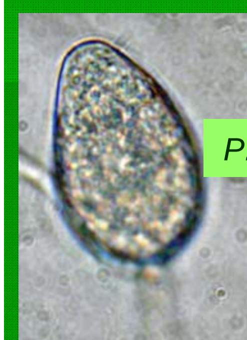
P. cactorum

SEMIPAPILLATE



P. citricola

NON-PAPILLATE



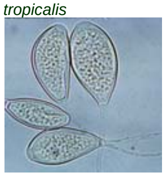
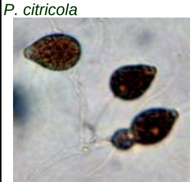
P. erytroseptica

MDL

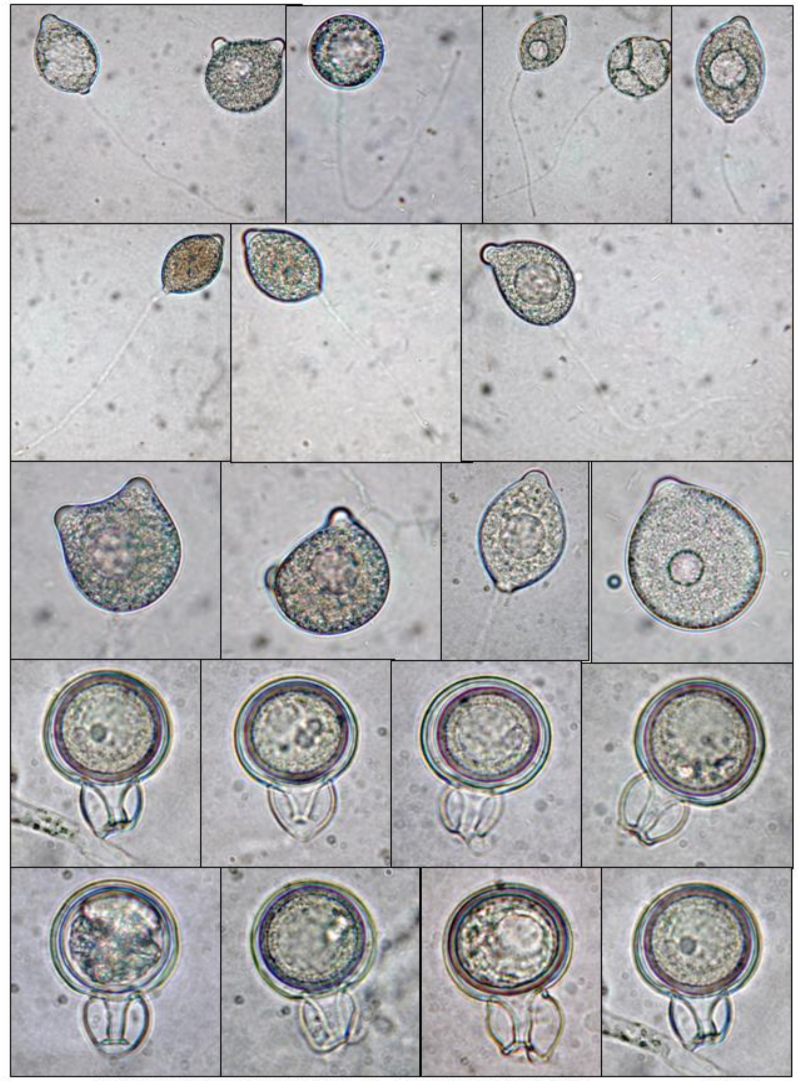
INTEGRATED MORPHOLOGICAL/PHYLOGENTIC KEY-2007

INTEGRATED MORPHOLOGICAL/MOLECULAR (PICTORIAL/PHYLOGENTIC) KEY FOR THE IDENTIFICATION OF 80 ??? *PHYTOPHTHORA* SPECIES

SPECIES IN COOKE CLADE 2

ASEXUAL STAGE				
SPORANGIOPHPORE	SPORANGIA	CHLAMYDOSPORES	HYPHAL SWELLINGS	
P. tropicalis 				
P. inflata 		ABSENT	ABSENT	SP C - Pe - Pr + Ch - Hs -
P. citricola 	 30-75 x21-44 av 47x34	ABSENT	ABSENT	SP C - Pe - Pr - Ch - Hs -
P. capsici 	 30-60 x 25-35 um			P? C + Pe L Pr - Ch +/- Hs +
P. glovera 11099-23 		ABSENT	ABSENT	SP C - Pe - Pr - Ch - Hs -

***Phytophthora capsici* Leonian (1922)**



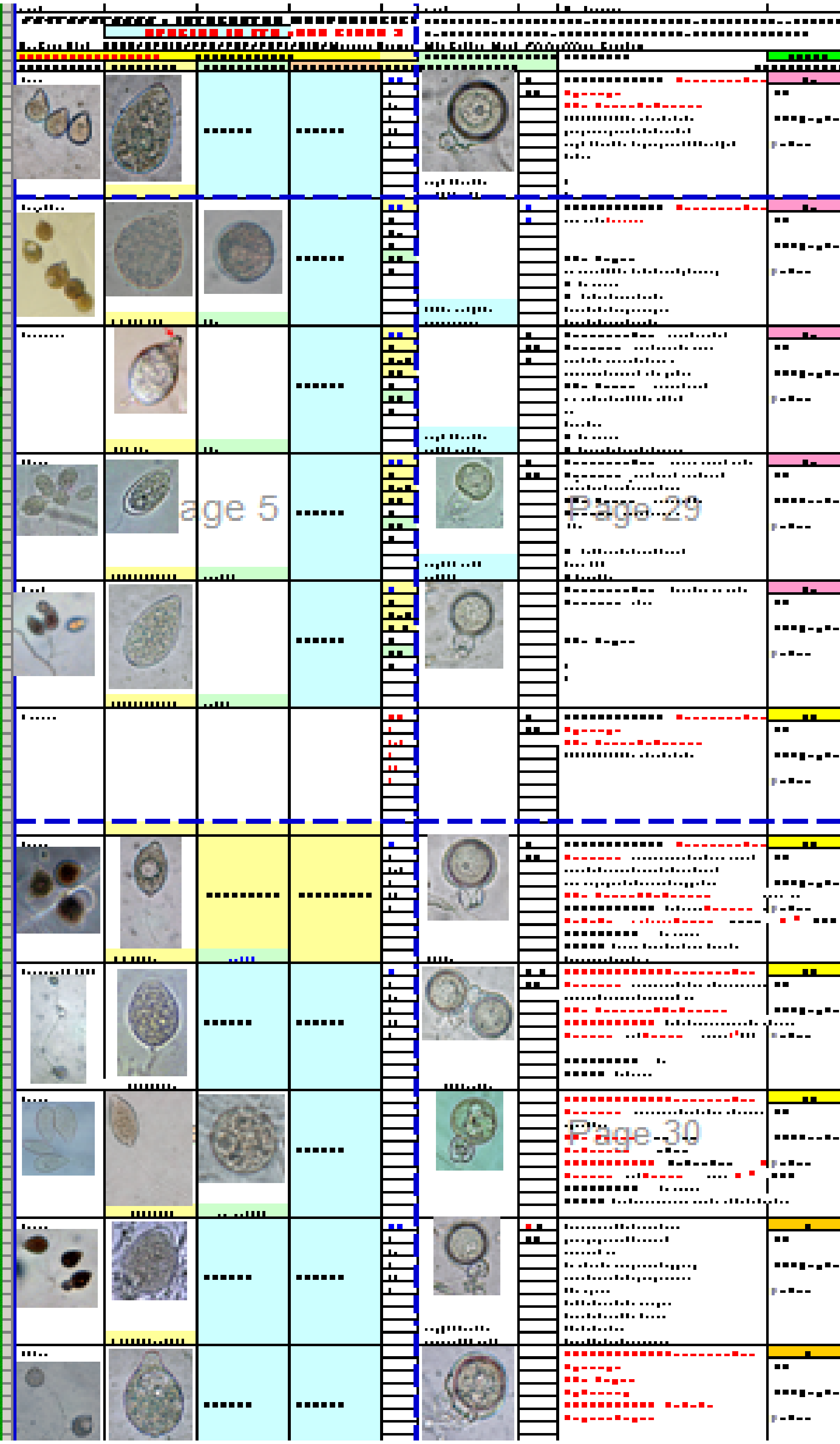
GLORIA ABAD USDA/AHIS/PPQ/MDL PLATES FOR *PHYTOPHTHORA* 4.20.07

MDL

INTEGRATED MORPHOLOGICAL/PHYLOGENTIC KEY-2007

Phytophthora species in CLADE 2

In Progress by ZG Abad



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

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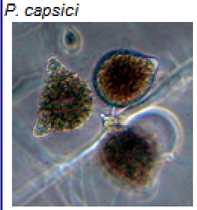
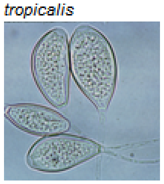
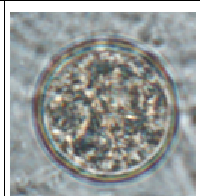
INTEGRATED MORPHOLOGICAL/PHYLOGENTIC KEY-2007

***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,		COMMENTS	CLADE
SPORANGIOPHPORE	SPORANGIA	CHLAMYDOSPORES	HYPHAL SWELLINGS	LEGEND	ANTHERIDIA, OOSPORES	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
P. sp. glovera 11099-23 	 43-61 x 26-36 um	ABSENT	ABSENT	P C - Pe - Pr - Ch - Hs -	 26-41 (av. 34) um	P/A HO III	ASEXUAL STAGE: Sporangiophore unbranched or simple sympodia. Sporangia papillate ovoid, obpyriform, obclavate, persistent and frequently with lateral attachment Chlamydospores and Hyphal swellings not known SEXUAL STAGE: Antheridia paragynous and amphyginous Oogonia smooth. Oospores aplerotic. T°: 35C **DISTRIBUTION:** Brazil **HOSTS:** Tobacco	**2b** ITS TEF 1 alpha β-tubulin
P. tropicalis 	 44 - 55 x 19 - 27	 common 27-34 µm	ABSENT				ASEXUAL STAGE: Sporangiophore umbellate and simple sympodia. Sporangia papillate ellipsoid and obpyriform with conpicuosly tapered bases. Chlamydospores common Hyphal swellings absent SEXUAL STAGE: Hetherothallic. Antheridia amphigynous Oogonia smooth. Oospores plerotic. T°: < 35C **DISTRIBUTION:** Cosmopolitan **HOSTS:** Black pepper, cocoa, macadamia, Rhododendron	**2b** ITS TEF 1 alpha β-tubulin

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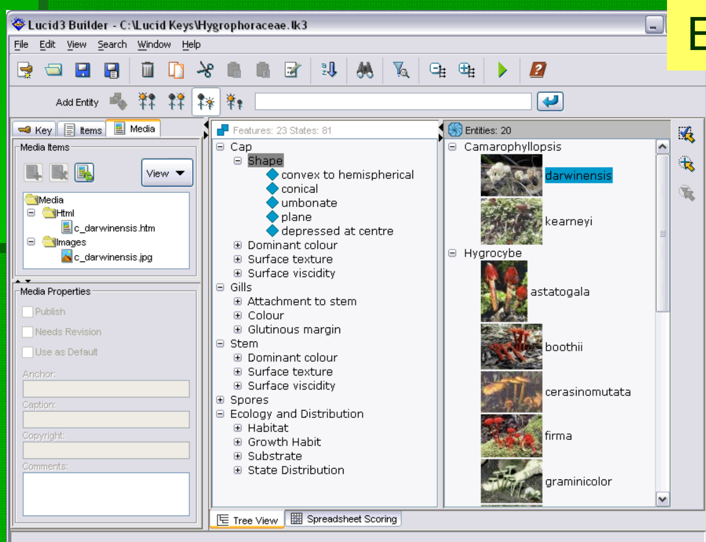
THE UNIVERSITY OF QUEENSLAND - AUSTRALIA

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

FUTURE
PYTHIUM
PHYTOPYTHIUM nov. gen
PYTHIOGETON

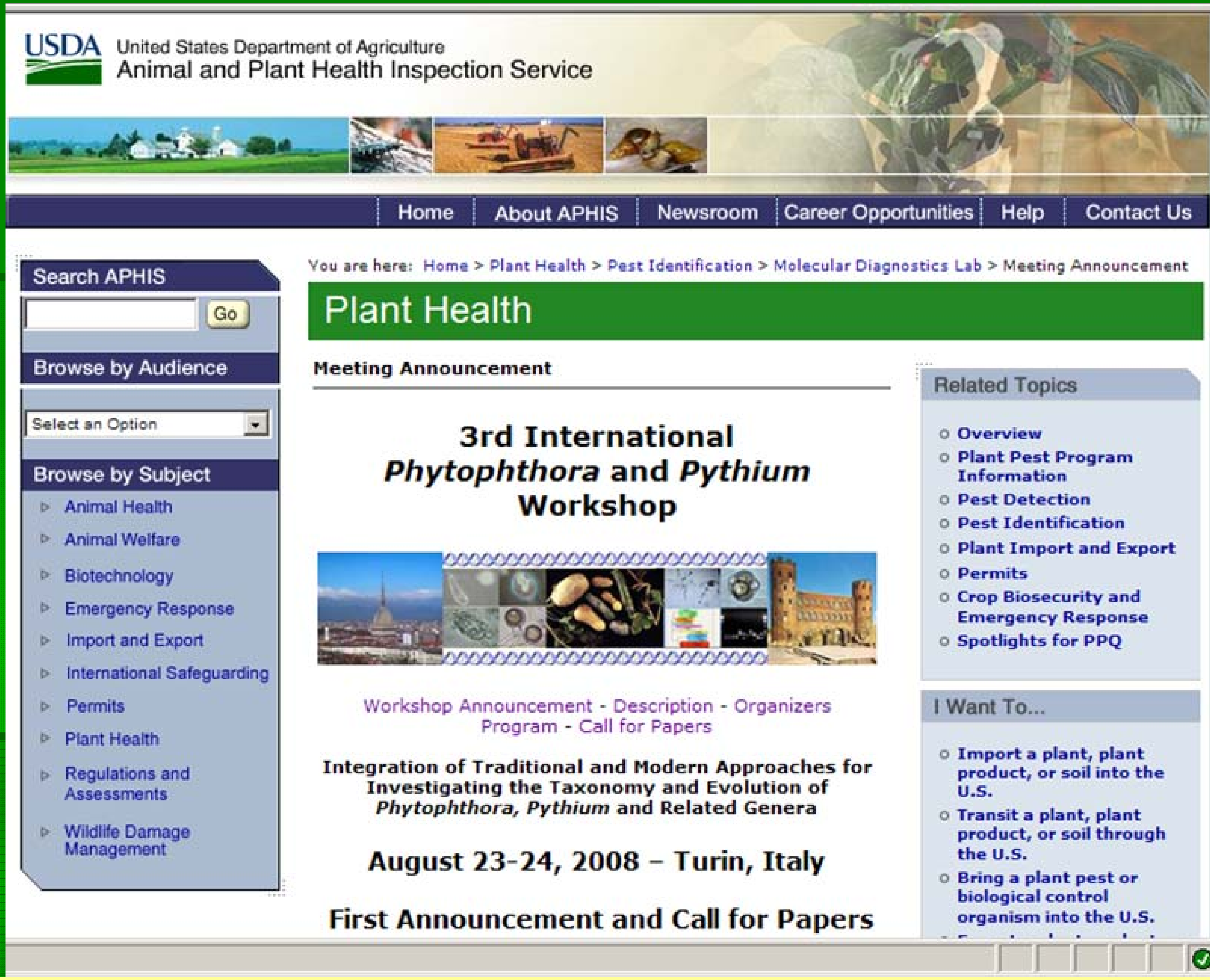
LISENCE TO Z.G.ABAD 2008 SOFTWARE

EXAMPLES



Lucid Keys Hygrophoraceae

Urban bee species of the San Francisco Bay area



http://www.aphis.usda.gov/plant_health/identification/phytophthora/index.shtml