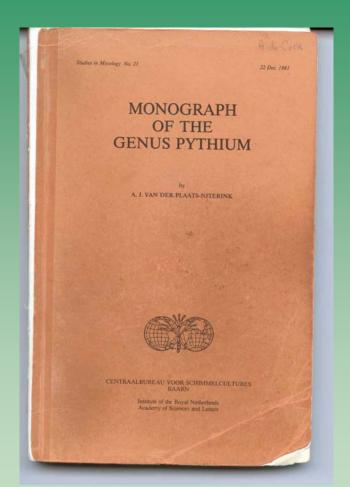
## Pythium: morphological taxonomy after the molecular revision

### Arthur de Cock<sup>a</sup>, Gloria Abad<sup>b</sup>, André Lévesque<sup>c</sup>, Gregg Robideae<sup>c</sup> & Henk Brouwer<sup>a</sup>

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Van de Plaats-Niterink -1981

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#### Molecular phylogeny and taxonomy of the genus Pythium

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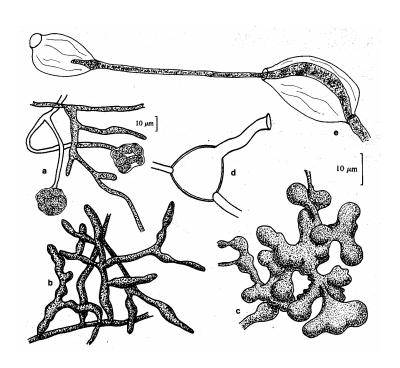
The phylogeny of 116 species and varieties of Pythium was studied using paraimony and phenetic analysis of the TIS region of the nuclear ribosonata DNA. The D1, D2 and D3 regions of the adjacent large subunit nuclear ribosonata DNA of half the Pythium strains were also sequenced and gave a phylogeny congener with the ITS data. All the 40 presently available ex-type strains were nucleaded in this study, as well as 20 sequences of recently described species from GenBank. Species for which no ex-type strains were available were represented by either authentic strains (s) strains used in the 1981 monograph of the genus by van der Plant-Niterink (33), or strains selected on morphological criteria (17). Paraimony analysis generated two major clealer representing the Pythium species with filamentous or globess speciangia. A small clade of species with contiguous speciangs was found in between the two main clade. A total number of 11 morphological characters. Many characters used in species descriptions, such as not never the consensation as one morphological characters. Many characters used in species descriptions, such as not never consensation as one conclusion with the secretion of Printing and the strains with all ITS sequences of Pythium in GenBank revealed limited infrasesectic variations with the exercision of Printing and Printenday. Printenday. Printenday Printenday and Computations. wan pis)ogeny. A comparison of the ex-type and representative strains with all Tis Sequences of Pythone in Genthan revealed limited intapsectic variations with the exception of P\_notineum, P\_i pregulare, P\_i betterodallicum, and P\_nitionum. The total number of species examined was 116 (including 60 ex-type strains). Twenty-six species had ITS exquences desirated on outself sentials to formenty described species, suggesting possible composition; The importance of comparing ITS sequences of putative new species to the now available ITS database in order to avoid unwarranted new species names bring introduced.

Studies of genera and species within the Suprolegation of the keys of Dick (1990) are the most recent tools available to identify most described species of the most important morphological characteristics for ideal in the substitution of the proposal subunit of 14 species of convergence, including P. monospermum and P. minorthal morphological characteristics for ideal interest in the proposal subunit of 14 species of convergence, including P. monospermum and P. minorthal morphological characteristics for ideal interest in the substitution of the proposal subunit of 14 species of convergence, including P. monospermum and P. minorthal subunition in the proposal subunit of 14 species of proposal subunit of 14 spec

Lévesque & De Cock - 2004



#### Sporangium types in Pythium

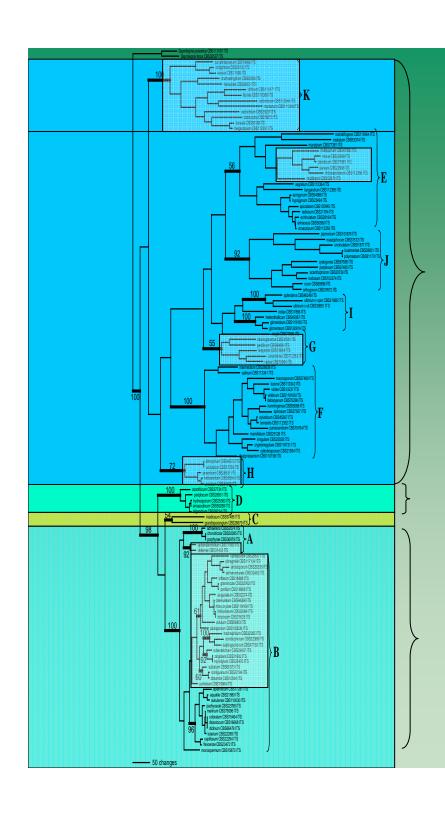


filamentous

filamentous-inflated

globose

globose, internally proliferating



#### ITS tree of 125 Pythium species

Correlation of clustering and sporangium type

#### **Globose**

internally proliferating

#### **Contiguous**

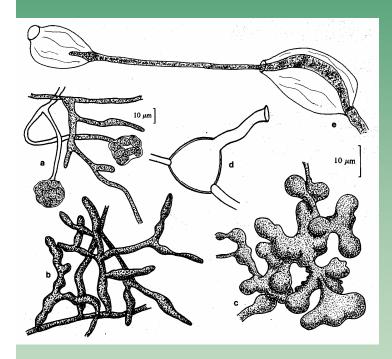
#### **Filamentous**

inflated

Tree generated by parsimony analysis with PAUP of ITS sequences of all *Pythium* species available in culture. Clades are labeled as in Lévesque and De Cock (2004).



#### Sporangium types in Pythium



filamentous

filamentous-inflated

contiguous



globose

globose, internally proliferating

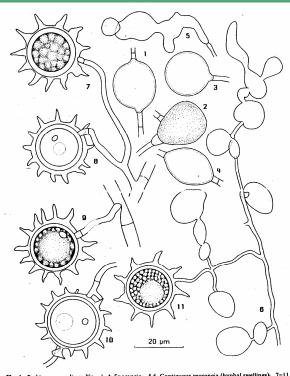
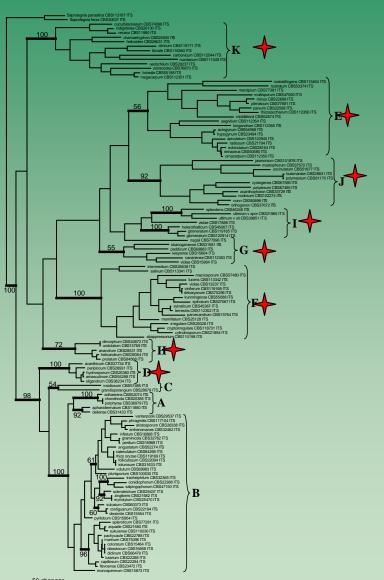


Fig. 4 Pythium amasculinum Yu. 1-4. Sporangia: 5.6. Contiguous sporangia (hyphal swellings): 7-11. Oogonia, antheridi and oospores [S 69-6, type].



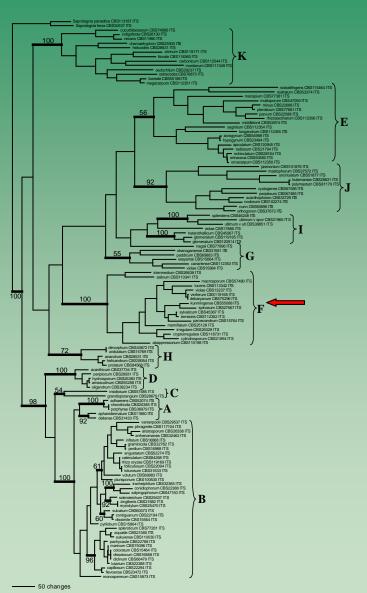


#### Oogonium ornamentation

Species with ornamented oogonia are present in

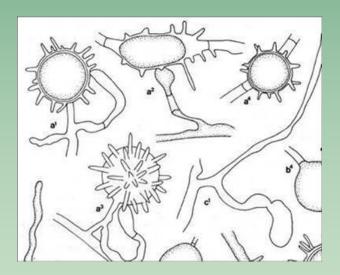
- each of the clades with globose sporangia
- the clade with contiguous spg
- in none of the clades with filamentous sporangia





#### Oogonium ornamentation

Ornamentation of oogonia in Clade F is typically digitate

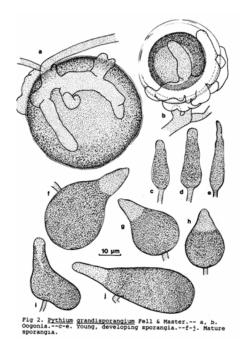


Pythium spinosum



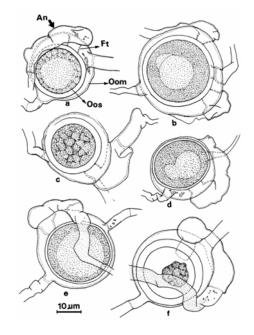
#### Correlation of clustering and other morphological characters





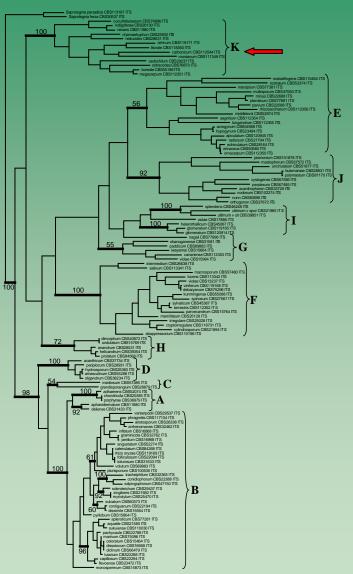
P. grandisporangium

Clade C: Morphology and habitat very different; phylogenetic relatedness not confirmed by COI and showing differences between Maximum Likelihood and Parsimony analyses for LSU.



P. insidiosum







Pythium carbonicum clade K





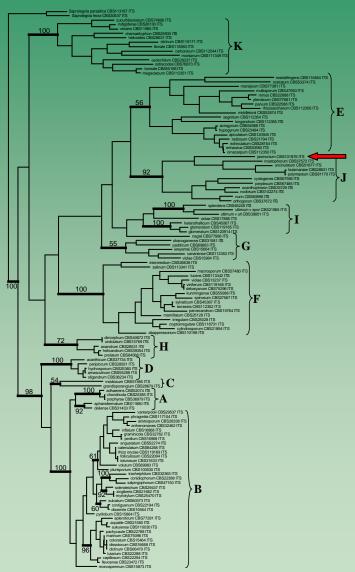
#### Oogonium ornamentation



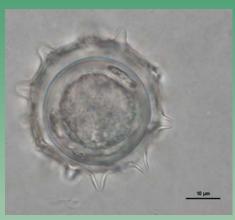
P. erinaceus clade E

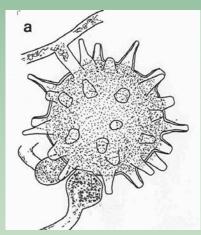
cross septa are present in part of the spines in Pythium ernaceus, P. echinulatum, P. radiosum, and P. ornacarpum









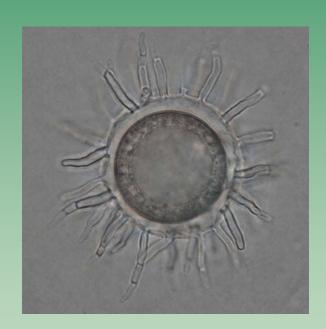


P. jasmonium sp. nov. clade J





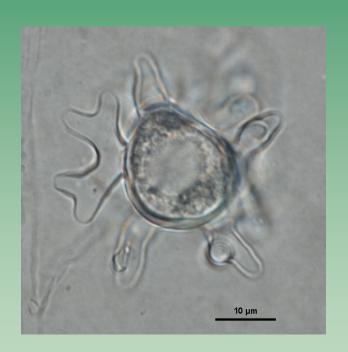




Pythium solare sp. nov. Clade I







Pythium paddicum Clade G

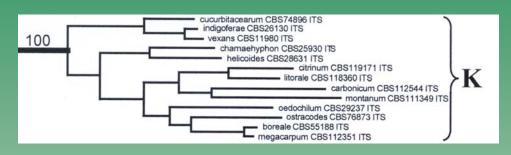


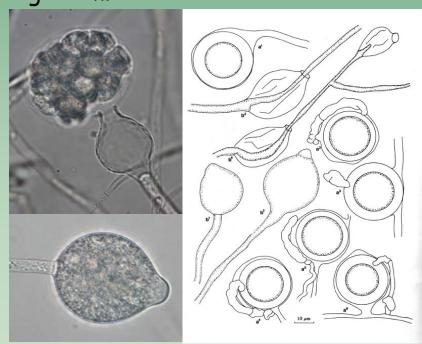
Correlation of clustering and other morphological characters



#### Correlation of clustering and other morphological characters

Clade K: sporangia globose to ovoid with papilla and often proliferating internally, large, oogonia, thick-walled oospores, 1-2 elongate antheridia, laterally applied to the oogonium.





P. carbonicum

P. ostracodes

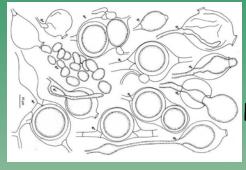
Sequence analysis shows this clade to be closer to *Phytophthora*.

Sporangia and oogonia may show similarity to *Phytophthora*, however, zoospore discharge is *Pythium*-like.

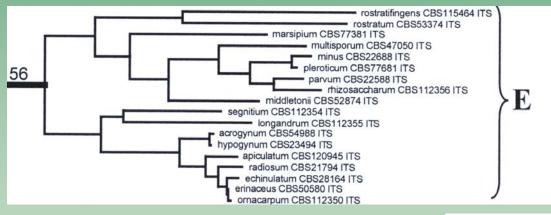
The clade represents a genus intermediate between *Phytophthora* and *Pythium* for which the name *Phytopythium* is proposed.



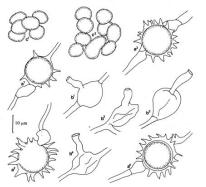
#### Correlation of clustering and other morphological characters



#### P. multisporum



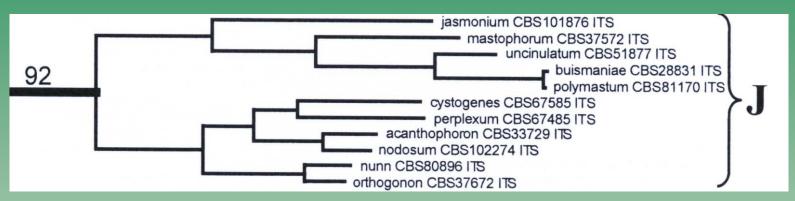
# Clade E: P. rostratifingens-clade: globose, proliferating sporangia or globose hyphal swellings. Oogonia smooth P. segnitium-clade: ovoid to elongate, nonproliferating sporangia; mostly a single, hypogynous antheridium.

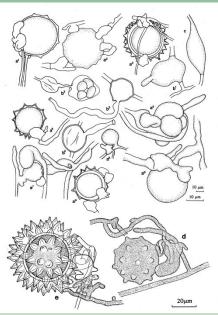


P. echinulatum



#### Correlation of clustering and other morphological characters



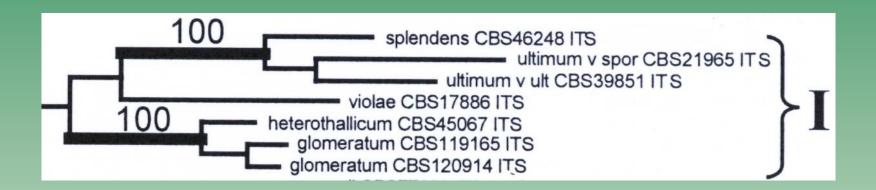


P. polymastum

Clade J: only the subclade P. jasmonium-polymastum is morphologically distinct: large oogonia with conical spines, thick-walled oospores, large globose sporangia.



#### Correlation of clustering and other morphological characters



Clade I: No obvious common morphological characters in this clade. Most species do not produce zoospores.



#### Correlation of clustering and other morphological characters

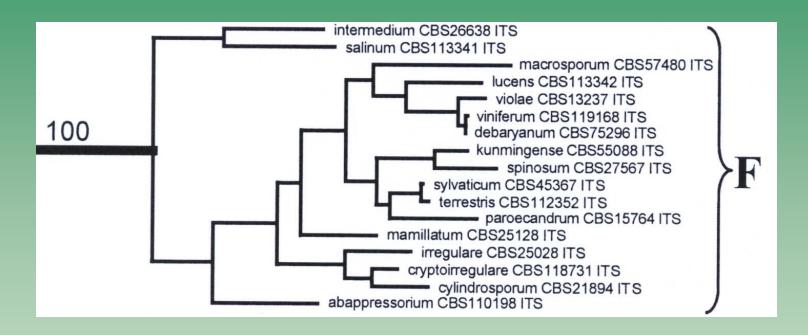


Clade 6: ovoid, internally proliferating sporangia and smooth oogonia.

Ornamentation on the oogonia of *P. paddicum* is unique. Other characters variable. Mainly from monocotyledons in Asia and the USA.



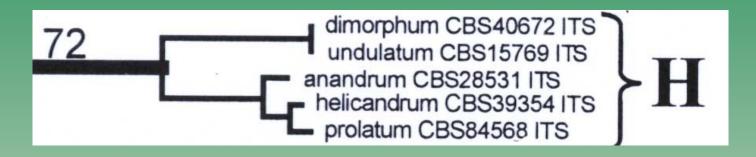
#### Correlation of clustering and other morphological characters

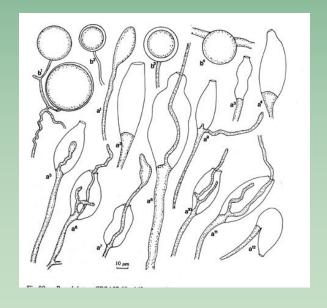


Clade F: important, fast growing phytopathogenic species with a worldwide distribution. Globose non-proliferating sporangia or hyphal swellings present. Most species do not or rarely produce zoospores.



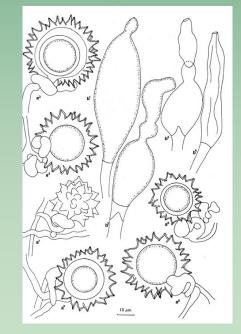
#### Correlation of clustering and other morphological characters





P. undulatum

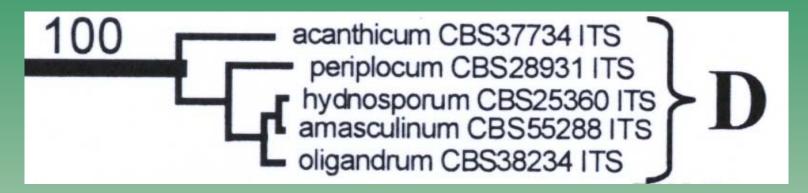
Clade H. Very large, ovoid to elongate, internally proliferating sporangia and ornamented oogonia.

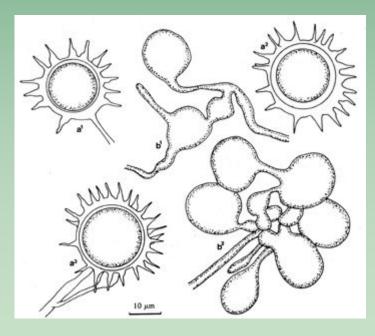


P. helicandrum



#### Correlation of clustering and other morphological characters





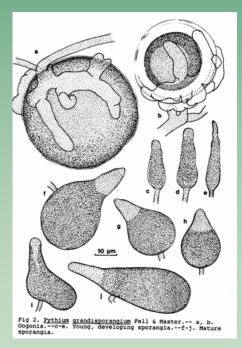
Clade D: Contiguous sporangia, oogonia with acute spines.
Antheridia absent or entirely attached to oogonium, constricted. Mycoparasites.

P. oligandrum



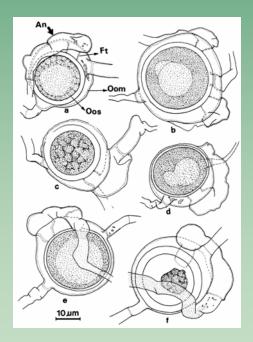
#### Correlation of clustering and other morphological characters





P. grandisporangium

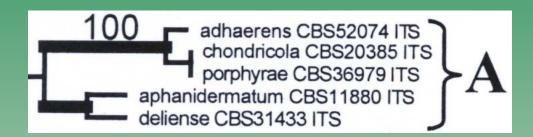
Clade C: Morphology and habitat very different; phylogenetic relatedness not confirmed by COI and showing differences between Maximum Likelihood and Parsimony analyses for LSU.

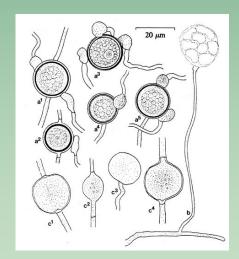


P. insidiosum

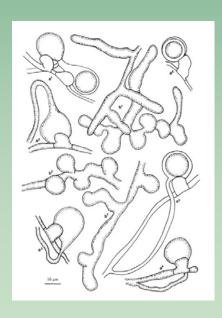


#### Correlation of clustering and other morphological characters





P. porphyrae

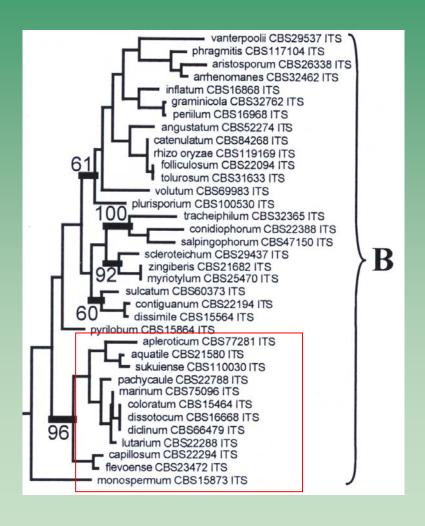


Clade A: P. adhaerens cluster: filamentous non-inflated sporangia, very slow growth. From algae. P. aphanidermatum cluster: filamentous inflated sporangia, very fast growth, often intercalary antheridia. From dicotyledons in warmer regions.

P. deliense



#### Correlation of clustering and other morphological characters



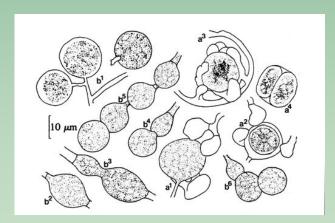
#### Clade B

P. vanterpoolii cluster: filamentous, inflated sporangia; smooth oogonia. Most other characters variable. Predominantly from grasses.

P. apleroticum-cluster: filamentous non-inflated sporangia, smooth oogonia, moderate growth rate.

#### "Species specific" morphology:

- ornamentation: P. paddicum, P. carbonicum, P. solare, P. jasmonium
- segmentation: insidiosum
- deciduous sporangia: intermedium, attrantheridium



P. intermedium

#### Characters that show no significant correlation with clustering:

- sporangium size
- antheridium origin and number
- · oogonium size
- · oospore wal thickness
- · apressoria
- · heterothallism
- · etc.

#### Conclusions:

- Sporangium type is evolutionary significant
- the contiguous type is a distinct sporangium type
- oogonium ornamentation is polyphyletic but shows correlation with some (sub-)clades
- some clades are characterized by a subset of characters
- most characters do not correlate with evolutionary patterns but they are useful for identification