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An annotated list of genus *Pythium* from India

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Abstract

Up-to-date information is presented based on an intensive search of literature records on the identity, occurrence, nomenclature, substratum, host ranges, geographical distribution and literature references of the genus *Pythium* from India. All *Pythium* species published until 2020 are included in this list. The survey result of all forms of analyses revealed that India has 55 species of *Pythium* belonging to the phylum Oomycota indicating the presence of rich mycoflora. Distribution of these *Pythium* species reported so far from freshwater and terrestrial habitats of various Indian states are listed alphabetically. The most frequently collected species are *Pythium aphanidermatum*, *P. spinosum*, and *P. ultimum*. The majority of these species were found as a parasite on a wide range of plants in both freshwater and terrestrial environment. Overall, this systematic checklist provides the total count of *Pythium* species, currently known to occur in India and it is also a valued addition for comparing *Pythium* diversity in India as well as the world. Besides, it represents the first comprehensive overview of *Pythium* since 1996 from India. The knowledge generated by this working checklist comprising accepted taxa in *Pythium* from India is hoped to be beneficial in the progress of the systematics, diversity, ecology, plant protection, aquaculture, ichthyopathology, quarantine and many other diverse arrays of applied scientific disciplines in the country.

Key words – Disease – distribution – ecology – parasitic – soil-borne pathogen – saprobes – systematic taxonomy

Introduction

The oomycete genus *Pythium* (Pythiaceae, Pythiales) is a large heterogeneous group currently placed under the kingdom Chromista or Heterokonta (also called Straminipila) in the supergroup Chromalveolates (Kirk et al. 2008, Beakes et al. 2014, Dubey et al. 2020a). This large genus of fungal-like organisms is characterized by profusely branched, well developed, filamentous (thread-like), coenocytic (non-septate) mycelium composed principally of cellulosic cell walls with filamentous to globose sporangia/zoosporangia like hyphal swellings containing asexually formed heterokont zoospores and sexually produced organs such as antheridia, oogonia and oospores (van der Plaats-Niterink 1981, Beakes et al. 2014). Currently, this cosmopolitan genus includes more than over 300 recorded species out of which 130 have been well-recognized (Dick 1990) with a wide range of life histories that includes many saprophytes, plant or animal pathogens and mycoparasites

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in various types of soil and aquatic environments (Lévesque & de Cock 2004, Webster & Weber 2007, Mufunda et al. 2017). The *Pythium* comprises endophytes, saprobes and plant pathogens. However, most of the species in this largest oomycete genus often serve as obligate saprotrophs on animal and plant debris; significantly helping in maintaining the natural nutrient cycling and the energy budget of the freshwater and terrestrial ecosystem around the world (Dick 2001, Dubey et al. 2020a). However, under certain favorable conditions, *Pythium* spp. can parasitize a wide range of hosts including algae, crustacean, fish, insects or mosquito larvae, humans beings, even other fungi or *Pythium* species as mycoparasites and plants (van der Plaats-Niterink 1981, Kawamura et al. 2005, Weiland et al. 2012, Ho 2013). The species belonging to *Pythium* are the causal agents of rot and damping-off diseases of numerous wild as well as cultivated plants (Martin & Loper 1999, Villa et al. 2006, Broders et al. 2007). The *Pythium*, being obligate plant parasites, cause a variety of plant diseases or can damage to plant products, in most cases collectively accounts for multibillion-dollar losses due to the death of a large area of the world economically important cash crops (van West et al. 2003). Thus the knowledge of this most economically important group oomycete in a particular area is important concerning the biology, systematics and taxonomy as well as for phytopathological remediation purposes to prevent such diseases or reduce the losses they cause.

To our knowledge, since the earliest record by Butler (1907), many *Pythium* specimens have been collected from India. The vast biodiversity and climatic conditions of India contribute to the vast diversity, distribution and host range of this group. However still, a large number of the representatives of this genus have not been reported and extensively studied from India. Further, the information pertaining to this genus and their host plant association is scattered and restricted to some regional studies in various plant pathological reports and some general fungal lists. Some publications provided lists of the *Pythium* from India (Rao 1963, Misra & Hall 1996), but these were incomplete, outdated and largely based on morphological data. Information regarding the occurrence and distribution of *Pythium* from India is difficult to obtain, primarily because literature is scattered and some of it is unavailable. Over the years with the advent of molecular biology, *Pythium* has undergone several taxonomic revisions, updates and a significant number of new records have been reported from India. The need for an up-to-date list is therefore evident. To remedy this, in the present contribution a comprehensive review of the species, host range and geographical distribution of *Pythium* in India is provided so that it will be more widely available to Indian phytopathologists and researchers interested in this ecological group. Moreover, data of earlier researchers are listed, to make this new checklist as complete as possible to serve as a baseline for future mycological studies.

Materials & Methods

All the previously published information relevant to the genus *Pythium* in India were surveyed and compiled (latest accessed 10/04/2020). The checklist was primarily based on an exhaustive bibliographic survey of the literature published in various national and international journals, online available digitized records of specimens, monographs, reports, books, book chapters and even magazines that included records of *Pythium* spp. from India. The different collections were compiled by disposing of each single species and subspecies/variety including the name of the species in alphabetical order and the authors' epithets, host range/substrate, habitat or geographical distribution, and related recent references. Besides, from a phytopathological point of view, a family-wise list of the susceptible host plant for *Pythium* mediated diseases was prepared to assess their host range and variation in India. All species names were cross-checked for its validity and some preceding names as recorded in the cited publications have been substituted with their currently accepted scientific name according to the fungal nomenclature database MycoBank and Species Fungorum (http://www.mycobank.org, www.speciesfungorum.org, www.indexfungorum.org) website.

Results

A total of 55 species and 4 varieties of the genus *Pythium* are listed and arranged alphabetically in chronological order with their respective substrate/host range, places of collection, and related references from India (Table 1). The most frequently collected *Pythium* species are *P. debaryanum*,

P. aquatile, P. aphanidermatum, P. deliense, P. dissotocum, P. graminicola, P. intermedium, P. middletonii, P. myriotylum, P. spinosum, P. ultimum, and *P. vexans*. While the distribution of *P. anguillulae-aceti, P. apleroticum, P. cucurbitacearum, P. drechsleri, P. echinogynum, P. elongatum, P. helicoides, P. hypogynum, P. indigoferae, P. kashmirense, P. lobatum, P. marsipium, P. monospermum, P. multisporum, P. parasiticum, P. periilum, P. periplocum, P. polytylum, P. pulchrum, P. rhizo-oryzae, P. rhizosaccharum, P. torulosum, P. stipitatum* and *P. campanulatum* were found to be rare. Besides, over 46 *Pythium* taxa were recorded over the plants either as a parasite or saprophyte. The plants belonging to the family Malvaceae, Zingiberaceae, Solanaceae, Gramineae, Zygnemataceae, Cucurbitaceae, Papaveraceae, Araceae, Fabaceae, Apiaceae, Brassicaceae, Piperaceae, Anabantidae, Rosaceae, Geraniaceae and Cyprinidae are mostly prone to *Pythium* infection. After compilation of the literature records, it was noticed that most of the taxa were reported from South India followed by North India, East India and West India, respectively. In between them, most reports are available from Coimbatore (Tamil Nadu), Nainital (Uttarakhand), Varanasi, Gorakhpur (Uttar Pradesh) and Hyderabad (Telangana), respectively. Neither of the taxa has been ever recorded from Indian states such as Punjab, Goa, Andhra Pradesh, Orissa, Chhattisgarh, Jharkhand, Arunachal Pradesh, Manipur, Mizoram, Nagaland, and Tripura. Even though of the above results, about one-third of all *Pythium* species are more or less uniformly distributed throughout India. These ubiquitous species include *P. graminicola, P. insidiosum, P. aphanidermatum, P. dissotocum, P. myriotylum, P. deliense, P. ultimum, P. catenulatum, P. debaryanum, P. dissotocum, P. intermedium, P. middletonii, P. spinosum* and *P.* vexans. The Indian checklist contains several species that have importance to humans, such as important pathogens of crops (e.g., *P. aphanidermatum, P. acanthophoron, P. aquatile, P. catenulatum, P. debaryanum, P. deliense, P. dissotocum, P. echinogynum, P. echinulatum* and *P. graminicola*, etc), algae (*P. carolinianum, P. catenulatum* and *P. cucurbitacearum*), fishes (*P. afertile* and *P. undulatum*), Mosquito larva and human (e.g., *P. insidiosum*). Most of the India *Pythium* species were recorded from soil and water habitats whereas neither spp. was reported from the marine environment. *P. acanthicum, P. apleroticum, P. drechsleri, P. elongatum, P. drechsleri, P. elongatum, P. kashmirense, P. lobatum, P. mamillatum, P. multisporum, P. parasiticum, P. periilum, P. pulchrum, P. rhizo-oryzae, P. rhizosaccharum* were reported to be saprophytic in India. In contrast, *P. acanthophoron, P. aphanidermatum, P. aquatile, P. carolinianum, P. catenulatum, P. debaryanum, P. deliense, P. dissotocum, P. echinulatum, P. helicoides, P. hydnosporum, P. indigoferae, P. irregular, P. middletonii, P. periplocum, P. spinosum, P. torulosum, P. vexansi, P. diclinum* were parasitic as well as saprophytic in their mode of nutrition. In this sense, *P. afertile, P. anguillulae-aceti, P. cucurbitacearum, P. echinogynum, P. graminicola, P. hypogynum, P. inflatum, P. insidiosum, P. intermedium, P. iwayamai, P. marsipium, P. monospermum, P. myriotylum, P. oedochilum, P. oligandrum, P. paroecandrum, P. polytylum, P. rostratum, P. splendens, P. ultimum, P. undulatum* were parasitic in their mode of nutrition. The majority of the listed *Pythium* taxa were identified sorely based on the morphological features such as vegetative organs like the formation of hyphal swellings; asexual structures such as size and shape of zoosporangium/ heterokont zoospores, the formation of papilla/discharged tubes and patterns of their discharge; and reproductive organs including structure, production and mode of attachment of the antheridium, oogonium and oospores. However, in recent years, several *Pythium* spp. such as *P. insidiosum, P. rhizosaccharum, P. aphanidermatum, P. dissotocum, P. myriotylum, P. deliense, P. rhizo-oryzae, P. graminicola, P. catenulatum, P. stipitatum, P. campanulatum* and *P. helicoides* were subjected to morpho-molecular evaluation and identified largely based on molecular data.

Discussion

The current checklist is the first in a series of lists on the traditional zoosporic fungi recorded for India. The present publication aims to combine all earlier biodiversity explorations and their information pertaining to the genus *Pythium* in one list. The *Pythium* is considered one of the least explored ecological niches for oomycete remaining today in India. The research in this area has been primarily hampered by a confusing taxonomy largely dependent on nineteenth-century concepts and

exceedingly inadequate literature. However, these water mold being an important biodiversity component have the potential of impacting global food security and the human economy. Some species of this cosmopolitan oomycete listed herewith are considered to be an important pathogen of cash crops (e.g., *P. aphanidermatum*, *P. myriotylum*, *P. arrhenomanes*, *P. dissotocum*, *P. elongatum*, and *P. spinosum*) and have been reported to cause seedling damping-off and root rot (Khulbe 2001). Owing to their economic importance, the present insight is needed to prepare an outlook for the future. In this sense, past works (1907-2020) on *Pythium* spp. reported from India were studied to provide a compile data on an annotated alphabetical checklist of the genus herewith.

Table 1 *Pythium* species recorded from India. Abbreviations: S: soil, W: water, PA: parasite, SA: saprotroph, MP: Madhya Pradesh, UP: Uttar Pradesh, KA: Karnataka, TN: Tamil Naidu, RA: Rajasthan, UK: Uttarakhand, AP: Andhra Pradesh, WB: West Bengal, GU: Gujrat, KE: Kerala, MS: Maharashtra, JK: Jammu and Kashmir, HP: Himachal Pradesh and ME: Meghalaya.

S. No.	*Pythium* species	Type of sample	Substrates	Nutrition	Collection data	Reference
1	*P. acanthicum* Drechsler	S	Agricultural soil	SA	Hyderabad, Vakarabad (Telangana); Gwalior (MP); Banglore (KA)	Joshi & Chauhan 1982
2	*P. acanthophoron* Sideris	S	*Gossypium* seed (Malvaceae) and *Zingiber officinale* (Zingiberaceae) rhizome	PA, SA	Coimbatore (TN); Udaipur (RA)	Lodha & Webster 1990
3	*P. afertile* Kanouse and Humphrey	W, S	Fish eggs, infected roots	PA	Nainital (UK); Varanasi (UP)	Kiran et al. 1982, Khulbe 1977, Sati 1981
4	*P. anguillulae-aceti* Sadebeck	S	*Solanum melongena* (Solanaceae)	PA	Bomori, Haldwani (UK)	Bhatt 2000
5	*P. aphanidermatum* (Edson) Fitzp	S	Reported on many monocotyledonous and dicotyledonous plants	PA, SA	Ubiquitous in nature throughout India	Muthukumar 2010, Ashwathi et al. 2017
6	*P. apleroticum* Tokunaga	W	Plant debris	SA	Varanasi (UP)	Sarkar et al. 1981
7	*P. aquatile* Hohnk	S, W	*Lycopersicon esculentum* (Solanaceae)	SA, PA	Gorakhpur (UP); Hissar (Haryana); Hyderabad (AP)	Prabhuji & Srivastava 1978, Manoharachary & Rao 1978
8	*P. campanulatum* Mathew, Singh, and Paul	S	Rhizosphere of *Zea mays* (Gramineae)	SA	Gorakhpur (UP)	Mathew et al. 2003
9	*P. carolinianum* Matthews	W, S	*Spirogyra* species (Zygnemataceae) and Vegetable debris	PA, SA	Coimbatore (TN); Hyderabad (Telangana); Prayagraj, Chandauli (UP)	Balakrishnan 1948, Rajagopalan & Ramakrishnan 1964, 1971, Dubey 2018
10	*P. catenulatum* Matthews	W, S	*Spirogyra* species (Zygnemataceae) and *Saccharum officinarum* (Poaceae)	PA, SA	Coimbatore (TN); Prayagraj, Chandauli (UP)	Balakrishnan 1948, Srinivasan 1956, Chona 1958, Dubey 2018
11	*P. cucurbitacearum* Takimoto	S	*Trichosanthes dioica* (Cucurbitaceae)	PA	Nadia (WB)	Chaudhuri 1975

Table 1 Continued.

S. No.	*Pythium* species	Type of sample	Substrates	Nutrition	Collection data	Reference
12	*P. debaryanum* Hesse	S	Reported on many monocotyledonous and dicotyledonous plants	PA, SA	Ubiquitous in nature throughout India	Butler 1907, 1913, Srivastava & Rao 1964, Kapoor 2008
13	*P. deliense* Meurs	S	Reported on many dicotylednous plants	PA, SA	Ubiquitous in nature throughout India	Haware & Joshi 1974, Jooju 2005, Muthukumar 2010
14	*P. diclinum* Tokunaga	S	Reported on many monocot and dicot plants	SA, PA	Surat (GU); Dehradun (UK); Kolkata (WB)	Butler 1907
15	*P. dissotocum* Drechsler	S, W	*Papaver somniferum* (Papaveraceae)	SA, PA	Barabanki, Lucknow (UP); New Delhi; Bangalore (KA); Kasargod (KE); Coimbatore (TN)	Chowdhry & Agarwal 1980, 1981, Alam et al. 1996, Bajpai et al. 1999
16	*P. drechsleri* Rajagopalan and Ramakrishnan	S	Agricultural soil	SA	Coimbatore (TN)	Rajagopalan & Ramakrishnan 1971
17	*P. echinogynum* Balghouthi, Jonathan, Gognies, Mliki and Belarbi	S	Turf grassroots (Poaceae)	PA	Nagpur (MS)	Balghouthi et al. 2013
18	*P. echinulatum* Matthews	S	*Triticum aestivum* (Poaceae)	SA, PA	Gorakhpur (UP); Nainital (UK); Vikarabad, Medak and Hyderabad (Telangana)	Rama Rao 1970, Verma 1987a
19	*P. elongatum* Mathews	W, S	Moist soil	SA	Hyderabad (Telangana); Nainital (UK)	Khulbe 1983
20	*P. graminicola* Subramaniam	S	Reported on many monocotyledonous and dicotyledonous plants	PA	Pusa (Bihar); New Delhi; Coimbatore, Chidambaram (TN); Jabalpur (MP); Chandauli (UP)	Subramaniam 1928, Ramakrishnan & Soumini 1955, Muthukumar 2010, Dubey et al. 2020a
21	*P. helicoides* Drechsler	S	*Amorphophallus paeoniifolius* (Araceae)	SA, PA	Coimbatore (TN), Nadia (WB)	Guha Roy & Hong 2008
22	*P. hydnosporum* (Montagne) Schroter	S, W	*Solanum tuberosum* (Solanaceae)	SA, PA	Kolkata (WB); Khasi Hills (Assam); Coonoor (TN)	Sydow & Butler 1907, Chowdhry & Agarwal 1980
23	*P. hypogynum* Middleton	S, W	*Triticum aestivum* (Poaceae)	PA	Udham Singh Nagar (UK)	Verma 1984
24	*P. indigoferae* Butler	S	Epiphyte on the leaves of *Indigofera arrecta* (Fabaceae) and *Cucumis sativus* (Cucurbitaceae)	SA, PA	Kolkata (WB)	Butler 1907

Table 1 Continued.

S. No.	*Pythium* species	Type of sample	Substrates	Nutrition	Collection data	Reference
25	*P. inflatum* Matthews	S	*Oryza* spp. (Poaceae) and *Lycopersicon esculentum* (Solanaceae)	PA	Hyderabad (Telangana); Nainital (UP)	Verma & Khulbe 1986, Verma 1987b
26	*P. insidiosum* De Cock	W	Mosquito larva, human	PA	Pondicherry; Hyderabad (Telangana); Madurai (TN)	Schurko et al. 2004, Kalra et al. 2018, Hasika et al. 2019
27	*P. intermedium* De Bary	S	Reported on many monocot and dicot plants	PA	Nagpur (MS); Bangalore (KA); Peechi (KE)	Ali & Nair 1989, Rao 1963
28	*P. irregulare* Buisman	S	*Coriandrum sativum* (Apiaceae)	SA, PA	Lucknow, Varanasi (UP); Bangalore (KA)	Agnihotri 1969, Sharma & Basu Chaudhary 1981
29	*P. iwayamai* Ito	S	*Lycopersicon esculentum* and *Solanum melongena* (Solanaceae)	PA	Bomori, Haldwani, Nainital, Rooshi (UK)	Bhatt 2000
30	*P. kashmirense* Paul	S	Plant debris	SA	Reasi (JK)	Paul & Bala 2008
31	*P. lobatum* Rajagopalan and Ramakrishnan	S	Moist soil	SA	Coimbatore (TN)	Rajagopalan & Ramakrishnan 1971
32	*P. mamillatum* Meurs	S	Moist soil	SA	Chennai (TN); Pakhal, Medak and Hyderabad (Telangana)	Ramakrishnan 1955, Rao 1963, Rama Rao 1970
33	*P. marsupium* Drechsler	S	*Solanum melongena* (Solanaceae)	PA	Bithoria, Haldwani (UK)	Bhatt 2000
34	*P. middletonii* Sparrow	S, W	Reported on many dicotylednous plants	SA, PA	Ubiquitous in nature throughout India	Singh & Pavgi 1974, Khulbe & Bhargava 1977
35	*P. monospermum* Pringsheim	W	*Zingiber officinale* (Zingiberaceae) and *Lepidium sativum* (Brassicaceae)	PA	Pusa (Bihar); Jabalpur (MP); Nainital (UK)	Rao 1963, Khulbe & Bhargava 1977
36	*P. multisporum* Poitras	S	Moist soil	SA	Kushinagar (UP)	Prabhuji & Srivastava 1978, Prabhuji & Sinha 1994
37	*P. myriotylum* Drechsler	W, S	Reported on many monocot and dicot plants	PA	Ubiquitous in nature throughout India	Devaki et al. 1991, Kumar et al. 2008, Geethu et al. 2013
38	*P. oedochilum* Drechsler	S	*Brasssica oleracea* var. *botrytis* (Brassicaceae)	PA	Annamalainagar and Coimbatore (TN)	Raghunathan 1968, Rajagopalan & Ramakrishnan 1964, 1971
39	*P. oligandrum* Drechsler	S	*Piper betle* (Piperaceae) and *Anabas testudineus* (Anabantidae)	PA	Lucknow, Gorakhpur and Varanasi (UP)	Srivastava et al. 2017a, b
40	*P. parasiticum* Rajagopalan and Ramakrishnan	S	Agricultural soil	SA	Chennai (TN)	Rajagopalan & Ramakrishnan 1971

Table 1 Continued.

S. No.	*Pythium* species	Type of sample	Substrates	Nutrition	Collection data	Reference
41	*P. paroecandrum* Drechsler	S, W	*Phaseolus vulgaris* (Fabaceae) Vegetable root	PA	Nainital and Nanakmatta (UK); Coimbatore (TN)	Balakrishnan 1948, Verma 1984
42	*P. periilum* Drechsler	S	*Brassica oleracea* var. *capitata*, *Brassica oleracea* var. *botrytis* (Brassicaceae)	SA	-	Plaats-Niterink 1981
43	*P. periplocum* Drechsler	S, W	Agricultural soil	SA, PA	Coimbatore (TN)	Balakrishnan 1948, Rajagopalan & Ramakrishnan 1964, 1971, Bisht et al. 1997
44	*P. periplocum* var. *coimbatorense* Balakrishnan	S	Vegetable debris	SA	Coimbatore (TN)	Balakrishnan 1948
45	*P. polytylum* Drechsler	S	Vegetable debris	PA	Solan (HP); Nainital (UK)	Verma & Khulbe 1985
46	*P. pulchrum* Minden	S, W	*Malus* sp. (Rosaceae), Crop field	SA	Nainital (UK)	Mer 1982
47	*P. rhizo-oryzae* Paul	S	*Hibiscus esculenta* (Malvaceae)	SA	Gorakhpur (UP)	Bala et al. 2006
48	*P. rhizosaccharum* Singh, Mathew, Masih and Paul	S	The rhizosphere of *Oryza sativa* (Poaceae)	SA	Gorakhpur (UP)	Singh et al. 2003
49	*P. rostratum* Butler	S	*Saccharum officinarum* (Poaceae)	PA	Pusa (Bihar); Nainital (UP)	Butler 1907, Verma & Khulbe 1985
50	*P. spinosum* Sawada	S, W	*Triticum aestivum* (Poaceae)	SA, PA	Ubiquitous in nature throughout India	Rama Rao 1970, Manoharachary & Reddy 1975, Sati & Tiwari 1992
51	*P. splendens* Braun	S	Reported on many monocotyledonous and dicotyledonous plants	PA	Lucknow (UP); Hesaraghatta (KA); Shillong (ME); Sirmaur (HP)	Shanmugam et al. 2010
52	*P. torulosum* Coker and Patterson	W	*Pelargonium graveolens* (Geraniaceae), *Zingiber officinale* (Zingiberaceae)	SA, PA	Varanasi (UP); Nainital (UK)	Khulbe & Verma 1983
53	*P. ultimum* Trow	S	Vegetable debris and *Triticum aestivum* (Poaceae)	PA	Salon (HP); Parbhani (MH)	Hudge & Deshpande 2014, Hudge et al. 2016, Kumar et al. 2018
54	*P. ultimum* Trow var. *ultimum*	S	*Solanum lycopersicum* (Solanaceae) and *Glycine max* (Fabaceae)	SA, PA	Ubiquitous in nature throughout India	Dohroo 1987, Muthukumar 2010
55	*P. ultimum* var. *sporangiiferum* Drechsler	S	Reported on many monocotyledonous and dicotyledonous plants	PA	Haldwani, Ramnagar, Ranikhet, Someshwar, Rooshi, Nainital (UK)	Bisht et al. 1997

Table 1 Continued.

S. No.	*Pythium* species	Type of sample	Substrates	Nutrition	Collection data	Reference
56	*P. undulatum* Petersen	W	Vegetable seedlings	PA	Nainital (UK)	Khulbe & Bhargava 1977, Sati 1991, Sati & Tiwari 1992
57	*P. vexans* de Bary	S	*Carassus auratus* (Cyprinidae) and *Brassica campestris* (Solanaceae), Temperate fish	SA, PA	Ubiquitous in nature throughout India	Dastur 1935, Ramakrishnan 1949, Wilson & Rahim 1978
58	*P. vexans var. minuta* Mer and Khulbe	S, W	Reported on many monocotyledonous and dicotyledonous plants	SA	Nainital (UK)	Mer & Khulbe 1983
59	*Pythium stipitatum* Karaca and Paul	S	Grass or Cyanodon dactylon roots (Poaceae)	SA	Nagpur (MH)	Karaca et al. 2009

Research related to *Pythium* started in the early 19th century with collections made by Butler (1907) in India. Studies about *Pythium* in India were intensified between the years 1950-1990. A checklist of Indian *Pythium* taxa was published by Misra & Hall (1996) which included 40 species and included a survey of all known taxa and all relevant literature until that time. Since then, a large amount of new information on taxonomy, distribution, and to a lesser extent ecology, has been published. This information is contained in many papers in various journals and books, some of them not easily accessible so that a new survey is necessary. Moreover, the yearly output of publications on the subject was increasing rapidly, so that an updated version of the bibliography and a checklist seemed necessary.

Most studies on *Pythium* in India have been conducted primarily from South India and Kumaon Himalayan region in North India (Khulbe 2001), and a total of 46 species have been recorded from these regions of the country. Moreover, the list also contains some saprophytes and some well-proven biological control agents among them. However, little research has been undertaken phytopathogenesis mediated negative attributes on the economy and food security by this necrotrophic generalistic pathogenic *Pythium* flora of fields worldwide, especially in India. It is therefore pertinent to understand the *Pythium* diversity and associated plant diseases, which will be helpful to develop relevant action plans for the future.

Most of the *Pythium* were identified based on their morphological features whereas little were studied from the molecular identification point of view. Identifying the species of *Pythium* sorely based on morphological features has always been problematic due to various reasons, such as variations of a specific morphological feature, difficulty in isolating certain species and the lack of molecular identification data for species. Due to these reasons, identifying *Pythium* species based on morphological features has been a constant problem for even the most experienced mycologists (Lévesque & de Cock 2004). Therefore, during the last decade, molecular techniques have significantly assisted in the identification of unknown *Pythium* species and a large number of additional new species records and new species have been added based on it. Further, based on the data present in the list, it can be concluded that still large areas in India are unexplored relative to *Pythium* biodiversity and studies in this field have been hampered by grossly inadequate literature and a confused taxonomy based largely on nineteenth-century concepts. It is equally likely that a large number of species have not yet been described because newly explored areas always yield new taxa. Besides, according to the recent primarily checklist of fungi of Gujarat state, India, the genus *Pythium* is never been recorded in Gujarat (Rajput et al. 2015). However, our list provided supporting evidence that this genus was reported from Gujrat (Butler 1907). According to our results, this oomycete parasitized a large no. of the host plant and animal species in this country like other

members of Oomycota (Dubey et al. 2018, 2019, 2020b). However, it is expected that more collections and further taxonomic studies will substantially increase our knowledge and provide a better understanding of their biology, ecological aspects, host-specificity, origin and divergence as well as the application of this oomycete in biocontrol. Therefore, it seems a prerequisite to launch a full-scale survey of these biologically intriguing group of oomycete in other parts of India to complete at least a modicum of their checklist. After that plenty of knowledge can be accumulated that would be useful in the compilation of mycological diversity in India.

Conclusion

The current checklist facilities access to the scattered Indian literature on the topic that may not be readily available to the student of Indian mycology and the international community. Besides, the correctly identified checklist is essential, as it can assist in gathering information pertaining to the historical development in the study of *Pythium* and its diversity in India. The exact knowledge of this oomycete diversity is important because these water molds are the most-significant decomposers of plant and animal originated complex organic materials and normally comprise a major proportion of total microbial biomass. Nevertheless, the recent impact of global climate change and the better-known role of mycobiota activities in the biogeochemical cycling of elements have enforced the importance of assessing the position of Indian mycobiota and its diversity. Further, the pathogenic species mentioned in the list can assist phytopathologists to confidently name disease causal agents, lead quarantine to put in place effective measures to prevent the entry of unwanted species, allow plant breeders to breed resistant varieties and biochemists to confidently put names to species producing novel chemicals. This shows clearly that the compilation of the checklist has fulfilled its purpose to encourage Indian mycologists to search for additional taxa. Besides, this checklist will help in making the evaluations of the oomycetes recorded in the country.

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