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Indian *Pucciniales*: taxonomic outline with important descriptive notes

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Abstract

Rusts constitute a major group of the Kingdom Fungi and they are distributed all over the world on a wide range of wild and cultivated plants. It is the largest natural group of plant pathogens including 95% of the subphylum *Pucciniomycotina* and about 8% of all described Fungi. This article provides an overview and outline of rust fungi of India with important descriptive notes. After compilation of available literature on Indian rust fungi from various sources, it was observed that these fungi are distributed in 16 families, 69 genera and 640 species. They belong to *Coleosporiaceae*, *Crossopsoraceae*, *Gymnosporangiaceae*, *Melampsoraceae*, *Milesinaceae*, *Ochropsoraceae*, *Phakopsoraceae*, *Phragmidiaceae*, *Pileolariaceae*, *Pucciniaceae*, *Pucciniastraceae*, *Raveneliaceae*, *Skierkaceae*, *Sphaerophragmiaceae*, *Tranzscheliaceae* and *Zaghouaniaceae*. There are still many rust fungi with uncertain taxonomic position, and they have been referred to *incertae sedis*. The placement of all fungal genera is provided at the class, order and family-level along with number of species in a genus. Notes for each rust family along with total Indian records and other taxonomic information on transferred genera and species are also presented. A phylogenetic analysis from a combined LSU and ITS dataset for 25 rust genera is presented to provide a better understanding of their phylogeny and evolution.

Key words – India – Phylogeny – *Pucciniomycotina* – rust fungi – Systematics

Introduction

Rust fungi (*Basidiomycota*, *Pucciniales*) are a highly diverse group of obligate biotrophic parasites, distributed in all geographical areas on a wide range of wild and cultivated plants ranging

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from ferns, Gymnosperms and Angiosperms (Duplessis et al. 2011). They are called rusts as one of their spore types i.e. the urediniospores and (uredinia) on host surface are often rust coloured. These fungi are unique and fascinating group of organisms possessing diverse structures (spermogonia, two anamorphs, teleomorphs and basidiospores) in their life cycle. Besides having up to five or six morphologically and functionally distinct spore types, many rust fungi exhibit complicated life cycles with variable host plant specificity. Because of their obligate parasitic nature, actively growing rusts survive only on living hosts and produce teliospores towards the end of the growing season. Species of *Pucciniomycotina* show simple life cycle (simple teliosporic yeasts) to the complex elaborate five-stage life cycles of the biotrophic rust fungi, the latter regarded as the most complex organisms in Kingdom Fungi (Lutz et al. 2004). Along with various spore types, some rust fungi require alternation between two exclusive and unrelated host plant taxa to complete their life cycle (heteroecious rust), although others can complete their life cycle on a single host plant (autoecious rust) (Kolmer et al. 2009). Parasitism and host specialization is highly developed in rust fungi (Savile et al. 1971, Duplessis et al. 2011). They constitute one of the major groups of plant pathogenic fungi. *Puccininales* is the most speciose order in *Pucciniomycotina* and include 95% of the subphylum and ca. 8% of all described Fungi (Kirk et al. 2008).

The rust fungi have a long research history, mostly due to their economic importance in agriculture and forestry, and easily noticeable symptoms (Cummins & Hiratsuka 2003). Taxonomically the rust fungi belong to *Pucciniomycotina*, one of the three subphyla of Basidiomycota. Further, these fungi are placed in class *Pucciniomycetes* and order *Pucciniales*. In some systems of classifications, the rust fungi are placed in the subclass *Heterobasidiomycetes* based on basidial morphology while in other systems, they are with smut fungi in *Teliomycetes* based on their similar basidial characteristics (Talbot 1971, Webster 1980). Different morphological characters have been emphasized in earlier system of rust taxonomy and classifications (Ono & Hennen 1983). Initially, rust fungi were classified into three (or four) families, *Melampsoraceae*, (*Coleosporiaceae*), *Pucciniaceae* and *Zaghouaniaceae* based on the characteristics of basidia and teliospores (Sydow & Sydow 1915, Cunningham 1931). Classification of rust fungi in subfamilies or tribes and morphology of telia in taxonomy was also considered (Sydow & Sydow 1915, Dietel 1928). Use of morphology of spermogonial (0) and aecial (I) stages was emphasized by Hiratsuka & Cummins (1963) and Hiratsuka (1983) in the classification of rust fungi. The morphological characters of telium (Thirumalachar & Cummins 1949) and teliospores (Dietel 1928, Thirumalachar & Cummins 1948, Thirumalachar & Mundkur 1949) played an important role in the taxonomic placement of rust fungi (Alexopoulus 1962). However, with the combination of different character of uredinia, aecia, type of spermogonia and telia, there has been several conflicting taxonomic hypotheses with time and this led to the proposal of 13-family system of classification of rust fungi. Based on telial morphology, three families were accepted: *Melampsoraceae* (sessile teliospores formed in columns in the telium), *Pucciniaceae* (stalked teliospores, produced in a single layer in the telium) and *Coleosporiaceae* (do not form a promycelium but karyogamy and meiosis occur directly within the teliospores that become septate during the germination process). Cummins & Hiratsuka (1983, 2003) proposed 13 families. This was one of the the most accepted systems of rust classification till the incorporation of molecular data in systematic studies.

With the use of modern techniques (molecular studies) along with conventional methods (morphological studies), new taxonomic suggestions have been proposed regarding interrelationships of different groups of fungi. However, the earlier systems of classifications of rust fungi were mainly based on shape, size and other morphological characters of different spores and spore producing structures. Based on recent molecular techniques (DNA sequence data from the large ribosomal subunit) and ultrastructural investigations, it was observed that rusts are distantly related to some of the smuts (Aime et al. 2006, Kijpornyongpan et al. 2018). Subsequently Swann & Taylor (1995a, b) and Swann et al. (2001) proposed the separation of class *Urediniomycetes* (the rust fungi), including the rusts (*Uredinales*), from class *Ustilaginomycetes* (the smut fungi) and class *Hymenomycetes* mushrooms and shelf or bracket fungi) under division *Basidiomycota*. Within the class *Urediniomycetes*, true rusts (*Uredinales*) account for over 95% of the species and more than 75% of

the genera. Several research series on fungal diversity published in recent years provided an updated information on addition, exclusion, correct taxonomic position and transferred taxa of fungi. Aime (2006) examined representative species from the 13 families proposed by Cummins & Hiratsuka (2003) and based on sequence analyses of the 18S and 28S nuclear rDNA regions, three major suborders were proposed *Uredinineae, Melampsorineae* and *Mikronegeriineae*. The *Uredinineae* includes species which produce the aecial stage on angiospermous host with pedicellate teliospores. Similarly, *Melampsorineae* comprises heteroecious, mostly macrocyclic rust species producing aecial stage on gymnosperms and producing sessile teliospores. *Mikronegeriineae* accomodates species with aecial stage usually on non-pine gymnosperms and in microcyclic types the teliospores functioned as urediniospores, with short pedicellate or sessile teliospores. He et al. (2019) presented notes, outline and divergence times of *Basidiomycota*. They differentiated *Urediniomycetes* from *Basidiomycetes*, as the nuclear membrane partially degrades during mitosis (semiopen pleuromitosis) in some *Urediniomycetes* while mitosis in basidiomycetes proceeds with preservation of the nuclear membrane (intranuclear pleuromitosis). They also differentiated rusts and smuts as non-basidiomata forming members of Basidiomycota, which comprises *Pucciniomycotina* and *Ustilaginomycotina*, respectively. They included eight families, *Coleosporiaceae, Mikronegeriaceae, Phakopsoraceae, Phragmidiaceae, Pileolariaceae, Pucciniaceae, Raveneliaceae* and *Sphaerophragmiaceae* in order *Pucciniales*, class *Pucciniomycetes* and subphylum *Pucciniomycotina* in their phylogenetic studies. However, they also presented the estimated number for taxa in *Basidiomycota*, of which, order *Pucciniales* possesses 15 families, 162 genera and 8105 species. Recently, Wijayawardene et al. (2020) outlined the kingdom Fungi up to genus level. They also presented 15 families (138 genera) under the order *Pucciniales*, class *Pucciniomycetes* and phylum *Basidiomycota*. It is interesting to mention here that the majority of *Pucciniomycotina* species (ca. 7500 of nearly 8500) belong to a single order *Pucciniales* that cause rust diseases in numerous plants (He et al. 2019, Wijayawardene et al. 2020, Aime & McTaggart 2020). The recent higher-rank classification for rust fungi is provided by Aime & McTaggart (2020), wherein they proposed the addition of four new suborders and seven new families, with some amendments in existing families. The classification of *Pucciniales* now comprises seven suborders and 18 families.

To understand the status of research on rust fungi in India, we have started this part here with the beginning of Indian mycological research. Here foreign visiting scientists or emigrant experts in the 18th and 19th centuries carried out most of the research. This started with the mycological studies initiated by K.R. Kirtikar in late 19th century who collected and identified numerous fungi. Although the special credit to initiate mycological research in India goes to A. Barclay and E.J. Butler because of their contribution to initiate and organize research on mycology and plant pathology in India. After the establishment of the Imperial Agricultural Research Institute at Pusa (Bihar) during the year 1905 with the generous grant of 30,000 pounds from an American philanthropist, Mr. Henry Phipps, mycological research in India gained momentum. With the earlier efforts of E.J. Butler, the first imperial mycologists to the then British Government of India, a firm foundation of mycology and plant pathology was laid in this country and he is aptly referred to as the Father of Indian Mycology (Subramanian 1986). This research continued with the passage of time and involvement of many more mycologists. With the advancement in mycological research, B.B. Mundkur and M.J. Thirumalachar laid down a pioneer contribution in the studies of rust and smut fungi as *Ustilaginales* of India (Mundkar & Thirumalachar 1952). Foundation of the Indian Phytopathological Society was also laid down by B. B. Mundkur along with S.R. Bose, both sereved as its earliest presidents. K.C. Mehta (1940) studied the problem of the recurrence of the wheat rust in plains of India. They mainly focused on cereal rust of India. Balchandra Bhavanishankar Mundkur and Mandayam Jeersannidhi Thirumalachar in 1952 jointly published a consolidated list of Indian *Ustilaginales*. Similarly, Thirumalachar & Mundkar (1950) published a very useful appendix of genera of rust fungi. Simultaneously, Hans Sydow, a German mycologist, son of Paul Sydow also contributed a lot in understanding the Himalayan mycoflora including rust fungi. Similarly, George Baker Cummins, A. Barclay and Joseph Charles Arthur investigated the rusts occurring near North Western Himalayas. D.P. Mishra along with other mycologists also investigated rust fungi of agricultural crops in India.

Several other mycologists contributed significantly to the development of research on rust fungi in India on a regional basis. Pioneering work of C. Mohanan cannot be neglected as modern mycologists. He worked on biodiversity of plant pathogenic fungi of the Western Ghats and published a book entitled "Rust Fungi of Kerala, India". Some names worth mentioning are Ramesh Chand Sharma, Sanjeev Sharma, R.K. Sharma, S.N. Sachan and Ajay Kumar Gautam, who actively worked in the past and are still engaged in studies of various aspects of rust fungi of Himachal Pradesh. Dr. E.J. Butler & G.R. Bisby compiled a monograph "The Fungi of India", in 1931. The fungi of India series have been revised from time to time and updated by several workers. However, the contribution of great Indian mycologists K.D. Bagchee, T.S. Ramakrishnan, J.H. Mitter, K.J. Narsimhan, S.N. Das Gupta, R.N. Tandon, R. Prasad, T.S. Sadasivan, C.V. Subramaniam and many more cannot be ignored. The taxonomic research on rust fungi in India has been based primarily on morphology of certain spore stages. Only a few studies published recently have employed modern tools and techniques for identification of rust fungi. Several institutes like Indian Type Culture Collection (ITCC) New Delhi; National Fungal Culture Collection of India (NFCCI) Pune, Maharashtra; CSIR-IMTECH Chandigarh, NBAIM Mau and many more are actively carrying research on fungal taxonomy and other related aspects and providing facilities for molecular characterisation of fungi including rust fungi in India. A major scientific breakthrough of the Indian Council of Agricultural Research (ICAR) scientists lead to the decoding of genomes of 15 strains of wheat rust fungus *Puccinia triticina*. Herbarium Cryptogamae Indiae Orientalis (HCIO) has a rich collection of rusts, smuts, powdery mildews and meliolales fungi and has more than 3500 type specimens (Maheswari et al. 2012). HCIO documented a comprehensive checklist of *Puccinia* species of India along with herbarium photographs and brief description (Kamil et al. 2013). Similarly, "Rust fungi of Kerala, India" (Mohanan 2010); First checklist of rust fungi in the genus *Puccinia* from Himachal Pradesh, India" (Gautam & Avasthi 2016a); and "A checklist of rust fungi from Himachal Pradesh, India" (Gautam & Avasthi 2019) are the recent compilations of rust fungi from India. In subsequent years, a plethora of articles on *Pucciniales* (*Uredinales*) has been published, which has added a lot to understanding this group of fungi, thus it is essential and pragmmatic to compile it into a single document. Therefore, we are starting a series of publications on rust fungal diversity from India, and this first paper provides basic information and the latest trends related to taxonomic outline of rust fungi of India with important descriptive notes.

Materials & Methods

Layout of the paper

A brief description of each genus up to its higher taxonomic rank related with rust fungi of India is provided. During the listing of genera, their species, and other higher taxonomic ranks into a single outline, all generic names are listed from previously published literature pertaining to rust fungi of India. The detailed literature in reference to Indian rust fungi is summarised in the present study under the heading "literature used during the study of rust fungi". The names of some species have been replaced by currently accepted names after consultation of MycoBank (www.mycobank.org)/ and Species Fungorum (www.speciesfungorum.org) websites and this has been indicated in such cases. For general outline of Indian rust fungi, we adopted He et al. (2019) and Wijayawardene et al. (2020). Aime & McTaggart (2020) was followed to provide a higher-rank classification of rust fungi. To confirm their scientific entity where some generic/species names have been updated with currently accepted name, more literature on rust fungi was consulted (Cummins & Hiratsuka 2003, Aime 2006, Aime et al. 2018, Aime & McTaggart 2020. After complete verification, accepted taxa of rust fungi of *Basidiomycota* up to species level are presented in detailed. The existing and currently accepted names of various genera and species of rust fungi are provided as a separate section in this manuscript.

Phylogenetic analyses

Most of the rust fungi reported from India were characterized mainly based on the

morphological characters of uredia and telia or other successive stages observed on collected samples. However, rust fungi reported from India lack molecular studies.

Based on earlier studies on Indian rust fungi, a checklist was prepared and the DNA sequence data from the LSU and ITS rDNA regions available for same rust fungi reported from other countries were downloaded from GenBank and through published literature (Maier et al. 2003, Aime 2006, Aime et al. 2006, Aime & McTaggart 2020). Individual nucleotide sequences of LSU and ITS were aligned distinctly using MAFFT 7 (http://mafft. cbrc.jp/alignment/server/) (Katoh & Standley 2013) and then manual checking and editing where necessary in BioEdit v.7.0.9 (Hall 1999). The ITS sequences of taxa containing weak aligned portions, incomplete data, missing sequence data and gaps were removed. The separate aligned gene regions of LSU and ITS were combined in BioEdit. The combined multigene sequence alignment was converted to PHYLIP format (.phy) using ALTER (alignment trans-formation environment: (http://sing.eiuvigo.es/ALTER/; 2021) for randomized accelerated maximum likelihood (RAxML) analysis. The aligned LSU and ITS single gene datasets and a concatenated dataset of LSU and ITS genes were analyzed with maximum likelihood using the RAxML-HPC2 on XSEDE (8.2.8) (Stamatakis et al. 2008, Stamatakis 2014) in the CIPRES Science Gateway platform (Miller et al. 2010) using GTR+I+G model of evolution. Maximum Likelihood bootstrap values greater than 70% were given above each node. Phylogenetic trees were visualized with FigTree v1.4.0 program (Rambaut 2012) and reorganized in Microsoft power point (2016).

Table 1 GenBank and voucher/culture collection accession numbers of species included in the phylogenetic study

Taxon	**Voucher/culture**	**GenBank accession Numbers**		**References**
		ITS	**LSU**	
Cerotelium fici	LAH20019AM	--	MK135779	Ishaq et al. (unpublished)
Chrysomyxa pirolae	190CHP_PCG_DU2		GU049555	Feau et al. (2011)
Coleosporium asterum	MCA3077	--	MG907226	Aime et al. (2018)
Coleosporium bletiae	BSC1	--	MN108162	Zhou (unpublished)
Coleosporium campanulae	--	--	KP017565	Tian et al. (unpublished)
Coleosporium campanulae	LB09265/ZT_Myc_58002	KY810467	--	Beenken et al. (2017)
Coleosporium inulae	U717	--	MG907223	Aime et al. (2018)
Coleosporium inulae	LB09168/ZT_Myc_57996	KY810470	--	Beenken et al. (2017)
Coleosporium ipomoeae	JRH 485	MF769644	--	McTaggart & Aime (2018)
Coleosporium ipomoeae	R232	--	EU851160	Zuluaga et al. (2011)
Coleosporium senecionis	LB08877/ZT_Myc_57995	KY810472	--	
Coleosporium senecionis	PDD 98309	--	KJ716348	Beenken et al. (2017)
Coleosporium xanthoxyli	KUS-F30013	--	MK530184	Shin et al. (2019)
Cronartium quercuum	CqvGa-1	L76495	--	Vogler & Bruns (1998)
Cronartium ribicola	--	KX963430	--	Kaitera et al. (2017)
			AF426240	Maier et al. (2003)
Crossopsora ziziphi	BPI 877877	--	MG744558	Souza et al. (2018)
Gymnosporangium clavariiforme	LD 1019	HM114220	--	Dervis et al. (2011)
Gymnosporangium clavariiforme	HMAS:24626	--	KU342766	Zhao et al. (2016)
Gymnosporangium confusum	LD 1021	HM114219	--	Dervis et al. (2011)
Gymnosporangium confusum	20140808B H22	--	KP261043	Fernandez & Alvarado (2016)
Hyalopsora polypodii	BPI 893256	KY798367	--	Demers & Castlebury (unpublished)
Hyalopsora polypodii	DB 1681	--	AY512852	Begerow et al. (unpublished)

Table 1 Continued.

Taxon	Voucher/culture	GenBank accession Numbers		References
		ITS	LSU	
Kernkampella breyniae	BRIP:56909	--	KJ862346	McTaggart et al. (2015)
Kweilingia divina	MCA3493	--	MG907215	Aime et al. (2018)
Leucotelium pruni-persicae	--	AB097450	--	Osaki (unpublished)
Maravalia pterocarpi	HNCM1	KU301795	--	Wang et al. (2016)
Melampsora caprearum	GE14_3_2	KY649193	--	Piskur (unpublished)
Melampsora caprearum	NYS-F-003819	--	KU550033	Zhao (unpublished)
Melampsora epitea	--	--	DQ354564	Aime (2006)
Melampsora epitea	1046MEE-SA-QC.1	GQ479218	--	Vialle (unpublished)
Melampsora euphorbiae	--	EF192199	--	Aime (unpublished)
Melampsora euphorbiae	BPI 863501	--	DQ437504	Aime et al. (2006)
Melampsora hypericorum	BPI 893298	--	KY798351	Demers & Castlebury (unpublished)
Melampsora hypericorum	PDD 97325	KJ716353	--	Padamsee & McKenzie (2014)
Melampsora populnea	892MPO-PTA-FR3.1	EU808037	--	Feau et al. (2009)
Melampsora populnea	--	--	AY444786	Pei et al. (2005)
Melampsora salicis-albae	HMAAC4068 HMAAC4068	--	MK372199	Wang (unpublished)
Melampsora salicis-albae	13125 F	FJ455128	--	Eslami et al. (unpublished)
Melampsoridium betulinum	KR-M-0048135	--	MK302187	Bubner et al. (2019)
Melampsoridium betulinum	H 6034375	KF031552	--	McKenzie et al. (2013)
Melampsoridium hiratsukanum	421	KC313888	--	Blomquist et al. (2014)
Melampsoridium hiratsukanum	KR-M-0048149	--	MK302188	Bubner et al. (2019)
Milesina exigua	KR-M-0050247	MH908478	MK302211	Bubner et al. (2019)
Milesina polypodii	KR-M-0043190	--	MK302190	Bubner et al. (2019)
Nyssopsora thwaitesii	AMH:9528	KF550283	--	Baiswar et al. (2014)
Ochropsora ariae	KR-M-42604	KX228773	KX228778	Scholler et al. (2019)
Phakopsora apoda	PDD 72076	MG461668	MG461668	Demers & Castlebury (unpublished)
Phakopsora cingens	BRIP:55628	--	KP729474	Maier et al. (2016)
Phakopsora meibomiae	Brazil 82-1	AF333501	--	Frederick et al. (2002)
Phakopsora meibomiae	R188	--	EU851164	Zuluaga et al. (2011)
Phakopsora phyllanthi	83	KF528025	--	Beenken (2014)
Phakopsora phyllanthi	BPI 843632	--	KY764084	Demers et al. (unpublished)
Phakopsora ziziphi-vulgaris	HMJAU8595	MK296536	MK296506	Ji (unpublished)
Phragmidium barclayi	HMAS-67281	--	MG669117	Liu et al. (2018)
Phragmidium brevipedicellatum	HMUT100463	--	KU059170	Xu et al. (unpublished)
Phragmidium butleri	HMAS-67841	--	MG669118	Liu et al. (2018)
Phragmidium fragariae	--	--	AF426217	Maier et al. (2003)
Phragmidium mucronatum	TFS01	--	KJ867552	El-Deeb (unpublished)
Phragmidium potentillae	BRIP:60089	--	KT199403	McTaggart et al. (2016b)

Table 1 Continued.

Taxon	Voucher/culture	GenBank accession Numbers		References
		ITS	LSU	
Phragmidium potentillae	HMJAU8609	MK296538	--	Ji (unpublished)
Phragmidium rosae-moschatae	BPI 893257	--	KY798368	Demers & Castlebury (unpublished)
Pileolaria pistaciae	--	MG860928	KY314266	Ishaq et al. (2020)
Puccinia actaeae-agropyri	TUB 14959	--	DQ917746	Maier et al. (2007)
Puccinia antirrhini	BPI 910208	--	KY764090	Demers et al. (unpublished)
Puccinia arenariae	BPI 893275		KY798385	Demers et al. (unpublished)
Puccinia argentata	IMI 502182	--	KC433402	Tanner et al. (unpublished)
Puccinia bistortae	TUB 14964	--	DQ917697	Maier et al. (2007)
Puccinia brachypodii	HSZ0975	GQ457303	--	Jin et al. (2010)
Puccinia brachypodii	BRIP 59466	--	KX999868	Marin-Felix et al. (2017)
Puccinia bupleuri	BPI 910217	--	KY764100	Demers et al. (unpublished)
Puccinia canaliculata	U-77	HQ412647		Deadman et al. (2011)
Puccinia carthami	SAF 1	AF064822		Berthier-Schaad (unpublished)
Puccinia carthami	--		AY787782	Deadman et al. (2005)
Puccinia cenchri	BPI055581	--	KY575080	Demers & Castlebury (unpublished)
Puccinia chloridis-incompletae	HSZ1393	KM096427	KM096427	Mahadevakumar (unpublished)
Puccinia chrysanthemi	HSZ2154	KX369039	--	Szabo & Nguyen (unpublished)
Puccinia chrysanthemi	R79F	--	HQ201322	Alaei (unpublished)
Puccinia circaeae	TUB 14969	--	DQ917716	Maier et al. (2007)
Puccinia coronata	--	--	DQ354526	Aime et al. (2006)
Puccinia crepidis-japonicae	BPI 893282	--	KY798360	Demers & Castlebury (unpublished)
Puccinia cyperi	BRIP 60997	KU296885	KU296885	McTaggart et al. (2016a)
Puccinia dactylidina	PUR F15426	JX533546	JX533546	Liu et al. (2013)
Puccinia dioicae	DAR 77052	EF635897	--	Morin et al. (2009)
Puccinia drabae	R209-16555	EU014054	EU014055	Alaei et al. (2009)
Puccinia ferruginosa	IBA7553	--	AB190901	Engkhaninun et al. (unpublished)
Puccinia ferruginosa	TSH-R6237	AB188126	--	Engkhaninun et al. (2005)
Puccinia graminis	72_2	--	JQ688991	Berlin et al. (2012)
Puccinia heterospora	BPI 893307	KY798362	--	Demers & Castlebury (unpublished)
Puccinia heterospora	BRIP 60937	--	KU296886	McTaggart et al. (2016a)
Puccinia heucherae	RHS5296/05	--	DQ359702	Henricot et al. (2007)
Puccinia hieracii	DAOM 240969	--	HQ317515	Liu et al. (2015)
Puccinia hordei	PDD:101656	--	KX985762	Padamsee & McKenzie (2017)
Puccinia hydrocotyles	--	--	GU936635	Zuluaga et al. (2011)
Puccinia iridis	KUS-F23394	--	MK446720	Choi et al. (2019)
Puccinia iridis	KUS-F30180	MK446718		Choi et al. (2019)
Puccinia kuehnii	BPI 881011	--	HQ666891	Saumtally et al. (2011)

Table 1 Continued.

Taxon	Voucher/culture	GenBank accession Numbers		References
		ITS	LSU	
Puccinia kuehnii	090687	GU564421	--	Glynn et al. (2010)
Puccinia lantanae	R190	--	EU851144	Zuluaga et al. (2011)
Puccinia lateritia	BPI 910249	--	KY764134	Demers et al. (unpublished)
Puccinia liberta	BRIP 59686	--	KX999881	Marin-Felix et al. (2017)
Puccinia linkii	DAOM:242721	KM851040	--	Mulvey & Hambleton (2015)
uccinia linkii	DAOM:243230	--	KM851041	Mulvey & Hambleton (2015)
Puccinia malvacearum	AFTOL-ID 1629	EF561641	--	Matheny & Hibbett (unpublished)
Puccinia malvacearum	U1384	--	MG907249	Aime et al. (2018)
Puccinia melanocephala	PM_NayMex_Xalsco	MG564638	--	Bermudez et al. (unpublished)
Puccinia melanocephala	PM_ColMex_CE_Tecoman	--	MG564636	Bermudez et al. (unpublished)
Puccinia menthae	BPI 910255	KY764141	--	Demers et al. (unpublished)
Puccinia menthae	BPI 871110		DQ354513	Aime et al. (2006)
Puccinia nakanishikii	BPI 910261	KY764147	--	Demers et al. (unpublished)
Puccinia nakanishikii	--	--	GU058002	Dixon et al. (2010)
Puccinia nepalensis	BA66	--	KX014746	Ali et al. (2017)
Puccinia nepalensis	BA651	KX225481	--	Ali et al. 2017)
Puccinia nitida	BPI 843472	--	KY764148	Demers et al. (unpublished)
Puccinia oahuensis	BPI087481	--	KY575092	Demers & Castlebury (unpublished)
Puccinia obscura	KR14322	--	FJ669234	Scholler et al. (2011)
Puccinia obscura	--	AF468042	--	Weber et al. (2003)
Puccinia ocimi	BPI 910262	KY764149	KY764149	Demers et al. (unpublished)
Puccinia operta	BPI142436		KY575095	Demers & Castlebury (unpublished)
Puccinia oxalidis	KUS-F27920	MH325473	--	Lee et al. (2019)
Puccinia oxalidis	BPI 893310	--	KY798348	Demers & Castlebury (unpublished)
Puccinia paspali	BPI841180	--	KY575098	Demers & Castlebury (unpublished)
Puccinia peradeniyae	BPI 089014	KX190906	KX190906	Demers et al. (2017)
Puccinia pimpinellae	--	GU058023	GU058023	Dixon et al. (2010)
Puccinia polygoni-amphibii	BPI 893289	--	KY798381	Demers & Castlebury (unpublished)
Puccinia polysora	--	HM467909	GU058024	Yu et al. (unpublished)
Puccinia porri	22-16	KY492366	--	Ristic et al. (unpublished)
Puccinia recondita	BPI 910319	--	KY798399	Demers & Castlebury (unpublished)
Puccinia rufipes	--	AJ406071	--	Virtudazo et al. (2001)
Puccinia scirpi	BRIP 61027	KX999892	KX999892	Marin-Felix et al. (2017)
Puccinia striiformis	HSZ1834	GQ457306	--	Jin et al. (2010)
Puccinia striiformis	HSZ1828	--	GQ457304	Jin et al. (2010)
Puccinia substriata	--	GU058028	--	Dixon et al. (2010)

Table 1 Continued.

Taxon	Voucher/culture	GenBank accession Numbers		References
		ITS	LSU	
Puccinia substriata	BPI106260		KY575101	Demers & Castlebury (unpublished)
Puccinia tanaceti	R221	HQ201323	HQ201324	Alaei (unpublished)
Puccinia thlaspeos	--	L76177		Roy et al. (1998)
Puccinia thlaspeos	--	L76183		Roy et al. (1998)
Puccinia turgida	NA224	MH144383	--	Otálora & Berndt (2018)
Puccinia turgida	NA223	MH144382		Otálora & Berndt (2018)
Puccinia versicolor	U902	--	MG907252	Aime et al. (2018)
Puccinia violae	BPI 842321	DQ354509	--	Aime (2006)
Puccinia violae	--	--	GU058029	Dixon et al. (2010)
Puccinia xanthii	BRIP48819	EU659694	--	Seier et al. (2009)
Puccinia xanthii	BRIP 56946		KX999896	Marin-Felix et al. (2017)
Pucciniastrum coryli	TSH-R4237 (IBA8641)	AB221419	--	Liang et al. (2006)
Ravenelia acaciae-arabicae	PREM61853	--	MN072675	Ebinghaus et al. (2020)
Ravenelia acaciae-pennatulae	U115	--	MG907213	Aime et al. (2018)
Ravenelia acaciicola	PREM61861	--	MN072683	Ebinghaus et al. (2020)
Ravenelia evansii	PREM61209	MG945959	--	Ebinghaus et al. (2018)
Ravenelia evansii	PREM61028	--	MG945996	Ebinghaus et al. (2018)
Tranzschelia discolor	U-884	DQ995341	--	Deadman et al. (2007)
Tranzschelia discolor	BRIP 57662	--	KR994891	Doungsa-Ard (unpublished)
Tranzschelia pruni-spinosae	KR-M-0002755	--	KX228774	Scholler et al. (2019)
Uromyces aloes	2020-6-28-0005	MT136509	--	Bily et al. (unpublished)
Uromyces aloes	WM 3290	--	DQ917740	Maier et al. (2007)
Uromyces ciceris-arietini	--	GU058030	--	Dixon et al. (2010)
Uromyces ciceris-arietini		--	GQ914998	Stuteville et al. (2010)
Uromyces clignyi	DAOM 192217	HM131364	--	Liu & Hambleton (2013)
Uromyces commelinae	JW100	KF982855	--	Kwon & Kim (2014)
Uromyces coronatus	DAOM 32991	HM131365	--	Liu & Hambleton (2013)
Uromyces coronatus	BPI 910293		KY764191	Demers et al. (unpublished)
Uromyces dactylidis	PRC:705	KM667955	--	Hrabetova et al. (2015)
Uromyces dactylidis	TUB 14997	--	DQ917745	Maier et al. (2007)
Uromyces dolicholi	DAOM 116149	HQ317563	HQ317563	Liu et al. (2015)
Uromyces eragrostidis	DAOM 106767	HQ317561	--	Liu et al. (2015)
Uromyces eragrostidis	BPI004474	--	KY575113	Demers & Castlebury (unpublished)
Uromyces euphorbiae	PUR N11621	KT750329	--	Rosskopf et al. (unpublished)
Uromyces euphorbiae	BPI 863673	--	KT750330	Rosskopf et al. (unpublished)
Uromyces geranii	BRIP 60100	--	KX999898	Marin-Felix et al. (2017)
Uromyces hedysari-obscuri	DAOM 189699	HQ317573	--	Liu et al. (2015)
Uromyces hedysari-obscuri	DAOM 223015	--	HQ317572	Liu et al. (2015)
Uromyces lespedezae-procumbentis	BPI 910294	KY764193	KY764193	Demers et al. (unpublished)

Table 1 Continued.

Taxon	Voucher/culture	GenBank accession Numbers		References
		ITS	LSU	
Uromyces minor	MVAP50000151	MK045314	MK045314	Blomquist (unpublished)
Uromyces muscari	DAOM 75626	HQ317552	HQ317552	Liu et al. (2015)
Uromyces orientalis	BRIP 60934	KX999899	KX999899	Marin-Felix et al. (2017)
Uromyces peglerae	BPI843311		KY575116	Demers & Castlebury (unpublished)
Uromyces pisi-sativi	--	DQ521591	--	Sagliocco et al. (unpublished)
Uromyces pisi-sativi	BRIP 60151	--	KX999900	Marin-Felix et al. (2017)
Uromyces polygoni-avicularis	DAOM 181565		HQ317558	Liu et al. (2015)
Uromyces rumicis	PDD:93529	KX985763	--	Padamsee & McKenzie (2017)
Uromyces rumicis	BPI 910298		KY764197	Demers et al. (unpublished)
Uromyces setariae-italicae	BPI863744	KY575068		Demers & Castlebury (unpublished)
Uromyces setariae-italicae	BPI863750	--	KY575069	Demers & Castlebury (unpublished)
Uromyces striatus	U-675	HQ412651	--	Deadman et al. (2011)
Uromyces striatus	DAOM 240966	--	HQ317512	Liu et al. (2015)
Uromyces strobilanthis	BPI 893253	--	KY798375	Demers & Castlebury (unpublished)
Uromyces tenuicutis	BRIP 60012	--	KX999904	Marin-Felix et al. (2017)
Uromyces trifolii	--	--	GU936634	Zuluaga et al. (2011)
Uromyces viciae-fabae	--	AB115665	--	Chung et al. (2004)
Uromyces viciae-fabae		--	AF426199	Maier et al. (2003)
Uromyces vignae	H92019	AB115731	--	Chung et al. (2004)
Uromyces vignae	BRIP 60213	--	KX999906	Marin-Felix et al. (2017)
Taphrina pruni	CBS 358.35	MH855700	MH867219	Vu et al. 2019)

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Angiopsora: Bagchee & Singh 1960, Bahadur & Sinha 1967, Ramakrishnan 1950, Ramakrishnan & Sundaram 1954b, Thirumalachar & Mundkar 1951, Vaheeduddin 1955. ***Arthuria***: Gokhle & Patel 1953. ***Bubakia***: Butler & Bisby 1931, Mundkar 1938, 1943, Ramakrishnan & Ramakrishnan 1950a. ***Calidion***: Ramakrishnan 1950. ***Chaconia***: Butler & Bisby 1931, Mishra et al. 1976, Patel et al. 1949, Patil & Thirumalachar 1971, Patil 1966a, Ramakrishnan 1950, Singh 1966. ***Ceropsora***: Bakshi & Singh 1960. ***Cerotelium***: Ahmad 1981, Arthur 1917, Bakshi et al. 1972, Butler 1914, Chowdhary 1948, Jain et al. 1966, Joshi & Vashiist 1959, Nagraj et al. 1971, Patil & Thirumalachar 1971, Patil 1966a, Pawar & Kulkarni 1973, Payak 1949, Ramachar et al. 1978, Ramakrishnan 1952, Rangaswamy et al. 1968, Sathe 1972b, Sydow & Mitter 1935, Thite & Patil 1970, Vasudeva 1962, Venkatakrishaiya 1958, Wakhloo 1962, Yadav 1963a, Yadav & Thirumalachar 1955. ***Chrysocelis***: Ramakrishnan & Ramakrishnan 1949. ***Chrysomyxa***: Bakshi & Singh 1972, Barclay 1890a, Butler 1906, 1910, Dietal 1890, Puri 1955, Sydow & Butler 1901, Ulbitch 1938. ***Coleosporium***: Anonymous 1950, Arthur 1934, Bagchee 1950b, Bakshi et al. 1972, Barclay 1890b, Berkeley 1856, Butler & Bisby 1931, Cummins 1943, Dewan & Kar 1974, Fleming 1874, Goswami & Singh 1973, Hafeezkhan 1928b, Kamal et al. 1979, Mitter & Tandon 1932a, b, Patil & Thirumalachar 1971, Patil 1966a, Prasada 1951, Puri 1955, Sanwal 1951b, Sydow 1922, Sydow & Mitter 1933, Sydow et al. 1937, Sydow & Butler 1901, Sydow et al. 1907, Sydow et al. 1912, Wani & Thirumalachar 1969, Yadav 1964a, Yadav & Thirumalachar 1955. ***Corbulopsora***: Thirumalachar 1947. ***Cronartium***: Anonymous 1950, Bagchee 1933, 1950a, b, c, Bakshi et al. 1972,

Butler & Bisby 1931, Goswami & Singh 1973, Hafeezkhan 1928a, Puri 1955. ***Crossopsora***: Chavan & Bakare 1974, Malviya & Jain 1981, Mundkar & Thirumalachar 1945, Mundkar & Thirumalachar 1952, Patil & Thirumalachar 1971, Patil 1966a, Ramakrishnan & Soumini 1946a, Sunderam 1961, Sydow et al. 1912, Yadav 1963b. ***Cystopsora***: Ramakrishnan & Sundaram 1952a, Rangaswamy et al. 1968, Sharma 1977. ***Dasturella***: Butler & Bisby 1931, Mishra & Nema 1976, Mundkar & Kheshwala 1943, Nema & Mishra 1965, Patel et al. 1949, 1951b, Patil & Thirumalachar 1971, Patil 1966a, Rangaswamy et al. 1968, Sathe 1965a, Thirumalachar et al. 1956, Thirumalachar & Gopalkrishan 1947, Yadav 1964a. ***Didymopsorella***: Rangaswamy et al. 1968, Thirumalachar 1950a, 1951, Thirumalachar & Mundkar 1950. ***Diorchidium***: Sydow et al. 1907, Yadav 1953. ***Elateraecium***: Thirumalachar et al. 1966. ***Endophyllum***: Arthur 1934, Cummins 1943, Gokhle et al. 1955, Singh & Jalan 1965, Nagraj et al. 1971, Patil 1966a, Thirumalachar & Govindu 1954, Thirumalachar & Narsimhan 1950b. ***Gambleola***: Butler 1906, Sydow & Butler 1901, Sydow et al. 1907. ***Goplana***: Ramakrishnan & Ramakrishnan 1949. ***Gymnopuccinia***: Ramakrishnan 1951c, Thite & Patil 1970. ***Gymnosporangium***: Arthur 1934, Arthur & Cummins 1936a, Barclay 1890d, Butler 1906, Cummins 1943, Sydow 1938, Sydow & Butler 1901. ***Hamaspora***: Goswami & Singh 1973, Massee 1892, Ramakrishnan & Sundaram 1954a. ***Hapalophragmium***: Jain et al. 1966, Mishra 1969, Ramakrishnan & Ramakrishnan 1948a, Thirumalachar 1950c. ***Hemileia***: Ananth & Chokanna 1961, Cooke 1876b, Krishnamurthy & Rangaswamy 1947, Massee 1906, Nagraj et al. 1971, Parndekar 1964, Patil & Thirumalachar 1971, Patil 1977, 1966a, Ramakrishnan 1957b, Ramakrishnan & Soumini 1946b, Rangaswamy et al. 1968, Sydow & Mitter 1933, Sydow & Butler 1901, Thirumalachar 1947, Thirumalachar 1950b, Thirumalachar & Narsimhan 1947, Thite & Patil 1970, Yadav 1963b. ***Hyalopsora***: Anonymous 1936, Arthur 1934, Chona & Munjal 1955, Munjal & Kapoor 1961, Sydow 1938. ***Kernella***: Thirumalachar & Mundkar 1949. ***Kernkampella***: Rajendren 1970, Bhagyanarayana & Ramachar 1985. ***Kuehneola***: Chavan 1975, Malviya & Jain 1981, Patil 1966a, Thite & Patil 1970, Yadav 1963b, Bhagyanarayana & Rao 1995, Hosagoudar 1985. ***Kweilingia***: Bakshi et al. 1972, Gautam & Avasthi 2018. ***Leucotelium***: Sydow 1939, Sydow et al. 1912, Nema & Mishra 1965. ***Macabuna***: Kamal et al. 1979. ***Maravalia***: Ahmad 1981, Arthur & Cummins 1936b, Butler & Bisby 1931, Patil & Thirumalachar 1971, Patil 1966a, Thirumalachar 1949a, Yadav & Thirumalachar 1955. ***Masseeëlla***: Joshi & Vashiist 1959, Mundkar & Thirumalachar 1952, Patel et al. 1949, Patil 1966a, Patwardhan 1964, Ramakrishnan 1957a, Sharma 1975, Thirumalachar 1943b, c. ***Melampsora***: Agarwal et al. 1959, Ajrekar 1912, Bagchee 1950b, Bagchee & Singh 1960, Bakshi & Singh 1961, Barclay 1891, Butler 1905, 1918, Butler & Bisby 1931, 1960, Chavan & Bakare 1977, Cooke 1876b, Cummins 1943, Jain et al. 1966, Kala & Gaur 1983a, Kaul 1959a, b, Kern & Thurston 1944, Lele 1952, Manocharachary et al. 1976, Mcrae 1917, Mishra 1969, 1963a, Mishra & Prasad 1966, Pandotra 1966, Pandotra & Ganguly 1964b, Parndekar 1964, Patil & Thirumalachar 1971, Patil 1966a, Payak 1949, Puri 1955, Ramachar & Bhagyanarayana 1977a, b, Ramakrishnan & Ramakrishnan 1949, Rangaswamy et al. 1968, Ravindra Nath & Narahari Reddy 1964, Srivastava 1982, Sydow & Butler 1901, Sydow et al. 1907, Sydow et al. 1912, Thirumalachar 1941b, Vasudeva 1948, 1949, 1950a, b. ***Melampsoridium***: Bakshi et al. 1972, Narayan & Kamal 1985, Patil 1966a, Sathe 1966a, Singh & Pandey 1972. ***Milesina***: Anonymous 1959a, Bagchee & Singh 1960. ***Monosporidium***: Barclay 1890c, Parndekar 1964, Patil 1966a, Sydow et al. 1912, Gokhle & Patel 1951. ***Neophysopella***: Mundkar 1943, Vaheeduddin 1955, Bagchee & Singh 1960. ***Nyssopsora***: Mundkar & Thirumalachar 1952, Nagachan & Goswami 1985, Rangaswamy et al. 1968, Roy 1948. ***Ochropsora***: Arthur & Cummins 1936a. ***Olivea***: Bakshi et al. 1972, Butler & Bisby 1931, Pandotra & Ganguly 1964b, Patil 1966a. ***Peridermium***: Anonymous 1950, Bakshi & Singh 1972, Barclay 1890b, Butler & Bisby 1931, Champion 1922, Cooke 1878b, Hafeezkhan 1928a, Mitter & Tandon 1932a, Puri 1955, Sydow & Butler 1901, Berkeley 1856, Cooke 1877. ***Peridiopsora***: Sathe 1969b. ***Phakopsora***: Bahekar 1966, Butler 1912, Butler & Bisby 1931, Dietal 1890, Jhooty et al. 1977, Kala & Gaur 1983a, Mundkar 1943, Nagraj et al. 1971, Patel et al. 1985, Patil & Thirumalachar 1971, Patil 1977, Ramachar et al. 1978, Ramakrishnan & Subramanian 1952, Ramakrishnan 1951c, Ramakrishnan 1952, 1955a, 1956, Ramakrishnan & Ramakrishnan 1950a, Ramakrishnan et al.1952, Ramakrishnan & Sundaram 1954b, 1955a, b, Rangaswamy et al. 1968, Sathe 1972a, Sharma & Jain

1981, Sydow 1938, Sydow et al. 1907, Sydow et al. 1912, Thirumalachar 1947, Uppal et al. 1935, Yadav 1963a, 1964a, Yadav & Thirumalachar 1955. ***Phragmidiella***: Patel et al. 1949, Patil 1966a, Thirumalachar & Mundkar 1949. ***Phragmidium***: Barclay 1890b, Barclay 1891, Bhattacharya & Baruah 1953, Cooke 1878a, b, Goswami & Singh 1973, Kala & Gaur 1983a, Mitter & Tandon 1932a, b, Mundkar 1938, Pandotra & Ganguly 1964b, Ramakrishnan & Sundaram 1953a, Sydow 1938, Sydow & Mitter 1935, Sydow et al. 1907, Sydow et al. 1911a, b. ***Physopella***: Agarwal et al. 1964, Khanna & Chandra 1975, Malviya & Jain 1981, Patil & Thirumalachar 1971, Ramachar 1966, Ramachar & Bhagyanarayana 1976, Sathe 1965d, Subramaniam & Ramakrishnan 1956. ***Pileolaria***: Sydow 1938, Gautam & Avasthi 2017c. ***Prospodium***: Bagyanarayana & Ravinder 1995, Bagyanarayana et al. 1998. ***Puccinia***: Agarwal et al. 1959, 1981, Ahmad 1977, Ahmad & Singh 1969, Ahmad et al. 1969, Anonymous 1950, Arthur 1934, Arthur & Cummins 1936a, Bagchee & Singh 1960, Balasubramanian 1973, Barclay 1890a, b, e, f, 1891, Berkeley 1856, Butler 1905, 1918, Butler & Bisby 1931, 1960, Butler & Hayman 1906, Chavan 1975, Chavan & Bakare 1974, Chavan & Bakare 1977, Chavan & Patil 1972, Chona et al. 1958, Chona & Munjal 1950, 1955, 1956, Chona et al. 1956, Chowdhary 1948, Cooke 1876a, b, Cooke 1878a, Cummins 1943, Cummins 1953, Dalela 1956, Dalela & Sinha 1964, Damle 1943, Darr & Shah 1980, Deoraj 1980, Dietal 1890, Dube 1958, Fleming 1874, Ganguly & Pandotra 1962, 1963, Gautam & Avasthi 2016b, Gautam & Avasthi 2017a, Gopinathnair 1972, Goswami 1974, Goswami & Singh 1973, Goyal et al. 1971, Gupta 1977, Gupta & Shukla 1955, Jadhav & Somani 1978a, b, Jain et al. 1966, Joshi & Lele 1984, Joshi & Merchand 1963, Joshi & Payak 1963, Joshi 1958, Joshi & Vashiist 1959, Kala & Gaur 1983a, b, Kamal et al. 1979, Kanaujia 1978, Kanaujia & Kishore 1981, Kanadswamy & Vijyalakshmi 1959, Kaul 1959b, Khanna 1961, Khosla et al. 1975, Khulbe & Verma 1978, Kolte & Awasthi 1979, Konger & Baruah 1958, Kumar et al. 1975, Malviya & Jain 1981, Mcrae 1917, Mehta 1934, Mishra et al. 1964, 1965, 1968, Mishra 1969, Mishra & Nema 1976, Mishra et al. 1976, Mishra & Mishra 1975, Mishra 1963b, Mishra & Lele 1963, Mishra & Sharma 1963, 1964, Mishra et al. 1975, Mitter & Tandon 1930, 1932a, b, 1937, Mundkar 1938, Mundkar & Ahmad 1946, Mundkar & Thirumalachar 1952, Mutkekar et al. 1968, Munshi 1976, Nema & Agarwal 1960, Nema & Mishra 1965, Padwick 1945a, b, Padwick & Khan 1944, Pandotra 1966, Pandotra & Ganguly 1962, Pandotra & Ganguly 1964a, b, Pandotra & Sastry 1969a, b, Parndekar 1964, Patel et al. 1949, 1950, Patil & Thirumalachar 1964, Patil & Thirumalachar 1971, Patil 1966a, Patil & Date 1980, Payak 1949, 1965, Payak & Khanna 1970, Payak & Mishra 1963, Payak & Renfro 1966, Prasad 1948, Prasada 1951, Rebenhorst 1878, Sharma & Shankar 1979, Rajendran 1966, Ramachar 1965, Ramachar et al. 1978, Ramachar & Bhagyanarayana 1976, Ramachar & Cummmins 1965, Ramakrishna & Subbayya 1973, Ramakrishnan 1950, Ramakrishnan 1952, 1955b, 1956, Ramakrishnan & Narasimhalu 1941, Ramakrishnan & Ramakrishnan 1946, Ramakrishnan & Ramakrishnan 1947, 1948a, b, Ramakrishnan & Ramakrishnan 1949, 1950b, c, Ramakrishnan et al. 1952a, b, Ramakrishnan & Sundaram 1952b, 1953b, 1954a, b, 1955a, 1956a, b, Rangaswamy et al. 1968, Roy 1964, 1968, Roy & Gupta 1959, Sachan et al. 1980, Sahni & Chona 1965, Salam & Ramachar 1955, Sathe 1965b, 1969a, 1971, Shanmugam et al. 1972, Sharma & Mukerji 1972, Sharma 1975, Sharma et al. 1979, Sharma & Singh 1964, Sharma 1957, Sharma et al. 1973, Shinde & More 1975, Shukla & Singh 1976, Siddiqui 1971, 1972, 1973, Singh & Kamal 1985, Singh & Sharma 1977, Singh 1962, Mishra et al. 1965, Mishra 1969, Sinha & Kapooria 1966, Sohi et al. 1967, Somani 1979, Soumini 1949, Srivastava 1979a, c, 1980, 1982, Subramaniam & Ramakrishnan 1956, Sunderam 1956, 1963, Sunderam et al. 1966, Sydow 1913, 1914, 1922, 1938, 1939, Sydow & Mitter 1935, Sydow et al. 1937, Sydow & Butler 1901, Sydow et al. 1907, Sydow et al. 1911a, b, Sydow et al. 1912, Thirumalachar 1941a, 1945, Thirumalachar 1947, 1949a, b, Thirumalachar & Mundkar 1951, Thirumalachar et al. 1943, Tilak & Rao 1968, Ulbitch 1938, Unni & Philip 1974, Uppal et al. 1935, Vasudeva 1948, 1949, 1950a, b, 1957, 1958, Wakhloo 1962, Yadav 1953, 1963b, 1964a, Yadav & Yadav 1965, Yadav et al. 1975. ***Pucciniastrum***: Bakshi et al. 1972, Patil 1966a. ***Pucciniosira***: Arthur 1934, Cummins 1943. ***Pucciniostele***: Barclay 1891, Sydow et al. 1912. ***Ramakrishnania***: Ramachar & Bhagyanarayana 1979. ***Ravenelia***: Berkeley 1839, Butler & Bisby 1931, Chavan & Bakare 1974, Cooke 1880a, b, Jain et al. 1966, Kapoor & Agarwal 1972, 1974, Mishra 1969, Mishra et al. 1976,

Mundkar & Prasad 1938, Narasimhan & Thirumalachar 1961, Patil & Thirumalachar 1971, Patil 1977, Patil & Thite 1978, Patil 1966a, b, Patil & Date 1977, Pavgi & Singh 1969, Petch 1912, Ramakrishnan 1952, 1957a, Ramakrishnan & Ramakrishnan 1948b, Ramakrishnan & Sundaram 1952b, Rangaswamy et al. 1968, Roy 1964, Salam & Ramachar 1956, Sanwal 1951a, Sathe 1965c, Siddiqui 1957, Sydow 1913, Sydow & Mitter 1933, Sydow & Butler 1901, Sydow et al. 1907, Sydow et al. 1912, Tyagi & Prasad 1972, 1978, Yadav 1963b, Yadav & Thirumalachar 1955. ***Roestelia***: Barclay 1891, Arthur & Cummins 1936a, Mitter & Tandon 1932a, 1937, Sydow et al. 1907. ***Scopella***: Butler & Bisby 1931, Cummins1950, Mundkar & Thirumalachar 1952, Narayan & Kamal 1985, Parndekar 1964, Patil & Thirumalachar 1971, Payak 1949, Solanki et al. 1985, Thirumalachar 1950c, Thirumalachar & Mundkar 1951. ***Skierka***: Chavan 1968, Gautam & Avasthi 2017c. ***Sphaerophragmium***: Cooke 1880a. ***Stakmania***: Sathe 1966c. ***Trachyspora***: Arthur 1934, Padwick & Merh 1943. ***Tranzschelia***: Patel et al. 1949, Waraitch & Khatri 1976, 1977. ***Trochodium***: Gharse 1944, Patil & Thirumalachar 1971, Patil 1966a, Thirumalachar 1942a. ***Uredinopsis***: Anonymous 1936, Munjal & Kapoor 1961, Patil 1966a, Puri 1955, Ramakrishnan & Ramakrishnan 1950b. ***Uredopeltis***: Ramachar et al. 1978, Sathe 1965e. ***Uromyces***: Agarwal et al. 1959, Ahmad 1941, Ajrekar 1912, Ajrekar & Tonapy 1923, Anonymous 1950, 1954, Arthur 1934, Arthur & Cummins 1936a, Asthana 1952, Bahadur & Sinha 1967, Barclay 1890a, 1891, Basuchaudhary & Singh 1971, Behera & Mukerji 1974, Butler & Bisby 1931, 1960, Chaudhari 1958, Chavan 1975, Chavan & Bakare 1973a, b, Chavan & Bakare 1974, Chavan & Bakare 1977, Cooke 1876a, Cummins 1943, Dietal 1890, Dube 1958, Dube et al. 1979, Dublish & Singh 1977, Gautam & Avasthi 2017b, Gerdemann & Bakshi 1976, Jain et al. 1966, Joshi & Reddy 1958, Joshi & Reddy 1959, Joshi 1958, Kapooria & Sinha 1966, Manocharachary 1975, Mathur 1967, Mathur & Singh 1964, Mishra 1969, Mishra & Khare 1969, Mishra & Nema 1976, Mishra et al. 1976, Mitter & Tandon 1930, 1932b, More & Moniz 1964, Nagachan & Verma 1984, Narasimhan & Thirumalachar 1964, Nema & Agarwal 1960, Nema & Mishra 1965, Padwick & Khan 1944, Padwick & Merh 1943, Pandotra 1966, Pandotra & Sastry 1969a, Parndekar 1964, Patel et al. 1949, Patil & Thirumalachar 1968, Patil & Thirumalachar 1962, Patil & Thirumalachar 1971, Patil 1966a, Patil & Date 1980, Pavgi & Upadhyay 1966, Payak 1949, 1953, 1962, Ponappa 1969, Prasad et al. 1962, Rebenhorst 1878, Ramachar et al. 1978, Ramakrishnan & Subramanian 1952, Ramakrishnan 1951b, Ramakrishnan 1952, Ramakrishnan & Ramakrishnan 1948b, Ramakrishnan & Rangaswamy 1948, Ramakrishnan & Shrinivasan 1950, Ramakrishnan et al. 1952a, b, Ramakrishnan & Sundaram 1955a, Rangaswamy et al. 1968, Rolla & Addala 1963, Sachan et al. 1980, Saini & Chand 1984, Saksena 1956, 1930, Sokhi & Sohi 1976, Srivastava 1979b, Sunderam 1964, Sydow 1913, 1922, 1938, Sydow & Mitter 1935, Sydow et al. 1937, Sydow & Butler 1901, Sydow et al. 1907, Sydow et al. 1912, Thite & Patil 1970, Ulbitch 1938, Uppal et al. 1935, Vasudeva 1948, 1949, 1950a, b, Yadav 1963b, Yadav & Thirumalachar 1955. ***Xenostele***: Ramakrishnan 1951a. ***Zaghouania***: Butler & Bisby 1931.

Pucciniales **genera incertae sedis**

Aecidium: Ajrekar 1936, Arthur & Cummins 1936a, Bagchee & Singh 1960, Barclay 1890a, b, 1891, Bhagat & Kelkar 1974, Butler & Bisby 1931, 1960, Chavan & Bakare 1973a, b, 1974, Chavan & Patil 1972, Cooke 1878a, Cummins 1943, Goswami 1972, Goswami & Bhattacharjee 1973, Gupta & Gupta1985, Hennings 1900, Hosagaudar 1984, Kamal & Singh 1981, Kamal et al. 1979, Mishra et al. 1976, Mitter & Tandon 1932a, b, Mundkar 1938, Mundkar & Thirumalachar 1952, Pandotra & Ganguly 1964b, Pandotra & Sastry 1969b, Patel et al. 1949, Patil & Thirumalachar 1971, Prasad et al. 1962, Ramachar 1956, Ramakrishnan 1959, 1960, Ramakrishnan & Ramakrishnan 1946, 1948a, 1949, Ramakrishnan et al. 1952a, b, Ramakrishnan & Sundaram 1953a, b, Rangaswamy et al. 1968, Salam & Ramachar 1955, 1956, Sathe 1965c, 1966b, Singh & Kamal 1985, Sunderam & Rao 1950, Sydow 1913, Sydow 1914, Sydow & Mitter 1933, Sydow & Mitter 1935, Sydow & Sydow 1904a, 1911, 1912a, b, Sydow 1921, Sydow & Sydow 1917, Sydow & Butler 1901, Sydow et al. 1907, Sydow et al. 1912, Thirumalachar 1947, Thirumalachar 1950c, Thirumalachar & Narsimhan 1950a, Thite & Patil 1970, Ulbitch 1938, Uppal et al. 1935, Yadav 19563b, Yadav & Saran 1985. ***Phragmotelium***: Thirumalachar 1942b, Thirumalachar et al. 1943. ***Tunicopsora*** Suj. Singh & P.C.

Pandey: Bakshi et al. 1972. ***Uraecium***: Ramakrishnan 1965, Ramakrishnan & Ramakrishnan 1948b. ***Uredo***: Anonymous 1959b, Bagchee & Singh 1960, Barclay 1890b, 1891, Berkeley 1839, Butler & Bisby 1931, 1960, Chavan 1975, Chavan & Bakare 1973a, b, 1974, Chavan & Bhambure 1975, Cooke 1876b, 1879, Kamal et al. 1979, Kanaujia & Kishore 1981, Kapoor & Agarwal 1974, Laundon & Ponappa 1966, Nagraj et al. 1971, Padwick 1945a, b, Padwick & Khan 1944, Pandotra 1966, Patel et al. 1951a, Patil 1977, Patil & Thite 1978, Rahalkar 1977, Ramachar et al. 1978, Ramakrishnan 1951a, 1952, 1956, 1957a, Ramakrishnan & Ramakrishnan 1948a, Ramakrishnan & Ramakrishnan 1949, Ramakrishnan et al. 1952a, Ramakrishnan & Sundaram 1953b, Rangaswamy et al. 1968, Sathe & Rahalkar 1976, Sunderam 1961, Sydow & Mitter 1935, Sydow et al. 1937, Sydow & Sydow 1904b, 1924, Sydow & Butler 1901, Sydow et al. 1912, Thirumalachar 1947, Thirumalachar 1950c, Vaheeduddin 1955, Yadav 1964b.

Results

Accepted taxa of rust fungi of *Basidiomycota* up to genus are summarized in Table 1 while, the species of each genus are mentioned in detailed outline of the fungi reported from India. The rust fungi of India comprised of 640 species and 69 genera belonging to 16 families. Highest numbers of species were reported in *Pucciniaceae* (393) followed by *Raveneliaceae* (61), *Phakopsoraceae* (50), *Coleosporiaceae* (32), *Phragmidiaceae* (27), *Pucciniastraceae* (19), *Melampsoraceae* (18), *Crossopsoraceae* (14), *Zaghouaniaceae* (13), *Gymnosporangiaceae* (7), *Milesinaceae* (5), *Skierkaceae* (3), *Tranzscheliaceae* (3), *Pileolariaceae* (2), *Ochropsoraceae* (1), *Sphaerophragmiaceae* (1). Similarly, when comparing the rust genera, highest number of species of rust fungi was found *Puccinia* (279), followed by *Uromyces* (89), *Ravenelia* (33), *Phakospora* (25), *Coleosporium* (19), *Phragmidium* (18), *Melampsora* (17) and *Maravalia* (11). Many taxa of rust fungi with uncertain taxonomic position are placed in *incertae sedis*. Similarly, the generic names have been transferred to new genera, but either their types or records from India still need to be revised. Such genera and their species are discussed in notes of Indian rust genera section of this manuscript.

Outline of rust fungi reported from India

The information presented in the outline is arranged as phylum followed by subphylum, class, order, family, genus and species.

Taxonomy

Basidiomycota R.T. Moore
Pucciniomycotina R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw.
Pucciniomycetes R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw.
Pucciniales Clem. & Shear

1. ***Coleosporiaceae*** Dietel, In: Engler & Prantl, Nat. Pflanzenfam., Teil. I (Leipzig) 1: 548. 1900. ***emend***. Aime & McTaggart
    Coleosporium Lév. (19)
        Coleosporium asterum (Dietel) Syd. & P. Syd.
        Coleosporium barclayense Bagchee
        Coleosporium bletiae Dietel
        Coleosporium campanulae (Pers.) Tul.
        Coleosporium clematidis Barclay
        Coleosporium datiscae Tranzschel
        Coleosporium inulae Rabenh.
        Coleosporium ipomoeae (Schwein.) Burrill
        Coleosporium himalayense Durrieu
        Coleosporium leptodermidis (Barclay) P. Syd. & Syd.

Coleosporium mitteri Syd.
Coleosporium myriactidis Syd.
Coleosporium oldenlandiae E.J. Butler
Coleosporium perillae P. Syd.
Coleosporium plectranthi Barclay
Coleosporium satyrii Mundk. & Thirum.
Coleosporium senecionis (Pers.) Fr.
Coleosporium sidae Sanwal
Coleosporium xanthoxyli Dietel & P. Syd. (1898)

Chrysomyxa Unger (7)
Chrysomyxa deformans (Dietel) Jacz.
Chrysomyxa dietelii Syd. & P. Syd.
Chrysomyxa himalensis Barclay
Chrysomyxa piceae Barclay
Chrysomyxa pirolae (DC.) Rostr.
Chrysomyxa vitis E.J. Butler
Chrysomyxa himalayensis Singh, Khan & Mishra

Cronartium Fr. (4)
Cronartium fici T.S. Ramakr. & K. Ramakr.
Cronartium himalayense Bagchee
Cronartium quercuum (Berk.) Miyabe ex Shirai
Cronartium ribicola J.C. Fisch.

Goplana Racib. (1)
Goplana indica T.S. Ramakr. & K. Ramakr.

Stakmania Kamat & Sathe (1)
Stakmania indica Kamat & Sathe

2. *Crossopsoraceae* Aime & McTaggart, In: Fungal Systematics and Evolution 7: 21–47. 2020

Angiopsora Mains (2)
Angiopsora cyrtococci T.S. Ramakr. & Sundaram
Angiopsora apoda (Har. & Pat.) Aime & McTaggart

Crossopsora Syd. & P. Syd. (3)
Crossopsora premnae (Petch) Syd. & P. Syd.
Crossopsora premnae-tomentosae T.S. Ramakr. & Soumini
Crossopsora symphorematis Sundaram
Crossopsora ziziphi (Syd., P. Syd. & E.J. Butler) Syd. & P. Syd.

Dasturella Mundk. & Khesw. (3)
Dasturella bambusina Mundk. & Khesw.
Dasturella boswelliae Patel, Payak & N.B. Kulk.
Dasturella oxytenantherae Sathe

Kweilingia Teng (2)
Kweilingia bagchii (Suj. Singh & P.C. Pandey) Buriticá
Kweilingia divina (Syd.) Buriticá

Neophysopella Jing X. Ji & Kakish. (3)
Neophysopella ampelopsidis (Dietel & P. Syd.) Jing X. Ji & Kakish.
Neophysopella meliosmae (Kusano) Jing X. Ji & Kakish.
Neophysopella meliosmae-myrianthae (Henn. & Shirai) Jing X. Ji & Kakish.

Physopella (2)
Physopella artocarpi (Berk. & Broome) Arthur
Physopella vernoniae (T.S. Ramakr.) Ramachar & Bhagyan.

3. ***Gymnosporangiaceae*** P. Zhou & L. Cai, Persoonia 45: 79. 2020. emend. Aime & McTaggart

Peridiopsora **Kamat & Sathe** (1)

Peridiopsora adelocaryi Kamat & Sathe

Gymnosporangium R. Hedw. ex DC. (3)

Gymnosporangium clavariiforme (Wulfen) DC.

Gymnosporangium confusum Plowr.

Gymnosporangium cunninghamianum Barclay

Roestelia Rebent. (3)

Roestelia distorta (Arthur & Cummins) F. Kern

Roestelia cunninghamianum (Barclay) F. Kern

Roestelia patula (Syd. & P. Syd.) F. Kern

4. ***Melampsoraceae*** Dietel, in Engler & Prantl, Nat. Pflanzenfam., Teil. I (Leipzig) 1: 38. 1897

Ceropsora B.K. Bakshi & Suj. Singh (1)

Ceropsora piceae (Barclay) B.K. Bakshi & Suj. Singh

Melampsora Castagne (17)

Melampsora caprearum Thüm.

Melampsora ciliata Barclay

Melampsora damnosa (Sacc.) Lind.

Melampsora epitea Thüm.

Melampsora eucalypti Rabenh.

Melampsora euphorbiae (Ficinus & C. Schub.) Castagne

Melampsora euphorbiae-geniculatae F. Kern & Thurst.

Melampsora geniculatae Ramachar & Bhagyan.

Melampsora hypericorum (DC.) J. Schröt.

Melampsora lini (Ehrenb.) Lév.

Melampsora mundkurii Thirum.

Melampsora oblonga Bagchee

Melampsora populnea (Pers.) P. Karst.

Melampsora salicis-albae Kleb.

Melampsora salicis-wallichianae Ulbr.

Melampsora sancti-johannis Barclay

Melampsora stereospermi T.S. Ramakr. & K. Ramakr.

Melampsora yoshinagai Henn.

Melampsora caprearum Thüm.

5. ***Milesinaceae*** Aime & McTaggart, In: Fungal Systematics and Evolution 7: 21–47. 2020

Milesina Magnus (3)

Milesina coniogrammes Hirats. f.

Milesina exigua Faull

Milesina polypodii (F.B. White) Aime & Rossman

Uredinopsis Magnus (2)

Uredinopsis macrosperma (Cooke) Magnus

Uredinopsis syngrammes Munjal & J.N. Kapoor

6. ***Ochropsoraceae*** (Arthur) Aime & McTaggart, In: Fungal Systematics and Evolution 7: 21–47. 2020

Ochropsora Dietel (1)

Ochropsora ariae (Fuckel) Ramsb.

7. ***Phakopsoraceae*** Cummins & Y. Hirats., Illustr. Gen. Rust Fungi, rev. Edn (St. Paul): 13. 1983. emend. Aime & McTaggart

Arthuria Jackson (2)

Arthuria glochidii Gokhale, Patel & Thirum.

Arthuria tylophorae T.S. Ramakr.

Bubakia Arthur (1)

Bubakia indica T.S. Ramakr. & K. Ramakr.

Cerotelium Arthur (7)

Cerotelium bauhiniae Thirum. & Yadav

Cerotelium fici (Castagne) Arthur

Cerotelium kirganeliae Thirum. & Yadav

Cerotelium peregrinum (P. Syd. & Syd. & E.J. Butler) Arthur

Cerotelium terminaliae-paniculatae Nag Raj, Govindu & Thirum.

Cerotelium trichosanthis (Petch) Nag Raj, Govindu & Thirum.

Cerotelium wagateae Thirum. & Gopalkr.

Macabuna Buriticá & J.F. Hennen (1)

Macabuna ziziphi (Pat.) Buriticá & J.F. Hennen

Monosporidium Barclay (3)

Monosporidium andrachnes Barclay ex Sacc.

Monosporidium euphorbiae Barclay ex Sacc.

Monosporidium pavettae (Gokhale & Patel) Buriticá

Masseeella Dietel (6)

Masseeella breyniae Thirum.

Masseeella capparis (Hobson bis ex Cooke) Dietel

Masseeella flueggeae Syd.

Masseeella narasimhanii Thirum.

Masseeella putranjivae T.S. Ramakr.

Masseeella terminaliae Patw.

Phakopsora Dietel (25)

Phakopsora apludae M.S. Patil

Phakopsora artemisiae Hirats. f.

Phakopsora caseariae Yadav

Phakopsora chorisandrae T.S. Ramakr. & G.S. Reddy

Phakopsora cingens (Syd. & P. Syd.) Hirats.

Phakopsora cronartiiformis Dietel

Phakopsora desmium (Berk. & Broome) Cummins

Phakopsora elephantopodis Hirats

Phakopsora elettariae (Racib.) Cummins

Phakopsora erythrinae Gäum.

Phakopsora fici-elasticae T.S. Ramakr.

Phakopsora formosana Syd. & P. Syd.

Phakopsora incompleta (Syd. & P. Syd.) Cummins

Phakopsora kirganeliae T.S. Ramakr. & K. Ramakr.

Phakopsora mangalorica T.S. Ramakr. & Sundaram

Phakopsora meibomiae (Arthur) Arthur

Phakopsora pachyrhizi Syd. & P. Syd.

Phakopsora odinae Mundk.

Phakopsora pachyrhizi Syd. & P. Syd.

Phakopsora parasnathii Yadav & Thirum.

Phakopsora phyllanthi Dietel

Phakopsora punctiformis (Barclay & Dietel) Dietel

Phakopsora sterculiae Nag Raj, Govindu & Thirum.

Phakopsora zingiberis T.S. Ramakr

Phakopsora ziziphi-vulgaris Dietel

Phragmidiella Henn. (3)
Phragmidiella aliena (Syd., P. Syd. & E.J. Butler) Buriticá & J.F. Hennen
Phragmidiella heterophragmatis (Mundk. & Thirum.) Thirum. & Mundk.
Phragmidiella holwayi (H.S. Jacks.) Buriticá
Pucciniostele Tranzschel & K.L. Kom. (1)
Pucciniostele clarkiana (Barclay) Tranzschel & K.L. Kom.
Uredopeltis Henn. (1)
Uredopeltis chevalieri J. Walker & R.G. Shivas

8. ***Phragmidiaceae*** Corda Icon. fung. (Prague) 1: 6. 1837
Hamaspora Körn. (2)
Hamaspora longissima (Thüm.) Körn.
Hamaspora rubi-sieboldii (Kawagoe) Dietel
Kuehneola Magnus (6)
Kuehneola grewiae (Mundk. & Thirum.) Thirum.
Kuehneola loeseneriana (Henn.) H.S. Jacks. & Holw.
Kuehneola flacourtiae (Mundk. & Thirum.) Thirum.
Kuehneola ramacharii Bagyan. & K.N. Rao
Kuehneola spondiadis Hosag.
Kuehneola ziziphi (T.S. Ramakr. & Subram.) Thirum.
Phragmidium Link (18)
Phragmidium assamense Syd. & P. Syd.
Phragmidium barclayi Dietel
Phragmidium brevipedicellatum Hirats. f.
Phragmidium bulbosum (Fr.) Schltdl.
Phragmidium butleri Syd. & P. Syd.
Phragmidium egenulum Syd., P. Syd. & E.J. Butler
Phragmidium fragariae (Rabenh.) Ces.
Phragmidium kamtschatkae (H.W. Anderson) Arthur & Cummins
Phragmidium mucronatum (Pers.) Schltdl.
Phragmidium orientale Syd. & P. Syd.
Phragmidium potentillae (Pers.) P. Karst.
Phragmidium rosae-moschatae Dietel
Phragmidium incompletum Barclay
Phragmidium laceianum Barclay
Phragmidium malvacearum Bert.
Phragmidium nepalense Barclay
Phragmidium octoloculare Barclay
Phragmidium quinqueloculare Barclay
Trachyspora Fuckel (1)
Trachyspora alchemillae (Pers.) Fuckel

9. ***Pileolariaceae*** (Arthur) Cummins & Y. Hirats., llustr. Gen. Rust Fungi, rev. Edn (St. Paul): 14. 1983. ***emend***. Aime & McTaggart
Pileolaria Castagne (2)
Pileolaria indica Syd.
Pileolaria pistaciae F.L. Tai & C.T. Wei

10. ***Pucciniastraceae*** Gäum. ex Leppik, Ann. bot. fenn. 9: 139. 1972. ***emend***. Aime & McTaggart
Hyalopsora Magnus (2)
Hyalopsora orientalis Chona & Munjal
Hyalopsora polypodii (Pers.) Magnus

Melampsoridium Kleb. (4)

Melampsoridium betulinum (Pers.) Kleb.
Melampsoridium hiratsukanum S. Ito ex Hirats. f.
Melampsoridium indicum Sathe
Melampsoridium inerme Suj. Singh & P.C. Pandey

Pucciniastrum G.H. Otth (6)

Pucciniastrum aceris Syd.
Pucciniastrum agrimoniae (Dietel) Tranzschel
Pucciniastrum celastri Syd. & P. Syd.
Pucciniastrum coriariae Dietel
Pucciniastrum coryli Kom.
Pucciniastrum gaultheriae Syd. & P. Syd.

Peridermium (Link) J.C. Schmidt & Kunze (7)

Peridermium brevius Barclay
Peridermium cedri Barclay
Peridermium ephedrae Cooke
Peridermium himalayense Bagchee
Peridermium orientale Cooke
Peridermium piceae Barclay
Peridermium thomsonii Berk.

11. ***Pucciniaceae*** Chevall., Fl. gén. env. Paris (Paris) 1: 413. 1826. emend. Aime & McTaggart

Caeoma Link (4)

Caeoma himalayense Suj. Singh, S.N. Khan & B.M. Misra
Caeoma scopariae K.N. Rao
Caeoma euphorbiae-geniculatae Ramachar & Bhagyan.
Caeoma indicum Rajendren

Chrysocelis Lagerh. & Dietel (1)

Chrysocelis butleri (Dietel, Syd. & P. Syd.) G.F. Laundon

Corbulopsora Cummins (1)

Corbulopsora cumminsii Thirum.

Endophyllum Lév. (8)

Endophyllum cassiae Nag Raj, Govindu & Thirum.
Endophyllum cassiae (Bres.) F. Stevens & Mendiola
Endophyllum elaeagni-latifoliae (Petch) Gokhale, Thirum. & Patel
Endophyllum emiliae-sonchifoliae Nag Raj, Govindu & Thirum.
Endophyllum heliotropii Thirum. & Naras.
Endophyllum kaernbachii (Henn.) F. Stevens & Mendiola
Endophyllum maheshwarii Hard. Singh & Jalan
Endophyllum macowanianum (Thüm.) Pole-Evans
Endophyllum spilanthis Thirum. & Govindu

Gambleola Massee (1)

Gambleola cornuta Massee

Hapalophragmium Syd. & P. Syd. (4)

Hapalophragmium anamalaiense T.S. Ramakr. & K. Ramakr.
Hapalophragmium mysorense Thirum.
Hapalophragmium ponderosum Syd., P. Syd. & E.J. Butler
Hapalophragmium tandonii Mitter

Kernella Thirum. (1)

*Kernella lauricola (*Thirum.) Thirum.

Puccinia Pers. (279)

Puccinia acanthospermi Henn.

Puccinia acrophila Peck
Puccinia actaeae-agropyri E. Fisch.
Puccinia adjuncta Mitter
Puccinia aggregata Syd. & P. Syd.
Puccinia agrostidis Plowr.
Puccinia ahmadiana Syd.
Puccinia ainsliaeae P. Syd. & Syd.
Puccinia altii Rud.
Puccinia amphilophidis Doidge
Puccinia angelicae (Schumach.) Fuckel
Puccinia anodae P. Syd. & Syd.
Puccinia antirrhini Dietel & Holw.
Puccinia apii Desm.
Puccinia apludae Syd. & P. Syd.
Puccinia arachidis Speg.
Puccinia arenariae (Schumach.) J. Schröt.
Puccinia argentata (Schultz) G. Winter
Puccinia aristidae Tracy
Puccinia aristidicola Henn.
Puccinia arthraxonis-ciliaris Cummins
Puccinia arundinellae Barclay
Puccinia asterum (Schwein.) F. Kern
Puccinia atropuncta Peck & Clinton
Puccinia azanzae Yadav
Puccinia baradensis P.B. Chavan & U.V. Kulk.
Puccinia barbeyi (Roum.) Magnus
Puccinia behenis G.H. Otth
Puccinia belamcandae Dietel
Puccinia bellurensis Thirum.
Puccinia betae-bengalensis Mundk. & Thirum.
Puccinia bistortae (F. Strauss) DC.
Puccinia blepharidis Henn.
Puccinia bottomleyae Doidge
Puccinia brachypodii G.H. Otth
Puccinia bulbostylidis Doidge
Puccinia bupleuri F. Rudolphi
Puccinia butleri Syd. & P. Syd.
Puccinia cacao McAlpine
Puccinia caheunsis Ell. & Ev.
Puccinia calcitrapae var. *filicinae Barclay*
Puccinia calcitrapae DC.
Puccinia calosperma Syd., P. Syd. & E.J. Butler
Puccinia calthae Link
Puccinia caricis-filicinae Barclay
Puccinia caricis-nubigenae Padwick & A. Khan
Puccinia cenchri Dietel & Holw.
Puccinia cephalandrae-indicae Syd. & P. Syd.
Puccinia chaerophylli Purton
Puccinia chloridis-incompletae T.S. Ramakr., Sriniv. & Sundaram
Puccinia chrysanthemi Roze
Puccinia circaeae Pers.
Puccinia citrina P. Syd. & Syd.

Puccinia citrulli Syd., P. Syd. & E.J. Butler
Puccinia citrullina Raghun. & K. Ramakr. ex Hosag. & Raghun.
Puccinia collettiana Barclay
Puccinia conclusa Thüm.
Puccinia congesta Berk. & Broome
Puccinia coronata Corda
Puccinia courtoisiae (Syd. & P. Syd.) Syd.
Puccinia crepidis-japonicae (Lindr.) Dietel
Puccinia crepidis-sibiricae Lindr.
Puccinia cressae Lagerh.
Puccinia ctenolepidis Ramachar & Bagyan.
Puccinia curculiginis Racib.
Puccinia curcumae T.S. Ramakr. & Sundaram
Puccinia cynodontis Lacroix ex Desm.
Puccinia cyperi Arthur
Puccinia cyperi-tagetiformis (Henn.) F. Kern
Puccinia dactylidina Bubák
Puccinia deodikarii K.R.G. Nair
Puccinia desertorum Syd. & P. Syd.
Puccinia digitariae Ramachar & George
Puccinia digitariae-biformis P.B. Chavan & Hosag.
Puccinia digitariae-vestitae Ramachar & Cummins
Puccinia dioicae Magnus
Puccinia dioscoreae Kom.
Puccinia dovrensis A. Blytt
Puccinia drabae F. Rudolphi
Puccinia droogensis E.J. Butler
Puccinia abutilonis Berk. & Broome
Puccinia aristidae var. chaetariae Cummins & S.M. Husain
Puccinia bulbocastani (A. Cumino) Fuckel
Puccinia canaliculata (Schwein.) Lagerh.
Puccinia centaureae H. Mart.
Puccinia chrysopogoni Barclay
Puccinia coronata f.sp. *avenae* P. Syd. & Syd.
Puccinia dissiliens Cooke
Puccinia duthiei Ellis & Tracy
Puccinia ellisii De Toni
Puccinia elytrariae Henn.
Puccinia engleriana Henn.
Puccinia enteropogonis P. Syd. & Syd.
Puccinia eragrostidis Petch
Puccinia eremuri Kom.
Puccinia erianthi Padwick & A. Khan
Puccinia eulaliae Barclay
Puccinia eutela Syd.
Puccinia exhauriens Thüm.
Puccinia expallens Syd. & P. Syd.
Puccinia echinopis DC.
Puccinia excelsa Barclay
Puccinia fagopyri Barclay
Puccinia fagopyricola Jørst.
Puccinia ferruginosa P. Syd. & Syd.

Puccinia festucae Plowr.
Puccinia fimbristylidis Arthur
Puccinia fimbristylidis-ferrugineae Ramachar, Bhagyan. & A. Kumar
Puccinia flaccida Berk. & Broome
Puccinia flavipes Syd. & P. Syd.
Puccinia fuirenicola Arthur
Puccinia fusca G. Winter
Puccinia garnotiae T.S. Ramakr. & Sundaram
Puccinia gentianae (F. Strauss) Link
Puccinia geranii-silvatici P. Karst.
Puccinia gerberae Pole-Evans
Puccinia gouaniae Holw.
Puccinia gracilenta Syd., P. Syd. & E.J. Butler
Puccinia graminis f. *avenae* Erikss. & Henning
Puccinia graminis Pers.
Puccinia graminis f. *agropyri* P.R. Mehta & R. Prasad
Puccinia graminis f. *poae* Erikss. & Henning
Puccinia graminis f. *tritici* Erikss. & Henning
Puccinia gymnopetali-wightii T.S. Ramakr., Sriniv. & Sundaram
Puccinia helianthi Schwein.
Puccinia heraclei Grev.
Puccinia heracleicola Cummins
Puccinia herqueri
Puccinia heterospora Berk. & M.A. Curtis
Puccinia heucherae (Schwein.) Dietel
Puccinia hieracii (Röhl.) H. Mart.
Puccinia himachalensis A.K. Gautam & S. Avasthi
Puccinia holboelliae-latifoliae Cummins
Puccinia hookeri P. Syd. & Syd.
Puccinia hordei G.H. Otth
Puccinia hyderabadensis Bagyan. & Ravinder
Puccinia hydrocotyles (Mont.) Cooke
Puccinia hypoxidis McAlpine
Puccinia inayatii Syd. & P. Syd.
Puccinia insidiosa Berk.
Puccinia intermixta Peck
Puccinia invenusta Syd. & P. Syd.
Puccinia investita Schwein.
Puccinia iridis Wallr.
Puccinia isachnes Petch
Puccinia jagopyri Barclay
Puccinia jasminicola T.S. Ramakr. & K. Ramakr.
Puccinia joerstadii S. Ahmad
Puccinia kalchbrenneri De Toni
Puccinia kenmorensis Cummins
Puccinia kraussiana Cooke
Puccinia kuehnii (W. Krüger) E.J. Butler
Puccinia kunthiana T.S. Ramakr., Sriniv. & Sundaram
Puccinia lantanae Farl.
Puccinia lateripes Berk. & Ravenel
Puccinia lateritia Berk. & M.A. Curtis
Puccinia launaeae Maire

Puccinia leiocarpa Thirum.
Puccinia leonotidicola Henn.
Puccinia leucadis P. Syd. & Syd.
Puccinia leucophaea Syd., P. Syd. & E.J. Butler
Puccinia leveillei Mont.
Puccinia levis (Sacc. & Bizz.) Magnus
Puccinia libani Magnus
Puccinia liberta F. Kern
Puccinia ligustici Ellis & Everh.
Puccinia linkii Klotzsch
Puccinia lithospermi Ellis & Kellerm.
Puccinia longirostris Kom
Puccinia luculenta (Syd. & P. Syd.) T.S. Ramakr. & K. Ramakr.
Puccinia macrorhynchi Rabenh.
Puccinia malvacearum Bertero ex Mont.
Puccinia melanocephala Syd. & P. Syd.
Puccinia melasmioides Tranzschel
Puccinia menthae Pers.
Puccinia merrillii Henn.
Puccinia microspora Dietel
Puccinia minutissima Arthur
Puccinia monticola Kom.
Puccinia mysorensis Syd.
Puccinia melothriicola Syd. & P. Syd.
Puccinia nakanishikii Dietel
Puccinia nepalensis Barclay & Dietel
Puccinia neyraudiae Syd. & P. Syd.
Puccinia nitida Barclay
Puccinia oahuensis Ellis & Everh.
Puccinia obscura J. Schröt.
Puccinia ocimi Doidge
Puccinia oligocarpa Syd., P. Syd. & E.J. Butler
Puccinia operculinae T.S. Ramakr. & Sundaram
Puccinia operta Mundk. & Thirum.
Puccinia opizii Bubák
Puccinia oplismeni Syd. & P. Syd.
Puccinia oreogeta Syd.
Puccinia oryzopsidis Syd., P. Syd. & E.J. Butler
Puccinia ottochloae T.S. Ramakr.
Puccinia oxalidis Dietel & Ellis
Puccinia pachypes Syd. & P. Syd.
Puccinia pacifica Blasdale ex Arthur
Puccinia padwickii Cummins
Puccinia panici-montani Fujik. ex Ramachar & Cummins
Puccinia paspali Tracy & Earle
Puccinia pectiniformis T.S. Ramakr., Sriniv. & Sundaram
Puccinia peradeniyae Demers & Castl.
Puccinia peraffinis Syd. & P. Syd.
Puccinia phragmitis (Schumach.) Tul.
Puccinia phyllocladiae Cooke
Puccinia phyllostachydis Kusano
Puccinia pieridiz Hazel.

Puccinia pimpinellae (F. Strauss) Link
Puccinia plicata Kom.
Puccinia pogonatheri Petch
Puccinia polliniae Barclay
Puccinia polliniae-quadrinervis Dietel
Puccinia polygoni-amphibii Pers.
Puccinia polygoni-weyrichii Miyabe
Puccinia polysora Underw.
Puccinia porri (Sowerby) G. Winter
Puccinia praecox Bubák
Puccinia prainiana Barclay
Puccinia prenanthis-purpureae (DC.) Lindr.
Puccinia princeps Syd. & P. Syd.
Puccinia propinqua Syd., P. Syd. & E.J. Butler
Puccinia prostii Moug.
Puccinia pseudocesatii Cummins
Puccinia pulverulenta Grev.
Puccinia pulvinata Rabenh.
Puccinia punctata Link
Puccinia purpurea Cooke
Puccinia pusilla Syd. & P. Syd.
Puccinia recondita Roberge ex Desm.
Puccinia ribis DC.
Puccinia recondita var. *simlensis* A.P. Misra, S.T. Ahmad & Sheodh. Singh
Puccinia ribis-caricis Kleb.
Puccinia rhynchosporae Syd. & P. Syd.
Puccinia romagnoliana Maire & Sacc.
Puccinia roscoeae Barclay
Puccinia rostrata Cooke
Puccinia rottboelliae P. Syd. & Syd.
Puccinia ruelliae Lagerh.
Puccinia rufipes Dietel
Puccinia sacchari Patel, Kamat & Y.A. Padhye
Puccinia sonchi Roberge ex Desm.
Puccinia satarensis P.B. Chavan & Bakare
Puccinia saussureae Thüm.
Puccinia saviculae Grev.
Puccinia saxifragae-ciliatae Barclay
Puccinia schedonnardi Kellerm. & Swingle
Puccinia schirajewskii Tranzschel
Puccinia scirpi DC.
Puccinia senecionis-scandentis Lindr.
Puccinia shiraiana P. Syd.
Puccinia silvaticella Arthur & Cummins
Puccinia solanacearum Sacc. & P. Syd.
Puccinia solani-giganteae T.S. Ramakr. & K. Ramakr.
Puccinia solmsii (Kuntze) Sacc. & P. Syd.
Puccinia sorghi Schwein.
Puccinia spongiosa Berk. & Broome
Puccinia stenotaphricola J. Walker
Puccinia striiformis Westend.
Puccinia striiformis f. *muehlenbergii*

Puccinia suaveolens (Pers.) Rostr.
Puccinia substriata Ellis & Barthol.
Puccinia swertiae G. Winter
Puccinia tanaceti DC.
Puccinia terminaliae T.S. Ramakr. & Sundaram
Puccinia thlaspeos Ficinus & C. Schub.
Puccinia thomasiana T.S. Ramakr. & K. Ramakr.
Puccinia thunbergiae Cooke
Puccinia thwaitesii Berk.
Puccinia tiliaefolia T.S. Ramakr. & Sundaram
Puccinia tragiae Cooke
Puccinia tricholepidis Syd.
Puccinia trollii P. Karst.
Puccinia turgida P. Syd. & Syd.
Puccinia tweediana T.S. Ramakr. & K. Ramakr.
Puccinia unica var. *chica* Cummins & S.M. Husain
Puccinia urticae Barclay
Puccinia ustalis Berk.
Puccinia verruca Thüm.
Puccinia vernoniae-monosis T.S. Ramakr. & K. Ramakr.
Puccinia versicolor Dietel & Holw.
Puccinia violae (Schumach.) DC.
Puccinia volutarellae Thirum.
Puccinia wangikarii Somani
Puccinia wattiana Barclay
Puccinia weyrehii Miyabe
Puccinia woodii (Kalchbr. & Cooke) P. Syd. & Syd.
Puccinia xanthii Schwein.
Puccinia xanthocarpi R.Y. Roy & P.C. Gupta
Puccinia xanthopoda Syd. & P. Syd.
Puccinia xanthosperma Syd. & P. Syd.
Puccinia zingiberis T.S. Ramakr.

Pucciniosira Lagerh (1)
Pucciniosira tuberculata (Ellis & Kellerm.) Buriticá & J.F. Hennen

Ramakrishnania Ramachar & Bhagyan. (1)
Ramakrishnania ixorae Ramachar & Bhagyan.

Trochodium Syd. & P. Syd. (2)
Trochodium ajrekarii Gharse
Trochodium sampathense Thirum.

Uromyces (Link) Unger (89)
Uromyces achrous Syd. & P. Syd.
Uromyces aconiti Fuckel
Uromyces acori T.S. Ramakr. & Rangaswami
Uromyces agropyri Barclay
Uromyces aloes (Cooke) Magnus
Uromyces ambiens Cooke
Uromyces amphilophis-insculptae T.S. Ramakr., Sriniv. & Sundaram
Uromyces andropogonis Tracy
Uromyces andropogonis-annulati Syd., P. Syd. & E.J. Butler
Uromyces anotidis-monospermatis T.S. Ramakr. & Sundaram
Uromyces anthyllidis (Grev.) J. Schröt.
Uromyces apludae Syd., P. Syd. & E.J. Butler

Uromyces appendiculatus (Pers.) Link
Uromyces behenis (DC.) Unger
Uromyces bidentis Lagerh.
Uromyces blainvilleae Berk.
Uromyces callicarpae (Petch) Fujik. ex S. Ito
Uromyces capitatus Syd. & P. Syd.
Uromyces ciceris-arietini (Grognot) Jacz. & G. Boyer
Uromyces clignyi Pat. & Har.
Uromyces clivalis Mitter
Uromyces commelinae Cooke
Uromyces coronatus Yoshin.
Uromyces dactylidis G.H. Otth
Uromyces decoratus Syd. & P. Syd.
Uromyces dolicholi Arthur
Uromyces eragrostidis Tracy
Uromyces eriochloae (Syd. & P. Syd.) Syd., P. Syd. & E.J. Butler
Uromyces euphorbiae Cooke & Peck
Uromyces fritillariae Thüm.
Uromyces geranii (DC.) G.H. Otth & Wartm.
Uromyces haussknechtii Tranzschel
*Uromyces hedysari-obscuri (*DC.) Carestia & Picc.
Uromyces heterogeneus Cooke
Uromyces hobsonii Vize
Uromyces hyderabadensis Ramachar, K.N. Rao & Bagyan.
Uromyces indigoferae f.sp. tinctoriae L.M. Joshi & A.R. Reddy
Uromyces ignobilis (Syd. & P. Syd.) Arthur
Uromyces inayatii Syd. & P. Syd.
Uromyces indicus Pat.
Uromyces indigoferae Dietel & Holw.
Uromyces lapponicus Lagerh.
Uromyces lespedezae-procumbentis (Schwein.) Lagerh.
Uromyces lespedezae-sericeae S. Ahmad
Uromyces lineolatus (Desm.) J. Schröt.
Uromyces loculiformis T.S. Ramakr. & K. Ramakr.
Uromyces macintirianus Barclay
Uromyces minor J. Schröt.
Uromyces mucunae Rabenh.
Uromyces muscari (Duby) Niessl
Uromyces mussooriensis Syd. & P. Syd.
Uromyces nilagiricus T.S. Ramakr. & K. Ramakr.
Uromyces orientalis Syd. & P. Syd.
Uromyces orthosiphonis T.S. Ramakr. & Sriniv.
Uromyces ottochloae Ramakr. T.S.
Uromyces panici-sanguinalis Rangel
Uromyces pavgii R.N. Goswami & Ngachan
Uromyces peglerae Pole-Evans
Uromyces pianhyensis Henn.
Uromyces pisi-sativi (Pers.) Liro
Uromyces polygoni-avicularis (Pers.) G.H. Otth
Uromyces pontederiicola Speg.
Uromyces poonensis W.D. More & Moniz
Uromyces proeminens (DC.) Lév.

Uromyces pseudarthriae Cooke
Uromyces ramacharii Ravinder & Bagyan.
Uromyces rottboelliae Arthur
Uromyces rugulosus Pat.
Uromyces rumicis (Schumach.) G. Winter
Uromyces satarensis P.B. Chavan & Bakare
Uromyces schoenanthi Syd. & P. Syd.
Uromyces setariae-italicae Yoshino
Uromyces sommerfeltii Hyl., Jørst. & Nannf.
Uromyces spegazzinii (De Toni) Arthur
Uromyces sphaeropleus Cooke
Uromyces sporgoni Clint & Peck. subsp. *asiaticus*
Uromyces striatus J. Schröt.
Uromyces strobilanthis Barclay
Uromyces superfluus P. Syd. & Syd.
Uromyces tenuicutis McAlpine
Uromyces triandrae T.S. Ramakr. & Sriniv.
Uromyces trichoneurae Doidge
Uromyces trifolii (R. Hedw.) Lév.
Uromyces trigonellae Pass.
Uromyces tripogonicola Payak & Thirum.
Uromyces trollii-caroli Ulbr.
Uromyces valerianae (Schumach.) Fuckel
Uromyces valerianae-wallichii (Dietel) Arthur & Cummins
Uromyces vestergrenii P. Syd. & Syd.
Uromyces viciae-fabae (Pers.) J. Schröt.
Uromyces vignae Barclay
Uromyces vossiae Barclay
Uromyces wedeliae-biflorae Boedijn
Uromyces wellingtonicus T.S. Ramakr. & K. Ramakr.

Xenostele Syd. & P. Syd. (1)
Xenostele litseae (Pat.) Syd. & P. Syd.

12. ***Raveneliaceae*** Leppik, Ann. bot. fenn. 9: 139. 1972. ***emend***. Aime & McTaggart

Chaconia Juel (1)
Chaconia butleri (Syd. & P. Syd.) Mains

Didymopsorella Thirum. (1)
Didymopsorella macrospora (Mundk. & Thirum.) Thirum.

Diorchidium Kalchbr. (3)
Diorchidium levigatum Syd., P. Syd. & E.J. Butler
Diorchidium orientale Syd., P. Syd. & E.J. Butler
Diorchidium tricholaenae Syd. & P. Syd.

Gymnopuccinia K. Ramakr. (1)
Gymnopuccinia pulneyensis K. Ramakr.

Kernkampella Rajendren (6)
Kernkampella breyniae (Syd. & P. Syd.) Rajendren
Kernkampella breyniae-patentis (Mundk. & Thirum.) Rajendren
Kernkampella coimbatorica (T.S. Ramakr. & Sundaram) G.F. Laundon
Kernkampella emblicae (Syd. & P. Syd.) G.F. Laundon
Kernkampella kirganeliae (Mundk. & Thirum.) G.F. Laundon
Kernkampella phyllanthi (Mundk. & Thirum.) G.F. Laundon

Maravalia Arthur (11)

Maravalia achroa (Syd.) Arthur & Cummins
Maravalia aulica (Syd.) Y. Ono
Maravalia ascotela (Syd.) Mains
Maravalia echinulata (Niessl ex Rabenh.) Y. Ono
Maravalia fici (Mundk. & Thirum.) Y. Ono
Maravalia gentilis (Syd.) Y. Ono
Maravalia ichnocarpi (Barclay) Sathe
Maravalia millettiae Yadav & Thirum.
Maravalia milletticola Y. Ono & J.F. Hennen
Maravalia mimusops (Cooke) Y. Ono
Maravalia pterocarpi (Thirum.) Thirum.

Scopella Mains (1)

Scopella dalbergiae (T.S. Ramakr. & K. Ramakr.) Ragunathan & K. Ramakr.

Olivea Arthur (3)

Olivea colebrookiana Thirum. & Yadav
Olivea isonandrae Hosag.
Olivea tectonae (Racib.) Thirum.

Ravenelia Berk. (33)

Ravenelia acaciae-arabicae Mundk. & Thirum.
Ravenelia acaciae-caesiae Tyagi & S.S. Prasad
Ravenelia acaciae-concinnae Mundk. & Thirum.
Ravenelia acaciae-intsiae B.V. Patil & Thirum.
Ravenelia acaciae-pennatulae Dietel
Ravenelia acaciae-pennatulae Dietel
Ravenelia acaciae-sumae Thirum. & Mundk.
Ravenelia acaciae-senegalae Sanwal
Ravenelia acaciicola Sanwal
Ravenelia aculeifera Berk.
Ravenelia ajmerensis Sanwal
Ravenelia albiziae-amarae Bacc.
Ravenelia burmanica Thaung
Ravenelia cassiicola G.F. Atk.
Ravenelia clemensae Syd.
Ravenelia deformis Tyagi & S.S. Prasad
Ravenelia tephrosiicola (Henn.) Hirats. f.
Ravenelia esculenta Naras. & Thirum.
Ravenelia evansii Syd. & P. Syd.
Ravenelia fragrans Long
Ravenelia hansfordii Cummins
Ravenelia hobsonii Cooke
Ravenelia indica Berk.
Ravenelia japonica Dietel & P. Syd.
Ravenelia karadensis P.B. Chavan & U.V. Kulk.
Ravenelia mitis Syd. & P. Syd.
Ravenelia mitteri Syd.
Ravenelia odoratissimae Tyagi & S.S. Prasad
Ravenelia ornata Syd. & P. Syd.
Ravenelia parasnathii Yadav
Ravenelia radhanagarensis Patil
Ravenelia satarensis P.B. Chavan & U.V. Kulk.
Ravenelia sayeedii M.A. Salam & Ramachar

Ravenelia sessilis Berk.
Ravenelia spicigerae B.V. Patil & Thirum.
Ravenelia stictica Berk. & Broome
Ravenelia sumatii S.D. Patil & Date
Ravenelia tandonii Syd.
Ravenelia taslimii Mundk.
Ravenelia versatilis (Peck) Dietel

Prospodium Arthur (2)
Prospodium erebia (Syd. & P. Syd.) Bagyan. & Ravinder
Prospodium tirumalense Bagyan., Ravinder & P. Ramesh

13. ***Skierkaceae*** (Arthur) Aime & McTaggart, Fungal Systematics and Evolution 7: 21–47, 2020.

Skierka Racib. (3)
Skierka agallochae Racib.
Skierka himalayensis A.K. Gautam & S. Avasthi
Skierka toddaliae (Petch) Hirats.

14. ***Sphaerophragmiaceae*** Cummins & Y. Hirats., Illustr. Gen. Rust Fungi, rev. Edn (St. Paul): 15. 1983. emend. Aime & McTaggart

Sphaerophragmium Magnus (1)
Sphaerophragmium acaciae (Cooke) Magnus

15. ***Tranzscheliaceae*** (Arthur) Aime & McTaggart, Fungal Systematics and Evolution 7: 21–47, 2020

Leucotelium Tranzschel (1)
Leucotelium pruni-persicae (Hori) Tranzschel

Tranzschelia Arthur (2)
Tranzschelia discolor (Fuckel) Tranzschel & M.A. Litv.
Tranzschelia pruni-spinosae (Pers.) Dietel

16. ***Zaghouaniaceae*** P. Syd. & Syd., Monogr. Uredin. (Lipsiae) 3(3): 586. 1915. ***emend***. Aime & McTaggart

Cystopsora E.J. Butler (1)
Cystopsora antidesmatis T.S. Ramakr. & Sundaram

Elateraecium Thirum., F. Kern & B.V. Patil (1)
Elateraecium salaciicola Thirum., F. Kern & B.V. Patil

Hemileia Berk. & Broome (10)
Hemileia canthii Berk. & Broome
Hemileia gardeniae-thunbergiae (Henn.) Maubl. & Roger
Hemileia holarrhenae Syd. & P. Syd.
Hemileia indica Massee
Hemileia jasmini C.S. Krishnam. & Rangaswami
Hemileia mysorensis Thirum. & Gopalakrishn.
Hemileia pavetticola Maubl. & Roger
Hemileia thomasii Thirum. & Naras.
Hemileia vastatrix Berk. & Broome
Hemileia wrightiae (Racib.) Racib.

Zaghouania Pat. (1)
Zaghouania oleae (E.J. Butler) Cummins

Pucciniales **genera incertae sedis**

Aecidium Vuill.

Aecidium adhatodae Syd. & P. Syd.
Aecidium aechmantherae Syd. & P. Syd.
Aecidium ajugae Syd. & P. Syd.
Aecidium anaphalidis-leptophyllae T.S. Ramakr., Sriniv. & Sundaram
Aecidium argyreiae Berk. & Broome
Aecidium brasiliense Dietel
Aecidium callianthum Syd.
Aecidium campanulae Pandotra & K.S.M. Sastry
Aecidium carviae Sathe
Aecidium cassiae-torae P.B. Chavan & Bakare
Aecidium cinnamomi Racib.
Aecidium cleomes Ellis & H.W. Anderson
Aecidium clerodendri Henn.
Aecidium colchici-aurei Ulbr.
Aecidium crassocephali Wakef. & Hansf.
Aecidium crini Kalchbr.
Aecidium crypticum Kalchbr. & Cooke
Aecidium cuspidatum T.S. Ramakr., Sriniv. & Sundaram
Aecidium delphinii Barthol.
Aecidium deutziae Dietel
Aecidium dichrocephalae Henn.
Aecidium diospyri A.L. Sm.
Aecidium distinctum Arthur & Cummins
Aecidium elaeocarpi-tuberculati Hosag.
Aecidium esculentum Barclay
Aecidium flavescens Barclay
Aecidium garciniae Sundaram & A.V. Rao
Aecidium girardiniae Syd. & P. Syd.
Aecidium gymnematis T.S. Ramakr. & Sundaram
Aecidium hartwegiae Thüm.
Aecidium hedyotidis Syd.
Aecidium hemidesmi Syd. & P. Syd.
Aecidium hemigraphidis B.V. Patil & Thirum.
Aecidium infrequens Barclay
Aecidium innatum Syd., P. Syd. & E.J. Butler
Aecidium inquitosense P. Henn**.**
Aecidium kamatii Sathe
Aecidium latifolium Massee
Aecidium leeae M.A. Salam & Ramachar
Aecidium lepidagathis Syd. & P. Syd.
Aecidium leucadinum Mitter
Aecidium lophanthi Henn.
Aecidium lophopetali Wakef.
Aecidium marsdeniae T.S. Ramakr. & K. Ramakr.
Aecidium melaleucum Syd. & P. Syd.
Aecidium meliosmae-wightii T.S. Ramakr., Sriniv. & Sundaram
Aecidium memecyli Thirum.
Aecidium microrhynchi Henn.
Aecidium miliare Berk. & Broome
Aecidium montanum E.J. Butler
Aecidium mori Barclay
Aecidium morobeanum Cummins

Aecidium myriactidis (Barclay) P. Syd. & Syd.
Aecidium nummulare Berk.
Aecidium ocimi Henn.
Aecidium orbiculare Barclay
Aecidium osmanthi Syd., P. Syd. & E.J. Butler
Aecidium painavuense Hosag.
Aecidium paramignyae Racib.
Aecidium pavoniae-odoratae T.S. Ramakr., Sriniv. & Sundaram
Aecidium peristrophes Syd. & P. Syd.
Aecidium petchii Sacc. & Trotter
Aecidium plectranthicola Cummins
Aecidium plectroniae Cooke
Aecidium ponderosum Syd. & P. Syd.
Aecidium poonense Sathe
Aecidium pulneyense T.S. Ramakr. & Sriniv.
Aecidium pupaliae Prasad, L.C. Sharma & R.D. Singh
Aecidium pygei Syd. & P. Syd.
Aecidium quintum Syd. & P. Syd.
Aecidium randiae Henn.
Aecidium rhododendri Barclay
Aecidium rhynchosiae Bagyan. & Ramachar
Aecidium rhytismoideum Berk. & Broome
Aecidium salamii G.F. Laundon
Aecidium satarense P.B. Chavan & S.K. Patil
Aecidium saussureae Johanson
Aecidium scutellariae Syd. & P. Syd.
Aecidium sinhagadense Sathe
Aecidium solani Mont.
Aecidium spilanthis T.S. Ramakr. & Sundaram
Aecidium stewartianum Cummins
Aecidium stewartii Arthur & Cummin
Aecidium stranvaesiae Syd. & P. Syd.
Aecidium strobilanthis Barclay
Aecidium tandonii Mitter
Aecidium terminaliae T.S. Ramakr. & K. Ramakr.
Aecidium travancoricum T.S. Ramakr.
Aecidium tricholepidis P.B. Chavan & Bakare
Aecidium tubulosum Pat. & Gaillard
Aecidium urceolatum Cooke
Aecidium urgineae Henn. & Pole-Evans
Aecidium vangueriae Cooke
Aecidium verbenae Speg.
Aecidium vernoniae-cinereae Petch
Aecidium walayarense T.S. Ramakr. & Sundaram
Aecidium withaniae Thüm.

Nyssopsora Arthur

Nyssopsora cedrelae (Hori) Tranzschel
Nyssopsora thirumalacharii R.N. Goswami & Ngachan
Nyssopsora thwaitesii (Berk. & Broome) Syd.

Phragmotelium Syd.

Phragmotelium burmanicum (Syd. & P. Syd.) Syd.
Phragmidium mysorense (Thirum. & Mundk.) B. Ali & Berndt

Tunicopsora Suj. Singh & P.C. Pandey

Tunicopsora bagchii Suj. Singh & P.C. Pandey

Uraecium *Arthur*

Uraecium nothopegiae T.S. Ramakr. & K. Ramakr.

Uredo Pers.

Uredo acaciae-concinnae Kapoor bis & D.K. Agarwal
Uredo acalyphae-fruticosae T.S. Ramakr., Sriniv. & Sundaram
Uredo allmaniae P.B. Chavan & U.V. Kulk.
Uredo alpestris J. Schröt.
Uredo amomi Petch
Uredo apludae Barclay
Uredo arachidis Lagerh.
Uredo brachylepidis T.S. Ramakr. & Sundaram
Uredo cajani Syd. & P. Syd.
Uredo carissae Thirum.
Uredo carissae–occidentalis Chavan & Kulkurni
Uredo cassiae K.N. Rao
Uredo cassiae-occidentalis T.S. Ramakr.
Uredo celastri Arthur & Cummins
Uredo celastri-paniculatae T.S. Ramakr. & Sundaram
Uredo chasaliae Petch
Uredo citri Vaheed.
Uredo davaoensis Syd. & P. Syd.
Uredo dalbergiae-latifoliae Hosag. & N.C. Nair
Uredo deutziae Barclay
Uredo dioscoreae Henn.
Uredo dioscoreae-sativae Syd. & P. Syd.
Uredo echinulata (Niessl.) Syd.
Uredo ehretiae Barclay
Uredo elephantopodis Petch
Uredo elettariae Thirum.
Uredo emiliae-scabrae T.S. Ramakr. & Sundaram
Uredo exasperata (Cooke) Sacc.
Uredo garugae Sundaram
Uredo gayanae J.C. Lindq.
Uredo gharsei Sathe & Rahalkar
Uredo gomphrenae Barclay
Uredo hygrophilicola G.F. Laundon & Ponnappa
Uredo hyperici-mysorensis Petch
Uredo khandalensis Sathe & Rahalkar
Uredo launeae–coromandelicae Chavan & Bakare
Uredo lipocarphae Syd. & P. Syd.
Uredo malabarica T.S. Ramakr. & K. Ramakr.
Uredo mannanurensis K.N. Rao
Uredo microspora (Vize) Sacc.
Uredo mundkurii P.B. Chavan
Uredo myriactidis Sundaram
Uredo neilgherriensis T.S. Ramakr.
Uredo niterogensis Rangel
Uredo ochnae K.N. Rao
Uredo ophiorrhizae Petch
Uredo ophiuri Syd., P. Syd. & E.J. Butler

Uredo paederiae Syd. & P. Syd.
Uredo pallidula Cooke & Massee
Uredo panacis Syd. & P. Syd.
Uredo paspali Pandotra
Uredo paspali-scrobiculati Syd. & P. Syd.
Uredo phyllanthi-niruris M.S. Patil
Uredo pileae Barclay
Uredo pouzolziae Syd. & P. Syd.
Uredo pterocarpi T.S. Ramakr.
Uredo punctoidea Cooke
Uredo ravennae Maire
Uredo rhinacanthi T.S. Ramakr. & Sundaram
Uredo rottboelliae Dietel
Uredo shuteriae T.S. Ramakr.
Uredo sesbaniae Henn.
Uredo setariae-tomentosae Ramachar, Bhagyan. & A. Kumar
Uredo sissoo Syd., P. Syd. & E.J. Butler
Uredo spinulosa (Cooke) Sacc.
Uredo tephrosiae Rabenh.
Uredo terminaliae Henn.
Uredo terminaliae-paniculatae T.S. Ramakr. & K. Ramakr.
Uredo thelypteridis Yadav
Uredo thelypteridis var. thelypteridis Yadav
Uredo verecunda Syd.
Uredo victoriae Cummins

Phylogenetic analysis

The phylogenetic analyses based on the combined LSU and ITS rDNA sequence dataset comprised 189 taxa including various genera from 13 families belonging to Pucciniales were assessed with *Taphrina pruni* CBS 358.35 as an outgroup taxon. RAxML analysis of the combined dataset produced the best tree with a final ML optimization likelihood value of -34581.032655. The genera from different families included in the phylogenetic analyses are *Coleosporiaceae*, *Cronartiaceae*, *Crossopsoraceae*, *Melampsoraceae*, *Milesinaceae*, *Ochropsoraceae*, *Phakopsoraceae*, *Phragmidiaceae*, *Pileolariaceae*, *Pucciniastraceae*, *Pucciniaceae*, *Raveneliaceae* and *Tranzscheliaceae*. The genera *Coleosporium, Chrysomyxa* clustered together in *Coleosporiaceae* clade with significant support from ML 93% and *Cronartia* formed a distinct clade sharing a sister group relationship with *Coleosporium* and *Chrysomyxa*. The *Melampsoraceae* clade is supported by taxa from *Melampsora* with significant support from ML 100%. The *Pucciniastraceae* clade consists of taxa from *Hyalospora, Melampsoridium* and *Pucciniastrum* and *Milesinaceae* includes *Milesina.* The genera *Ravenelia, Kernkampella* clustered in a *Raveneliaceae* clade and *Maravalia* formed a distinct lineage. While *Nyssopsora* belonging to Uredinineae *incertae sedis* formed a different lineage. The *Tranzschelia* includes *Tranzschelia* and *Leucotelium* and *Ochropsoraceae* comprises *Ochropsora.* The *Phakopsoraceae* includes *Cerotelium* and *Phakopsora* in a monophyletic clade. The *Crossopsoraceae* clade comprises *Angiopsora*, *Crossopsora* and *Kweilingia*. The *Phragmidiaceae* includes taxa from *Phragmidium* in monophyletic clade with significant support from ML 94%. The *Gymnosporangiaceae* comprised *Gymnosporangium* in a monophyletic clade with significant support from ML 96%. The *Pucciniaceae* includes polyphyletic taxa from *Puccinia* and *Uromyces.*

Notes of Indian rust genera

After going through the available literature on Indian rust fungi, it is now clear that identification of these fungi has primarily been based on morphological characters. Few studies are

reported to use modern tools and molecular based techniques (specifically DNA-based) in their taxonomy. But wth the use of all modern molecular methdologies, a number of alterations in existing system of classification of rust fungi has been proposed by Cummins & Hiratsuka (2003). Number of changes as proposed recently in classification of rust fungi (Aime 2006, Aime & McTaggart 2020), has led to the introcution of many new families as well as transfer of many genera and species. Keeping in view all the proposed changes, this outline of Indian *Pucciniales* incorporates updated changes. Of the 18 families of rust fungi, 16 are reported from India, consists 69 genera and 640 species. Most of the genera and species of Indian collections still required DNA based identification. Therefore, a brief description of each rust family along with total number of genera as well as species reported from India and their host families are provided in this section. In addition, a brief note, where further studies on Indian collections are urgently required to resolve their taxonomic uncertainty is also provided.

Phylum – ***Basidiomycota*** R. T. Moore, Bot. Mar.23: 371 (1980).

Synonyms – *Basidiomycota* Bold, Morph. Pl.: 7, 198 (1958), nomen invalidum

Basidiomycota is the second largest phyla of kingdom Fungi which shares 97% of all fungal species along with phylum *Ascomycota* (Wijayawardene et al. 2017, 2018, 2020, Niskanen et al. 2018). The fungi included in *Basidiomycota* possess basidia as meiosporocysts in the sexual life stage. The hyphae appeared to have single-layered wall (which actually is multi-layered) are divided by septa into mononucleate, binucleate, or multinucleate segments. The septal pore is generally closed, however, in some cases barrel-like thickening is present on both sides. Chemotaxonomy, formation of urease, siderochromes, and the type of ubiquinone system also differentiate basidiomycetous fungi from ascomycetes. In addition, the guanine-cytosine content of the total DNA exceeds 50% in basidiomycetous species. The updated outline of *Basidiomycota* includes four subphyla, 18 classes, 68 orders, 241 families, 1928 genera and 41270 species, of which rust fungi are included in subphylum *Pucciniomycotina* (He et al. 2019, Wijayawardene et al. 2020).

Subphylum: ***Pucciniomycotina*** R. Bauer, Begerow, J.P. Samp., M. Weiß & Oberw., Mycol. Progr.5: 45 (2006).

Equivalent to *Urediniomycetes* (Swann & Taylor 1995b, Kirk et al. 2001, Swann et al. 2001).

Pucciniomycotina is a diverse group of fungi, including rusts, yeasts, smut-like and jelly-like fungi. It is the sister to the *Ustilaginomycotina* and *Agaricomycotina*, forming the basal lineage of *Basidiomycota*. Species of *Pucciniomycotina* studied so far lack dolipores (septal pore swellings) and septal pore caps. Absence of the predominant cell wall sugar, mannose (Prillinger et al. 1993) and disc like spindle pole bodies (McLaughlin et al. 1995, Wells 1994), distinguishes them from most other *Basidiomycota*. These fungi show very simple to complex life cycle, considered as most complex organisms (Lutz et al. 2004). Most described species are predominantly phytopathogens but also include asymptomatic members. Subphylum *Pucciniomycotina* is estimated to have 10 classes, 22 orders, 49 families, 270 genera, and 8653 species with rust fungi placed in class *Pucciniomycetes* (He et al. 2019, Wijayawardene et al. 2020).

Class: ***Pucciniomycetes*** R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw., Mycol. Progr. 5: 48 (2006).

Equivalent to *Urediniomycetidae* (Swann et al. 2001).

Pucciniomycetes is a diverse class of subphylum *Pucciniomycotina*. It is one of the major classes of basidiomycete fungi containing about 8000 species (Kirk et al. 2008). Based on rDNA phylogenetic studies, rust fungi and their closest relatives in *Pucciniomycetes* are reported to have ambiguous phylogenetic positions within the *Pucciniomycotina* (Aime et al. 2006). All species of *Pucciniomycetes* are dikaryotic (containing two haploid nuclei per cell) except for *Septobasidiales*, which are monokaryotic (containing a single haploid nucleus per cell). Lack of clamp connections in their hyphae (Bauer et al. 2006) is another characteristic feature of these fungi. Production of asexual spores, especially among rusts, is often well developed (Bruckart et al. 2010). Sexual reproduction takes place via the formation of basidiospores. This class contains 5 orders, 20 families, 180 genera,

and 8016 species. Majority of the fungal species in *Pucciniomycetes* are parasitic in nature. *Pucciniales* is the most species-rich group of the *Pucciniomycetes* with over 95% of the species and 75% of the genera placed in this order, the plant parasitic rust fungi.

Order: ***Pucciniales*** Clem. & Shear, Gen. Fungi (2nd edn): 147 (1931).

Equivalent to *Uredinales*.

Exemplar genera: *Puccinia* Pers. 1801, *Uromyces* (Link) Unger 1832.

The *Pucciniales* is one of the largest and major orders in *Basidiomycota* (class *Pucciniomycetes*). This order mainly contains many important plant pathogens popularly known as rusts. These fungi are obligate plant parasites occurring on ferns, gymnosperms and angiosperms. They have been studied in detailed as many of the most devastating plant diseases in agricultural crops are caused by the members of *Pucciniales*. Morphologically, the species of *Pucciniales* are characterized by their rusty appearance on infected host parts such as leaves, petioles, tender shoots, stems, fruits, etc. and named for the typically rusty coloration of their urediniospores. These obligate parasites have highly complex life cycles with up to five spore stages and two unrelated hosts (Cummins & Hiratsuka 2003). Of 7800 described species, *Pucciniales* constitutes 25% of all known species in *Basidiomycota* and ca. 8% of all described Fungi (Kirk et al. 2008). The *Pucciniales* is estimated to have 15 families, ca. 150 genera and ca.7, 800 species, and is considered as the most speciose order of fungi (Kirk et al. 2008, Wijayawardene et al. (2020). Recently, a higher-rank classification for rust fungi, with notes on genera was provided by Aime & McTaggart (2020). They have proposed four new suborders and seven new families based on the evaluation of 80 % of accepted genera including type species wherever possible, and three DNA loci. As per this classification, *Pucciniales* now comprises seven suborders as *Araucariomycetineae, Melampsorineae, Mikronegeriineae, Raveneliineae, Rogerpetersoniineae, Skierkineae*, and *Uredinineae*. There are now 18 families *Araucariomycetaceae, Coleosporiaceae, Crossopsoraceae, Gymnosporangiaceae, Melampsoraceae, Milesinaceae, Ochropsoraceae, Phakopsoraceae, Phragmidiaceae, Pileolariaceae, Pucciniaceae, Pucciniastraceae, Raveneliaceae, Rogerpetersoniaceae, Skierkaceae, Sphaerophragmiaceae, Tranzscheliaceae*, and *Zaghouaniaceae* (Aime & McTaggart 2020). Therefore, we followed Aime & McTaggart (2020) to present updated information on genera and species in each family. The numbers of genera and species of rust fungi were presented as per Wijayawardene et al. (2020). The distinct characteristics of various spore stages (telia, teliospores, uredinia, uredinospores, aecia, aeciospores, spermogonia and basidia) for each family are summarized in this section. The notes on rust families reported from India are described here in this section of manuscript.

Coleosporiaceae Dietel, In: Engler & Prantl, Nat. Pflanzenfam., Teil. I (Leipzig) 1: 548. 1900. ***emend***. Aime & McTaggart

Type genus – ***Coleosporium*** Lév., Ann. Sci. Nat. Bot. III, Ser. 8: 373. 1847

The species of family *Coleosporiaceae* bear large, bladder-like aecia covered with well-developed peridium and have catenulate, verrucose aeciospores. Uredinia with rudimentary peridium or none and urediniospores are formed in chain with verrucose echinulate ornamentation on surface. The germ pores are mostly obscure and scattered. The teliospores are formed one by one (catenulate, pseudocatenulate or in a single layer) in erumpent, hard, waxy or gelatinous, pulvinate or columnar telia under the epidermis of the host plant. The teliospores are generally unicellular, thin walled and sessile with non-differentiated germ pores. The spermogonia are of Group I (type 2 or 3) (but Group II, type 9 in *Cronartium*). Most of the species are heteroecious and macrocyclic, with aecial stage on needle, buds and cones of conifers (Cummins & Hiratsuka 2003, Aime & McTaggart 2020).

Genera reported in India – *Coleosporium* (19), *Chrysomyxa* (7), *Cronartium* (4), *Goplana* (1), *Stakmania* (1) total 32 species.

Host families – *Asteraceae, Campanulaceae, Ericaceae, Gentianaceae, Grossulariaceae, Lamiaceae, Lauraceae, Moraceae, Phyllanthaceae, Pinaceae, Ranunculaceae.*

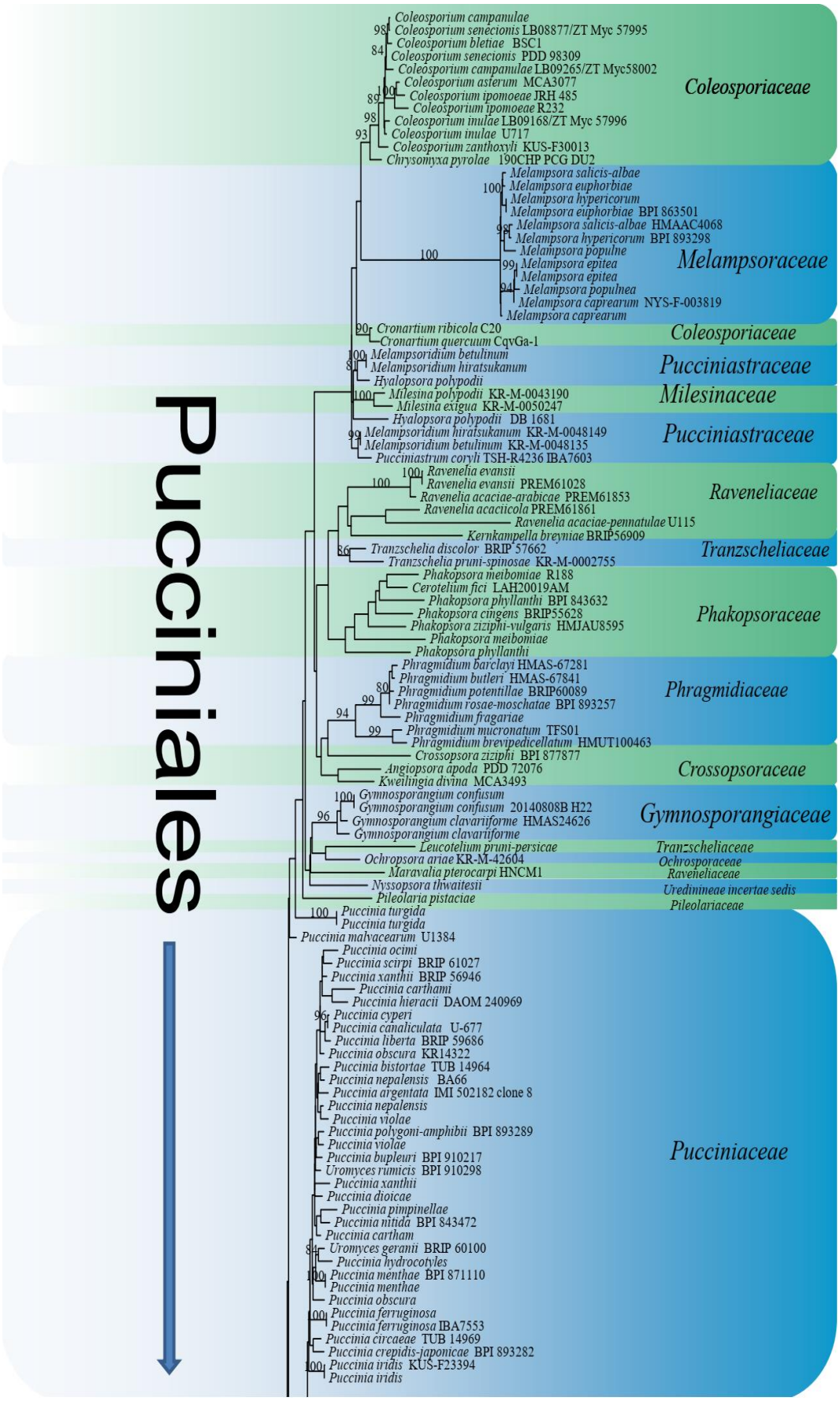

Figure 1 – Maximum likelihood phylogeny of Indian rust fungi based on two concatenated loci (LSU and ITS) of taxa from Pucciniales. Bootstrap support values for maximum likelihood equal to or

greater than 70% are given above each branch respectively. Outgroup taxon is *Taphrina pruni* CBS 358.35.

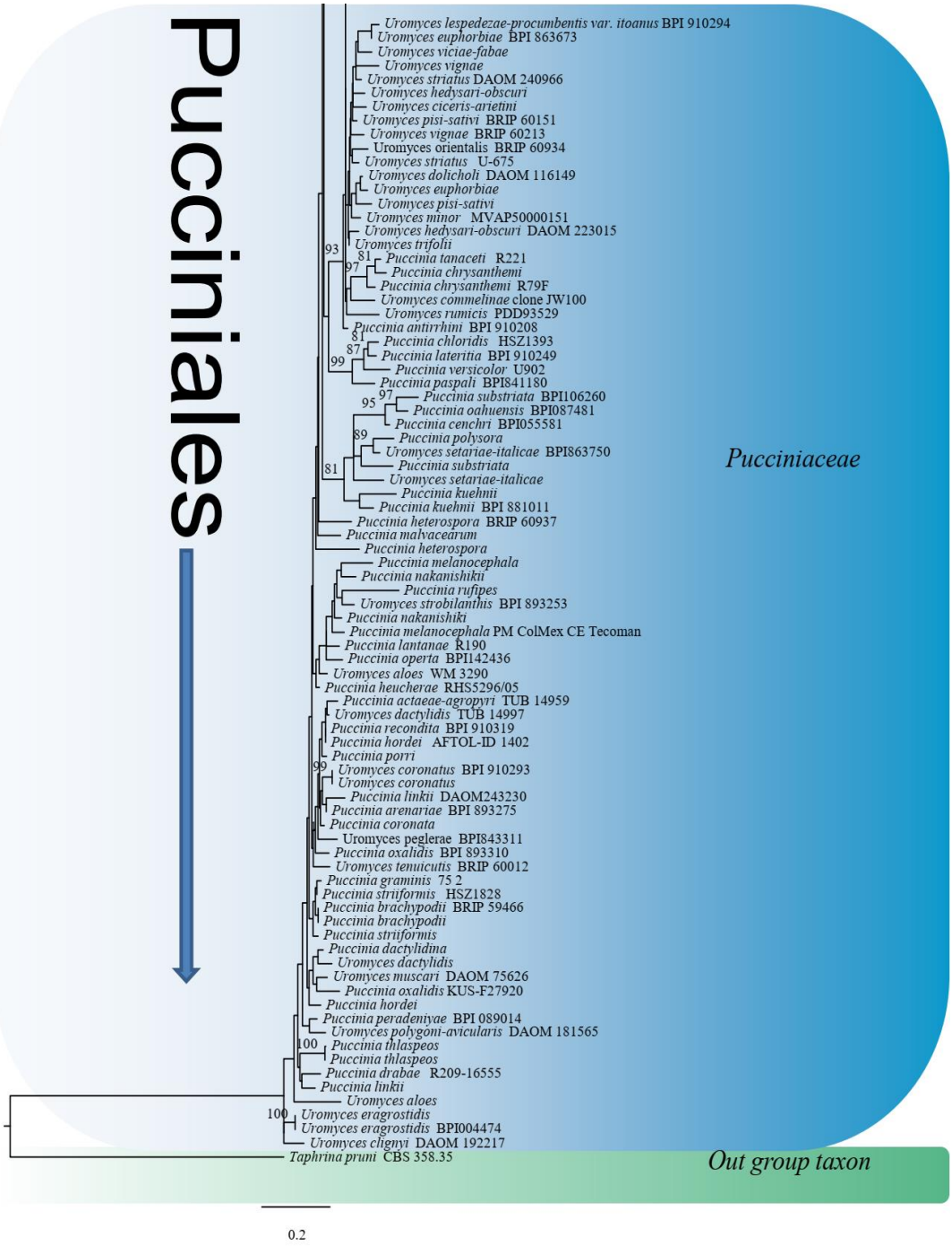

Figure 1 – Continued.

Notes – Two species of rust genus *Stakmania* (*S. formosana* and *S. indica*) were reported from India. Among the two, *S. formosana* Syd. & P. Syd. has been transferred to *Phakopsora formosana* while, *S. indica* Kamat & Sathe remains unchanged (Index Fungorum 2020). Hence, this species has been retained in this family.

Crossopsoraceae Aime & McTaggart, In: Fungal Systematics and Evolution 7: 21–47. 2020

Fig. 9

Type genus – ***Crossopsora*** Syd. & P. Syd., Annls mycol. 16(3/6): 243. 1919.

Crossopsoraceae is characterized by producing Group VI (type 7) spermogonia and aecidium-type aecia wherever known. Uredinia are of malupa-type and usually paraphysate. The teliospores produced by these fungi are 1-celled, compact and often produced in catenulate chains of a few to many cells. These spores germinate externally, with or without dormancy. The fungi in this family are mostly identified from the sporothallus (uredinial, and telial) stages. The genus *Neophysopella* in this family is macrocyclic and heteroecious in nature (Aime & McTaggart 2020) and considered the same for other genus/species also. A total of 7 genera have been included in this family, of which, six genera being reported from India.

Genera reported in India – *Angiopsora* (2), *Crossopsora* (3), *Dasturella* (3), *Kweilingia* (2), *Neophysopella* (2), *Physopella* (2); total 14 species.

Host families – *Poaceae, Rhamnaceae Verbenaceae.*

Notes – Two Indian records of the genus *Physopella* i.e. *P. artocarpi* (Berk. & Broome) Arthur and *P. vernoniae* (T.S. Ramakr.) Ramachar & Bhagyan are solely based on morphs. Since the genus *Physopella* has now been changed to *Neophysopella*, these two Indian records are still unchanged (Index Fungorum 2020). Hence, we retained this species in this family and proposed DNA based studies to resolve its taxonomic position.

Gymnosporangiaceae P. Zhou & L. Cai, Persoonia 45: 79. 2020. ***emend***. Aime & McTaggart

Type genus – ***Gymnosporangium*** R. Hedw. ex DC., In: Lamarck & de Candolle, Fl. franç., Edn 3 (Paris) 2: 216. 1805.

The family *Gymnosporangiaceae* consists of Group V (type 4) Spermogonia, bounded with well developed peripheral flexuous hyphae. Aecia *Roestelia*-type, subepidermal, with well-developed peridia (*Gymnosporangium*) or less frequently aecidium-type (*Gymnotelium*). Aeciospores catenulate, with intercalary cells. Urediniospores borne singly on pedicels in Uredo-type, subepidermal Uredinia. Telia subepidermal, erumpent consists mostly 2-celled teliospores, borne singly on gelatinising pedicels without dormancy via external basidia. Life cycle mostly demicyclic and heteroecious (Zhao et al. 2020, Aime & McTaggart 2020).

Genera reported in India – *Peridiopsora* (1) *Gymnosporangium* (3) *Roestelia* (3)

Host families – *Boraginaceae, Cupressaceae, Rosaceae.*

Notes – Based on puccinioid character of 2-celled, pedicellate teliospores, the genus name *Gymnosporangium* has been conserved against the older name *Roestelia* Rebent. (Aime et al. 2018b). Hence, the genus *Roestelia* has now been transferred to *Gymnosporangium*. Because of lack of molecular data, Indian records of this genus reported as *Roestelia distorta* (Arthur & Cummins) F. Kern, *Roestelia cunninghamianum* (Barclay) F. Kern and *Roestelia patula* (Syd. & P. Syd.) F. Kern are still unchanged (Index Fungorum 2020).

Melampsoraceae Dietel, in Engler & Prantl, Nat. Pflanzenfam., Teil. I (Leipzig) 1: 38. 1897.

Figs 2, 7, 9

Type genus – ***Melampsora*** Castagne, Obs. Plantes Acotylédonées Fam. Urédinié 2: 18. 1843.

Melampsoraceae is characterized by aecia without peridium or rudimentary if present with catenulate and verrucose aeciospores. Uredinia contain abundant paraphyses (sometimes rudimentary peridium also) and echinulate urediniospores with scattered or bizonate germ pores and borne singly. Telia are embedded (subepidermal or rarely subcuticular) containing unicellular, sessile, pigmented teliospores with one germ pore. Germination external or semi-external (*Ceropsora*). The basidium is external and spermogonia are of Group I (Type 2 or 3). These fungi are mostly macrocyclic and inhabit two different unrelated hosts or same host to produce all spore stages. Most of the species are heteroecious and macrocyclic; however, the species of *Ceropsora* are microcyclic. Total 100 species of *Melampsora* have been reported globally (He et al. 2019, Wijayawardene et al. 2020), of which only 17 species have been reported so far in India.

Genera reported in India – *Ceropsora* (1), *Melampsora* (17); total 18 species.

Host families – *Euphorbiaceae, Hypericaceae, Linaceae, Pinaceae, Salicaceae.*

Notes – The type species of the genus *Ceropsora* (*C. picea*) infecting *Picea* sp. was reported from India (Bakshi & Singh 1960). It was placed in family Coleosporiaceae (Cummins & Hiratsuka 2003, Wijayawardene et al. 2020). The telia of two species of *Ceropsora* viz., *C. picea* and *C. weirii* contain some thin-walled sterile cells on the sides (been interpreted as remnants of a peridermium). Teliospores of the genus are subtended by adherent crusts of sterile basal cells in the beginning that separate at dispersal stage (Bakshi & Singh 1960, Crane et al. 2000). Aime & McTaggart (2020) proposed the inclusion of the genus *Ceropsora* in to this family.

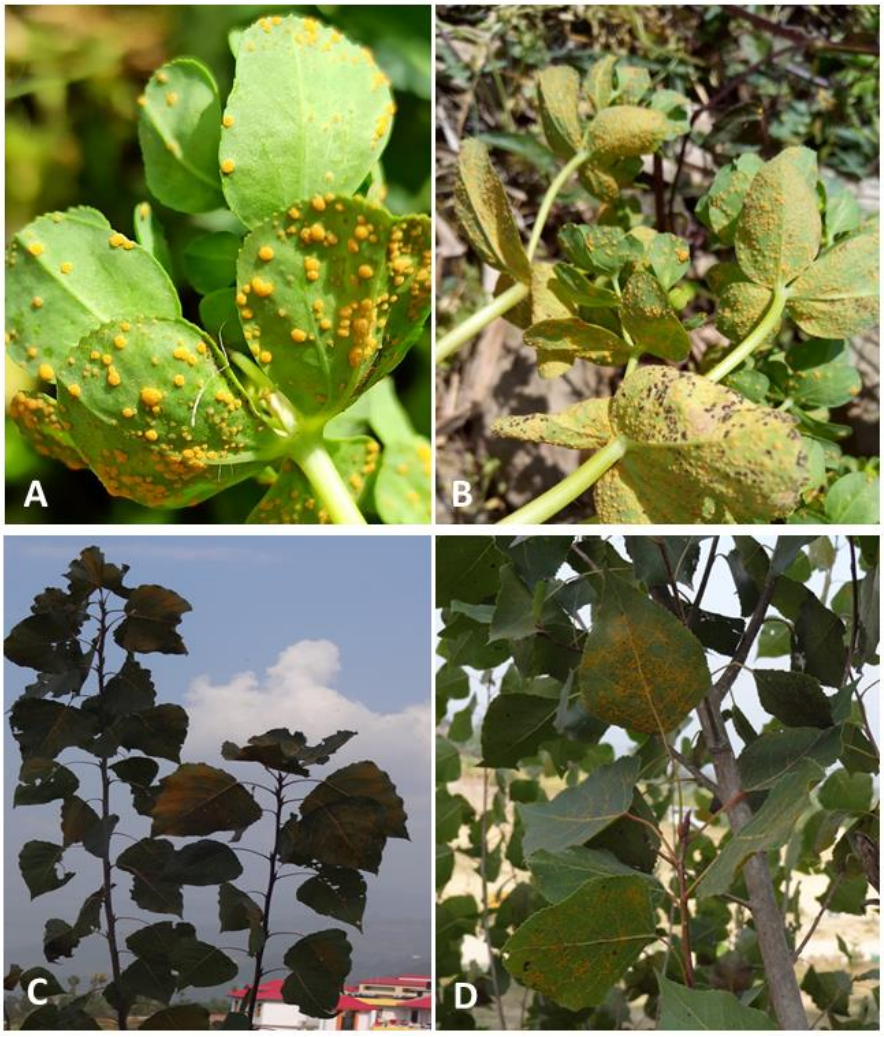

Figure 2 – Rust fungi *Melampsora* sp. A-B *Euphorbia helioscopia*. C-D *Populus* sp.

Milesinaceae Aime & McTaggart, In: Fungal Systematics and Evolution 7: 21–47. 2020

Type genus – *Milesina* Magnus, Ber. Deutsch. Bot. Ges. 27: 325. 1909.

Two important characters, production of colourless urediniospores in species that infect ferns and production of aecia (milesia-type) in species that infect *Ericaceae* differentiate this family from *Melampsorineae*. The important characters of this family include production of Group I (mostly type 1, also type 2 and 3) Spermogonia and colourless sori. Although urediniospores of *Naohidemyces* are orange in colour. The presence of peridermium-type aecia (milesia-type in Naohidemyces); milesia-type uredinia; 1- to many-celled, barely differentiated, sometimes laterally adherent teliospores with dormant germination are found. These fungi are mostly macrocyclic and heteroecious in nature. They produce sporothalli on ferns (except *Naohidemyces* on *Ericaceae*), and gametothalli on *Pinaceae*.

Genera reported in India – *Milesina* (3), *Uredinopsis* (2); total 5 species

Host families – *Dryopteridaceae*, *Pteridaceae.*

Note – This is newly proposed family by Aime & McTaggart (2020). Out of 4 genera included in this family (Aime & McTaggart 2020), two genera namely, *Milesina* and *Uredinopsis* are reported from India. Aime et al. (2018) recommended the protection of the name *Milesina* Magnus over *Milesia* F.B. White, but they do not found the type species of both the genera congeneric and recommended retaining both the genera. In India, the molecular studes on *Milesina* and *Uredinopsis* are also required to demonstrate their correct taxonomic position.

Ochropsoraceae (Arthur) Aime & McTaggart, In: Fungal Systematics and Evolution 7: 21–47. 2020

Type genus – *Ochropsora* Dietel, Ber. Dtsch. Bot. Ges. 13: 401. 1895.

The family *Ochropsoraceae* contains Group VI (type 7) spermogonia. Aecia are of aecidium-type, these states systemic in nature and overwintering as mycelium. Uredinia are of malupa-type. The genera of this family produce 1-cell deep telia forming crusts, which are at first subepidermal, then erumpent. Teliospores germinate without dormancy, either internally (*Ochropsora*) or externally (*Aplopsora*). These fungi are macrocyclic and heteroecious in nature.

Genera reported in India – *Ochropsora* (1); total 1 species

Host families – *Ranunculaceae.*

Note – Aime & McTaggart (2020) proposed *Ochropsoraceae* as new family. The rust genera *Aplopsora* and *Ochropsora* included in this family were previously treated within the *Chaconiaceae* (Cummins & Hiratsuka 2003). Of these, *Ochropsora* (*Ochropsora ariae* (Fuckel) Ramsb.) was also reported from India. However, only morphotaxonomic studies are available for this record, and molecular studies can be helpful to establish the correct taxonomic position.

Phakopsoraceae Cummins & Y. Hirats., Illustr. Gen. Rust Fungi, rev. Edn (St. Paul): 13. 1983. ***emend***. Aime & McTaggart

Type genus – *Phakopsora* Dietel, Ber. Deutsch. Bot. Ges. 13: 333. 1895.

The genera of *Phakopsoraceae* show both heteroecious and autoecious (species of *Bubakia*, *Masseeëlla* and *Nothoravenelia*) mode of life cycle on various hosts but not host restricted. Spermogonia are of Group IV (type 7). The aecia are caeoma-type (some *Masseeëlla* with aecidium-type) with aeciospores either verrucose or echinulate, borne singly or in chains. Uredinia lecythea or uredo-type consisting echinulate urediniospores, mostly borne singly (catenulate in *Arthuria*) with scattered germ pores or obscure. Both erumpent and embedded types of telia are found which contain 1-celled, sessile, catenulate or irregularly arranged teliospores with mostly 1 germ pore in each cell The majority of *Phakopsora* and *Uredopeltis* species are only known from the sporothallus (uredinial, and telial) stages (Cummins & Hiratsuka 2003, Aime & McTaggart 2020). This family comprises 15 genera and 209 species (Wijayawardene et al. 2020). Aime & McTaggart (2020) in recent treatment included 12 genera in this family, 10 being reported from India.

Genera reported in India – *Arthuria* (2), *Bubakia* (1), *Cerotelium* (7), *Macabuna* (1), *Monosporidium* (3), *Masseeëlla* (6), *Phakopsora* (25), *Phragmidiella* (3), *Pucciniostele* (1), *Uredopeltis* (1); total 50 species.

Host families – *Bignoniaceae, Burseraceae, Combretaceae, Euphorbiaceae, Fabaceae, Phyllanthaceae, Putranjivaceae, Rhamnaceae, Rubiaceae, Salicaceae, Saxifragaceae* and *Vitaceae.*

Notes – The rust genus *Bubakia* has now been transferred to *Phakopsora* (Index Fungorum 2021). It is often treated as a synonym of *Phakopsora* (Cummins & Hiratsuka 2003). But, Aime & McTaggart (2020) found a distinct lineage of the *Bubakia argentinensis* within *Phakopsoraceae* and similar characteristics and hosts with type, *B. crotonis*. Hence, they proposed *Bubakia* for these species. However, the only India record of *Bubakia indica* T.S. Ramakr. & K. Ramakr. still requires molecular studes, as it was identified based on morphology only. The genus *Masseeëlla* is also placed within this family (Aime & McTaggart 2020), although previously treated as *incertae sedis* within *Pucciniales* (Cummins & Hiratsuka 2003).

Phragmidiaceae Corda Icon. fung. (Prague) 1: 6. 1837 Figs 3, 9

Type genus – *Phragmidium* Link, Mag. Ges. Naturfr. Freunde Berlin 7: 30. 1816.

Phragmidiaceae is characterized by forming spermogonia Group IV (type 6, 8, 10 or 11). The aecia variable, caeoma-, petersonia- or uredo-type and are formed with or without peridium. Aeciospores are verrucose or echninulate aeciospores borne in chains or singly on pedicels with few or no paraphyses. Uredinia lecythea or uredo-type, thin-walled, with incurved paraphyses consisting of echninulate urediniospores borne singly and have scattered germ pores. Telia erumpent, with or without paraphyses, with teliospores born on short pedicels, 3- to several cells (by transverse septa) with 1 or more apical germ pore in each cell. Basidium is external. Life cycle is mainly of autoecious type. Wijayawardene et al. (2020) documented 13 genera and 178 species in this family; however, Aime & McTaggart (2020) included only 9 genera.

Genera reported in India – *Hamaspora* (2), *Kuehneola* (6), *Phragmidium* (18), *Trachyspora* (1); total 27 species.

Host families – *Poaceae*, *Rosaceae*.

Notes – Of the 9 genera included in this family, only 4 genera and 27 species have been reported in India. *Phragmidiaceae* species are confined almost exclusively to the *Rosoideae* subfamily of *Rosaceae* (Aime 2006).

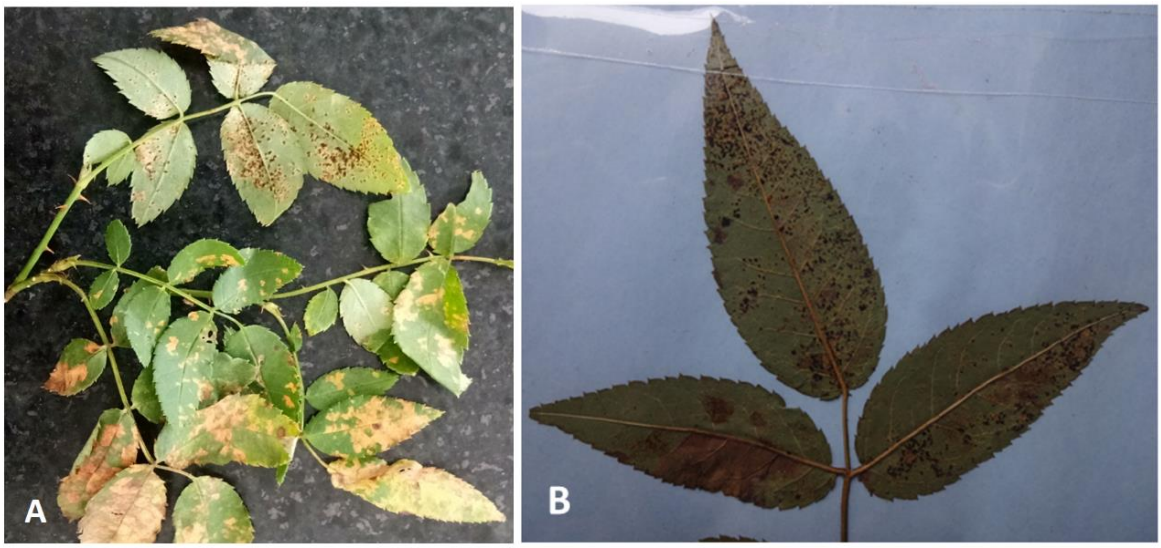

Figure 3 – A-B *Phragmidium* sp. on *Rosa* sp.

Pileolariaceae (Arthur) Cummins & Y. Hirats., llustr. Gen. Rust Fungi, rev. Edn (St. Paul): 14. 1983. ***emend***. Aime & McTaggart Figs 4A, 9

Type genus – *Pileolaria* Castagne, Obs. Plantes Acotylédonées Fam. Urédinées 1: 22. 1842.

The genera of the family are characterized by forming spermogonia Group VI (type 7). Aecia (uredo-type) with or without peridium contains reticulate, ridged, verrucose, spirally marked aeciospores borne singly and germ pores zonate. Uredia (uredo-type) are similar to aecia except not accompanied by spermogonia. Telia erumpent and having unicellular teliospores 1-celled, borne one or few on each pedicel with one germ pore per spore. Basidium is external. Species are mostly macrocyclic and autoecious. The genera of this family mostly inhabit members of *Anacardiaceae* (Cummins & Hiratsuka 2003, Aime & McTaggart 2020).

Genera reported in India – *Pileolaria* (2); total 2 species.

Host family – *Anacardiaceae.*

Notes – Four genera and 43 species have been documented in this family (Wijayawardene et al. 2020), of which two genera, *Pileolaria* and *Skierka* were reported from India. However, Aime & McTaggart (2020) included only the genus i.e. *Pileolaria* and proposed the placement of *Skierka* within another family. A total 25 species of *Pileolaria* are recorded worldwide (Index Fungorum 2021). The two Indian records (*P. indica* Syd. and *P. pistaciae* F.L. Tai & C.T. Wei) require further molecular studies.

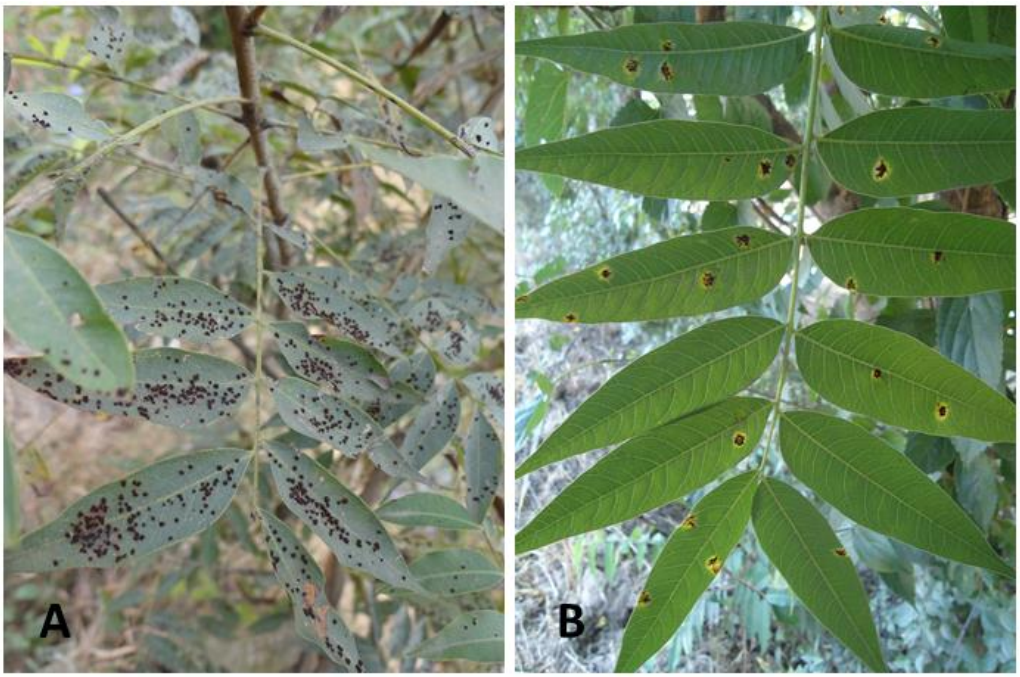

Figure 4 – Rust fungi. A *Pileolaria* sp. on *Pistacia* sp. B *Skierka* sp. on *Pistacia* sp.

Pucciniastraceae Gäum. ex Leppik, Ann. bot. fenn. 9: 139. 1972. ***emend***. Aime & McTaggart

Type genus – *Pucciniastrum* G.H. Otth, Mitt. Naturforsch. Ges. Bern 1861: 71. 1861.

Pucciniastraceae members are heteroecious and mostly macrocyclic. Spermogonia and aecia produced on conifers; uredinia and telia often on ferns. Spermogonia are of Group I (type 2 or 3). Aecia with well developed peridium and contain catenulate aeciospores. Uredinia are formed with cellular peridium and ostiolar opening and contain pedicellate or non pedicellate, echinulate urediniospores, borne singly and possess obscure, scattered or bizonate germ pores. Telia are not well differentiated i.e. either subepidermal or intradermal, not erumpent, composed of unicellular or multicellular, sessile teliospores having obscure or 1 germ pore per cell. Basidia are external (Cummins & Hiratsuka 2003, Aime & McTaggart 2020). The family was reported to contain 10 genera and 210 species (Wijayawardene et al. 2020). The recent higher rank classification for rust fungi proposed the inclusion of only six genera in this family (Aime & McTaggart 2020), of which four were recorded from India.

Genera reported in India – *Hyalopsora* (2), *Melampsoridium* (4), *Peridermium* (7), *Pucciniastrum* (6); total 19 species.

Host families – *Betulaceae, Celastraceae, Coriariaceae Magnoliaceae, Phyllanthaceae, Pinaceae, Pteridaceae, Rosaceae, Sapindaceae.*

Notes – As per the proposal to conserve the name of rust fungi (Aime et al. 2018), the sexual name *Melampsorella* has been conserved over *Peridermium*. However, the Indian records of *Peridermium* are devoid of any molecular studies and are still unchanged (Index Fungorum 2021).

Pucciniaceae Chevall., Fl. gén. env. Paris (Paris) 1: 413. 1826. ***emend***. Aime & McTaggart

Figs 5, 6, 7, 8

Type genus – *Puccinia* Pers., Synopsis methodica fungorum: 225. 1801.

Pucciniaceae is a largest family that infects nearly all the major angiospermous orders. They are destructive phytopathogens infecting mainly cereals such as wheat. Spermogonia belong to Group V (type 4). Aecidia are with or without a peridium and have verrucose aeciospores borne singly, or in chain (catenulate). Uredinia with palisade like peridium contain echinulate urediniospores borne singly and have many germ pores. The most important distinguishing character is that these fungi having stalked teliospores borne singly or united in telia with or without paraphyses. In some cases, palisade like peridium or separation of telia into locules by stromatoid paraphyses is also observed.

Teliospores are mostly 1 or 2 (rarely more) celled with one germ pore in each cell and germination mostly by external basidium (sometimes internal). The genera are mostly heteroecious exhibiting four spore stages usually upon two or more distinct hosts followed by an independent promycelial stage upon germination of the teliospores. The largest two genera are *Puccinia*, with two-celled teliospores, and *Uromyces* where they are one-celled. This is the most speciose family of the *Pucciniales*, and contains 21 genera and over 4961 species (Wijayawardene et al. 2020). Aime & McTaggart (2020) proposed the inclusion of 23 genera and 9 more genera likely to include in this family. Total 12 genera with 393 species have been recorded in India.

Genera reported in India – *Caeoma* (4), *Chrysocelis* (1), *Corbulopsora* (1), *Endophyllum* (8), *Gambleola* (1), *Hapalophragmium* (4), *Kernella* (1), *Puccinia* (279), *Pucciniosira* (1), *Ramakrishnania* (1), *Trochodium* (2), *Uromyces* (89); total 393 species.

Host families – *Acanthaceae, Apiaceae, Asteraceae, Berberidaceae, Boraginaceae, Celastraceae, Convolvulaceae, Cyperaceae, Elaeagnaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Lauraceae, Liliaceae, Loranthaceae, Malvaceae, Orchidaceae, Pinaceae, Plantaginaceae, Poaceae, Polygonaceae, Ranunculaceae, Rubiaceae, Saxifragaceae, Schisandraceae, Solanaceae.*

Notes – The genus *Caeoma*, as typified by *C. berberidis*, is a synonym of *Puccinia* (Aime et al. 2018). One of its species *C. torreyae* is presented as basionym of *Rogerpetersonia torreyae* (Bonar) Aime & McTaggart (Aime & McTaggart 2020) based on broad molecular assessment. Similarly, the genus *Trochodium* has now been transferred to *Uromyces*. The types of two genera, *Gambleola* and *Ramakrishnania* are of Indian origin and identified mainly based on mophotaxonomic characters. The Indian records for all three genera are still unchanged (Index fungorum 2021) and required investigation at molecular level.

Raveneliaceae Leppik, Ann. bot. fenn. 9: 139. 1972. ***emend***. Aime & McTaggart Fig. 9

Type genus – *Ravenelia* Berk., Gard. Chron. 13:132. 1853.

Raveneliaceae consists Group VI (type 5, 7) spermogonia. The genera of this family produce typically uredo- (rarely aecidium-, caeoma-, or lecythea-) type aecia with or without peridium and paraphyses. Aeciospores are pedicellate and echinulate or verrucose borne singly or in chain. Uredinia are of subepidermal or erumpent, with or without paraphyses. These are similar to aecia while unknown in some cases. Urediniospores borne singly, mostly echinulate with several germ pores. Telia are erumpent with or without paraphyses contain pedicellate, vertically septate or vertically or radially arranged 1- to many-celled teliospores (2 or more) on the top of pedicel, often subtended by hygroscopic crystals or with pedicel having apical cells. Each cell or spore contains one or two germ pores. Basidium is of external type. Members of this family have autoecious and macrocyclic type of life cycle mostly on *Fabaceae* or *Rosaceae*. Although 24 genera and 384 species have been documented within this family (Wijayawardene et al. 2020), Aime & McTaggart (2020) proposed the inclusion of 16 genera and 16 more genera likely to include in this family. Total 10 genera with 61 species have been recorded in India.

Genera reported in India – *Chaconia* (1), *Didymopsorella* (1), *Diorchidium* (3), *Gymnopuccinia* (1), *Kernkampella* (5), *Maravalia* (11), *Scopella* (1), *Olivea* (3), *Prospodium* (2) *Ravenelia* (33); total 61 species.

Host families – *Fabaceae, Oleaceae, Phyllanthaceae, Poaeae, Rubiaceae, Rutaceae.*

Notes – The identification of Indian records in this family, *Didymopsorella macrospora* (Mundk. & Thirum.) Thirum., *Gymnopuccinia pulneyensis* K. Ramakr. and *Scopella dalbergiae* (T.S. Ramakr. & K. Ramakr.) Ragunathan & K. Ramakr. is mainly based on their morphological caharcters. Similarly, the genus *Scopella* has now been transferred to *Maravalia.* However, its indian record *Scopella dalbergiae* (T.S. Ramakr. & K. Ramakr.) Ragunathan & K. Ramakr. is still unchanged. DNA sequence studies can be helpful to establish their correct taxonomic placement.

Skierkaceae (Arthur) Aime & McTaggart, Fungal Systematics and Evolution 7: 21–47, 2020. Figs 4B, 9

Type genus – *Skierka* Racib., Parasit. Alg. Pilze Javas (Jakarta) 2: 30. 1900.

Skierkaceae is a newly introduced family by Aime & McTaggart (2020), mainly characterized by subepidermal, periphysate, deep-seated spermogonia with convex hymenium. Aecia and uredinia uredo-type. The Uredia and telia (sporothalli sori) are deep-seated and subepidermal which differentailed these from all other rust fungi. Urediniospores and teliospores are single-celled produced on sporogenous cells through a narrow sorus opening. Before emenrgence, these spores leaving behind new spores on sporogenous cells from which they are detached. Teliospores strongly adherent, extruded in hair-like columns, germination external, without dormancy. These fungi possess autoecious and macrocyclic type of life cycle.

Genera reported in India – *Skierka* (3); total 3 species.

Host families – *Anacardiaceae.*

Notes – A total of 14 species of the genus *Skierka* have been reported so far (Index Fungorum 2021), three species reported from India too. *Skierka himalayensis* A.K. Gautam & S. Avasthi was reported as new from India (Gautam & Avasthi 2017c). But all three records are identified on based on morphological characters only and require molecular identification.

Sphaerophragmiaceae Cummins & Y. Hirats., Illustr. Gen. Rust Fungi, rev. Edn (St. Paul): 15. 1983. ***emend***. Aime & McTaggart

Type genus – *Sphaerophragmium* Magnus Ber. dt. bot. Ges 9: 121. 1891.

Spermogonia are mostly lacking and unknown, Group V (type 4) in *Sphenorchidium*, if present. Aecia are aecidium-type and uredinia resembling aecia (lecythea-type in *Sphenorchidium*). Teliospores 2- to multicelled, pedicellate, globose to subglobose, with furcated or simple blunt wall projections, with one germ pore per cell borne in compact telia (Beenken & Berndt 2010). In *Austropuccinia*, urediniospores with a smooth patch (tonsure) as comparison to echinulate or verrucose in other cases. Telia subepidermal to erumpent, cylindrical to ellipsoidal, with a rounded apex, 2-celled teliospores, constricted at the septum. Basidia are mostly external. Species are autoecious with variable life cycles. Wijayawardene et al. (2020) documented 2 genera and 25 species in this family, however, Aime & McTaggart (2020) proposed the inclusion of 5 genera.

Genera reported in India – *Sphaerophragmium* (1); total 1 species.

Host families – *Fabaceae.*

Notes – Only single genus *Sphaerophragmium* with one species (*S. acacia* (Cooke) Magnus) was reported from India. The identification of this species is solely based on moprhological characters, and DNA based molecular studies are necessary.

Tranzscheliaceae (Arthur) Aime & McTaggart, Fungal Systematics and Evolution 7: 21–47, 2020

Type genus – *Tranzschelia* Arthur, Rés. Sci. Congr. Int. Vienne: 340. 1906.

The rust fungi of family *Tranzscheliaceae* are mostly macrocyclic and heteroecious in nature. However, some microcyclic species may be found. The species consists of Group VI (type 7) spermogonia. Aecia are of aecidium type while, uredinia uredo-type. Teliospores produced cby theses fungi are 2-celled, pedicellate, produced from sterile basal cells.

Genera reported in India – *Leucotelium* (1), *Tranzschelia* (2); total 3 species

Host families – *Rosaceae.*

Notes – *Tranzscheliaceae* is proposed as new family by Aime & McTaggart (2020), included two genera, *Leucotelium* and *Tranzschelia*. Both the genera were previously treated within *Uropyxidaceae* (Cummins & Hiratsuka 2003). The Indian records of these genera still required DNA sequence based studies to establish their correct taxonomic position.

Zaghouaniaceae P. Syd. & Syd., Monogr. Uredin. (Lipsiae) 3(3): 586. 1915. ***emend***. Aime & McTaggart

Type genus – *Zaghouania* Pat., Bull. Soc. mycol. Fr. 17: 187. 1901

The species of this family most often consists of deep seated and non-periphysate Group III (type 12) spermogonia. Aecia are mostly petersonia-type (without peridium or intercalary cells). Aeciospores are echinulate or verrucose; borne singly or in chain. The uredinia are generally

produced without peridium (most often uredo-type) or weakly developed peridium in some cases and produce echinulate, singly borne ureniniospores. Telia are with or without paraphyses, produce teliospores germinating externally (internally in some cases) by apical growth without dormancy. These rust fungi have both autoecious and heteroecious mode of life cycle.

Genera reported in India – *Cystopsora* (1), *Elateraceium* (1), *Hemileia* (10), *Zaghouania* (1); total 13 species

Host families – *Apocynaceae*, *Celastraceae*, *Oleaceae*, *Penaeaceae*, *Phyllanthaceae*, *Rubiaceae.*

Notes – Aime & McTaggart (2020) included 8 genera in this family, of which, four genera namely *Cystopsora*, *Elateraceium*, *Hemileia*, *Zaghouania* have been reported from India. The genus *Cystopsora* is now considered as synonym of *Zaghouania* (Aime & McTaggart 2020). The identity of Indian record *Cystopsora antidesmatis* T.S. Ramakr. & Sundaram is mainly based on morphological observations. DNA sequence based studies are required to provide its exact taxonomic position.

Figure 5 – Rust fungi *Puccinia* spp. A *Rubia cordifolia.* B *Clematis* sp. C *Berberis* sp. D *Clematis* sp. E *Oxalis* sp. F *Mentha* sp.

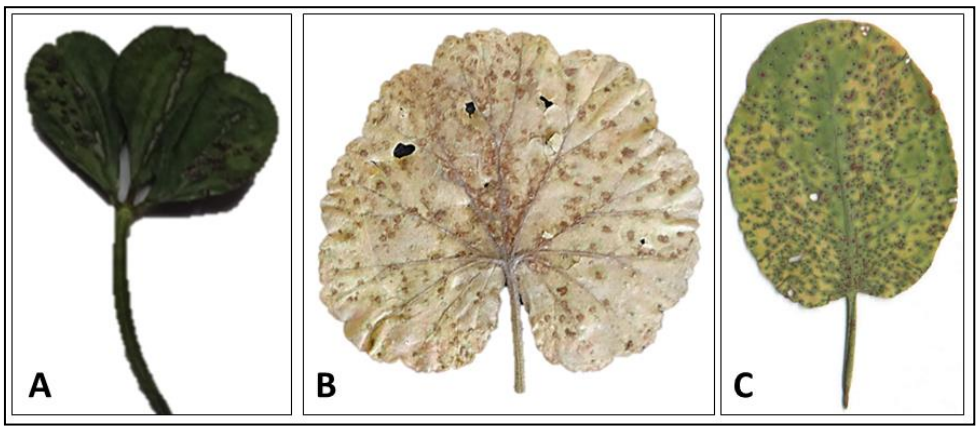

Figure 6 – Rust fungi *Uromyces* spp. A *Trifolium* sp. B *Geranium* sp. C *Rumex* sp.

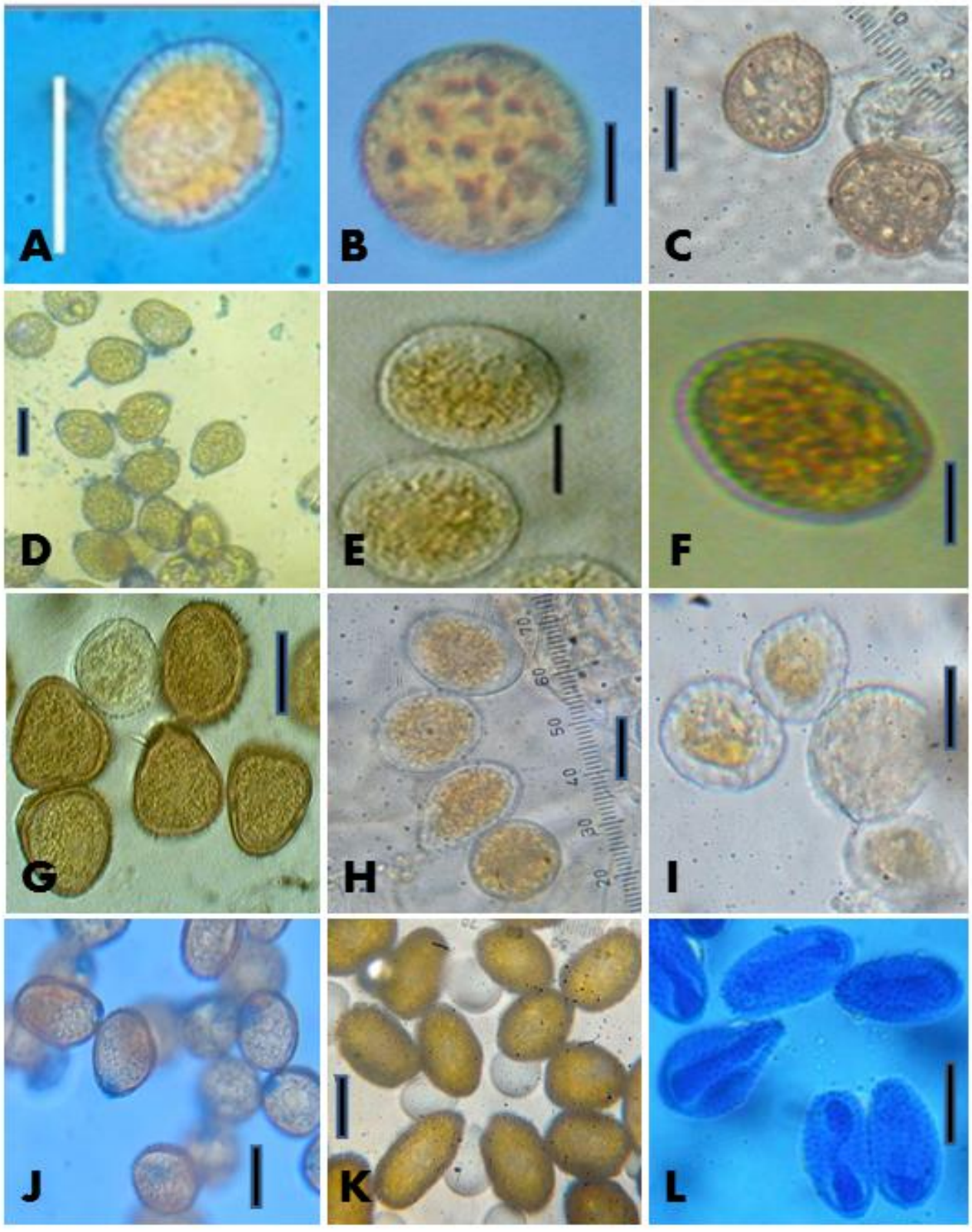

Figure 7 – *Uredinospores*. A *Puccinia himachalensis* on *Clematis* sp. B *P. tiliaefolia* on *Grewia* sp. C *P. fagopyri* on *Fagopyrum* sp. D *P. menthae* on *Mentha* sp. E *P. Oxalidis* on *Oxalis* sp. F *P. flavipes* on *Duchesnea* sp. G *P. abrupta* on *Parthenium* sp. H *P. colletiana* on *Rubia* sp. I *Melampsora caprearum* on *Salix* sp. J *P. Nepalensis* on *Rumex* sp. K *Uredo sp.* on *Ehretia* sp. L *Melampsora populnea* on *Populus* sp. Scale Bar = 10µm.

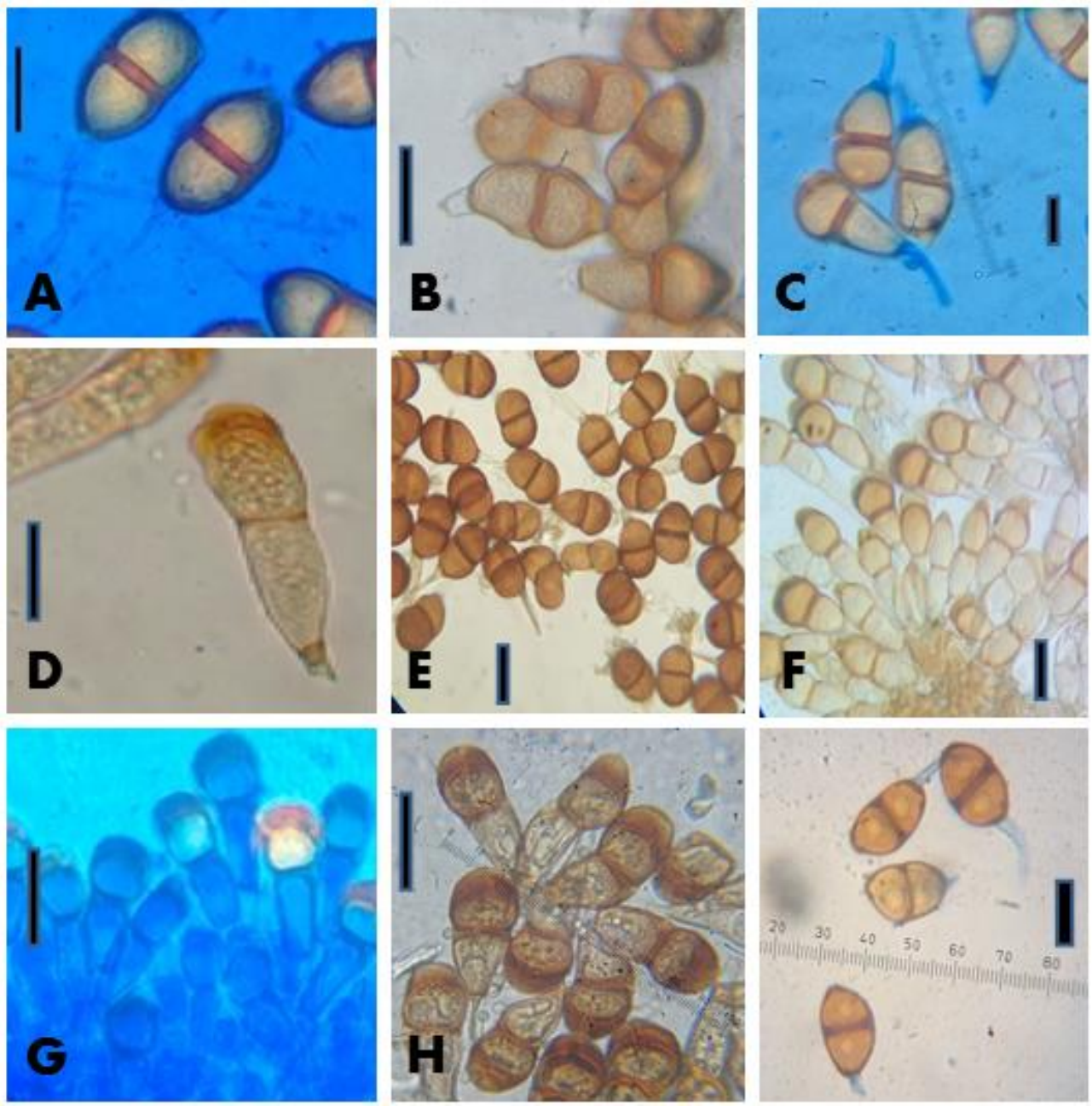

Figure 8 – Teliospores of *Puccinia*. A *P. himachalensis* on *Clematis* sp. B *P. fagopyri* on *Fagopyrum* sp. C *P. tiliaefolia* on *Grewia* sp. D *P. agrostdis* on *Aquilegia* sp. E *P. Cynodontis* on *Cyanodon* sp. F *P. cynodontis* on *Cyanodon* sp. G *P. colletiana* on *Rubia* sp. H *P. colletiana* on *Rubia* sp. I *P. gouriana* on *Clematis* sp. Scale Bar = 10µm.

Excluded and replaced names of rust fungi in India

With the use of DNA sequence based techniques, the economically important rusts are relatively well explored, but not much attention has been paid to species infecting wild plants in general. The identification of most of the Indian rust fungi is largely based on morphological characters especially morphology of certain spore stages. Use of DNA sequence based studies along with morphotaxonomic characters has made identification and characterization of rust fungi more efficient and accurate. The names of many rust genera/species as reported in the cited publications have been replaced with new accepted names. Numbers of genera and species of Indian rust fungi have also been replaced with currently accepted name according to MycoBank (www.mycobank.org)/ and Species Fungorum (www.speciesfungorum.org) websites and this is indicated in Table 3.

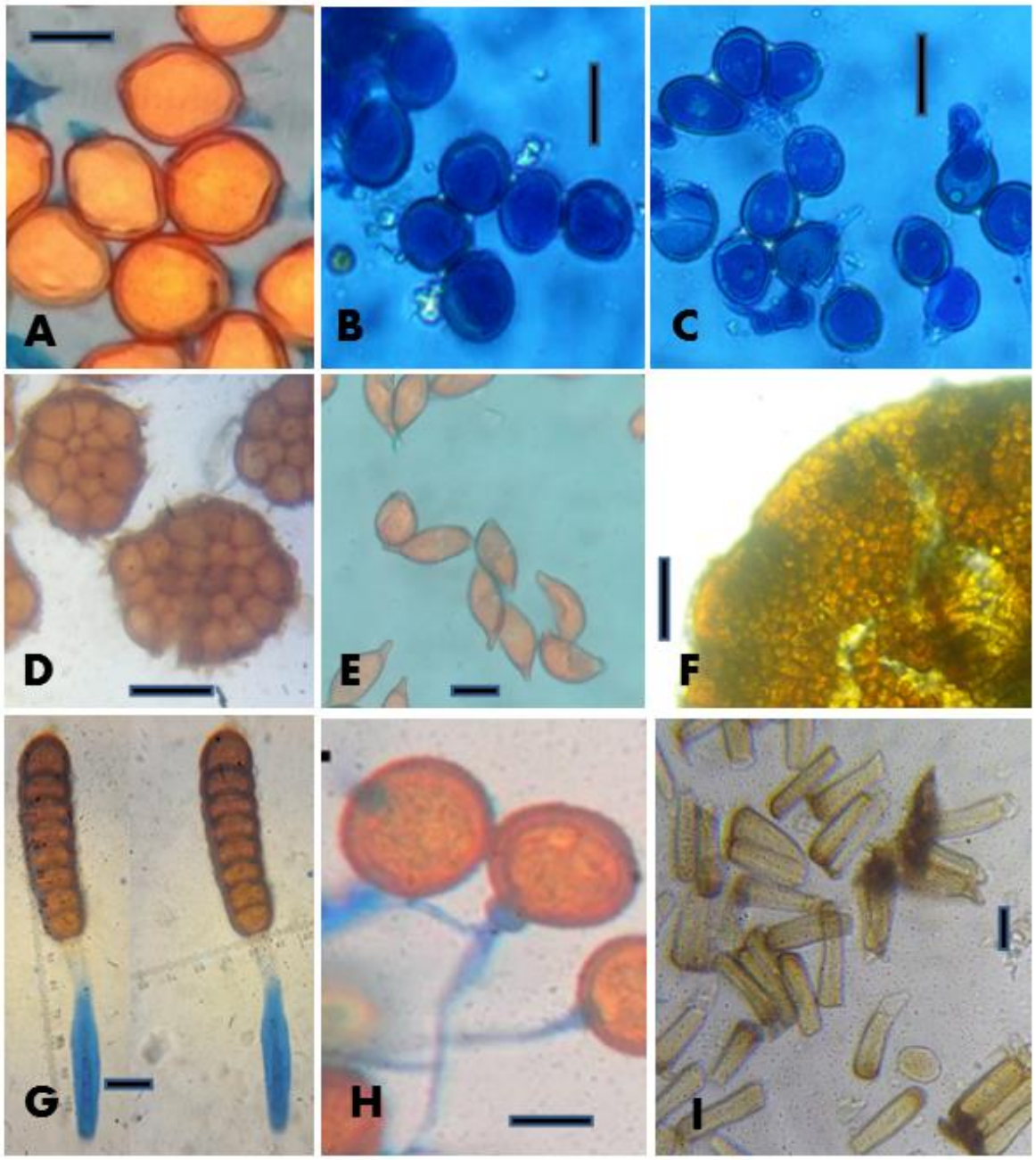

Figure 9 – Teliospores of rust fungi. A *Uromyces* on *Trifolium* sp. B *Uromyces* on *Rumex* sp. C *Uromyces* on *Geranium* sp. D *Ravenelia* on *Pongamia* sp. E *Skierka* on *Pistacia* sp. F *Kweilingia* on *Bamusa* sp. G *Phragmidium* on *Rosa* sp. H *Pileolaria* on *Pistacia* sp. I *Melampsora* on *Euphorbia* sp. Scale Bar = 10µm.

Table 3 Excluded and replaced names of rust fungi in India. (Index Fungorum 2020, Mycobank 2020)

Old Name	**New Name**
Acervulopsora ichnocarpi (Barclay) Thirum.	*Maravalia ichnocarpi* (Barclay) Sathe
Aecidium acanthospermi P.B. Chavan & Bakare	*Puccinia acanthospermi* Henn.
Aecidium asterum Schwein.	*Puccinia asterum* (Schwein.) F. Kern
Aecidium barleriae M.A. Salam & Ramachar	*Aecidium salamii* G.F. Laundon
Aecidium berberidis Pers. ex J.F. Gmel.	*Puccinia graminis* Pers.
Aecidium cassiae Bres.	*Endophyllum cassiae* (Bres.) F. Stevens & Mendiola
Aecidium cunninghamianum Barclay	*Roestelia cunninghamianum* (Barclay) F. Kern

Table 3 Continued.

Old Name	New Name
Aecidium elaeagni-latifoliae Petch	*Endophyllum elaeagni-latifoliae* (Petch) Gokhale, Thirum. & Patel
Aecidium kaernbachii Henn.	*Endophyllum kaernbachii* (Henn.) F. Stevens & Mendiola
Aecidium leucospermum DC.	*Ochropsora ariae* (Fuckel) Ramsb.
Aecidium macowanianum Thüm.	*Endophyllum macowanianum* (Thüm.) Pole-Evans
Aecidium meliosmae-myrianthae Henn. & Shirai	*Neophysopella meliosmae-myrianthae* (Henn. & Shirai) Jing X. Ji & Kakish.
Aecidium patulum Syd. & P. Syd.	*Roestelia patula* (Syd. & P. Syd.) F. Kern
Aecidium plectranthi Barclay	*Coleosporium plectranthi* (Barclay) Sacc.
Aecidium ranunculacearum DC.	*Uromyces dactylidis* G.H. Otth
Angiopsora ampelopsidis (Dietel & P. Syd.) Thirum. & F. Kern	*Neophysopella ampelopsidis* (Dietel & P. Syd.) Jing X. Ji & Kakish.
Angiopsora elephantopodis (Hirats.) Mundk. & Thirum.	*Phakopsora elephantopodis* Hirats.
Angiopsora meliosmae (Kusano) Thirum. & F. Kern	*Neophysopella meliosmae* (Kusano) Jing X. Ji & Kakish.
Angiopsora vernoniae T.S. Ramakr.	*Physopella vernoniae* (T.S. Ramakr.) Ramachar & Bhagyan.
Bubakia cingens (Syd. & P. Syd.) S. Ito	*Phakopsora cingens* (Syd. & P. Syd.) Hirats.
Catenulopsora flacourtiae Mundk. & Thirum.	*Kuehneola flacourtiae* (Mundk. & Thirum.) Thirum.
Catenulopsora grewiae Mundk. & Thirum.	*Kuehneola grewiae* (Mundk. & Thirum.) Thirum.
Catenulopsora ziziphi T.S. Ramakr. & Subram.	*Kuehneola ziziphi* (T.S. Ramakr. & Subram.) Thirum.
Cerotelium fici (Castagne) Arthur	*Puccinia fuirenicola* Arthur
Chnoopsora butleri Dietel, Syd. & P. Syd.	*Chrysocelis butleri* (Dietel, Syd. & P. Syd.) G.F. Laundon
Chnoopsora sancti-johannis (Barclay) Dietel	*Melampsora sancti-johannis* Barclay
Cystopsora oleae E.J. Butler	*Zaghouania oleae* (E.J. Butler) Cummins
Dasturella divina (Syd.) Mundk. & Khesw.	*Kweilingia divina* (Syd.) Buriticá
Dasturella grewiae (Pat. & Har.) Thirum.	*Uredopeltis chevalieri* J. Walker & R.G. Shivas
Didymopsorella toddaliae (Petch) Thirum.	*Skierka toddaliae (Petch) Hirats.,*
Elateraecium divinum (Syd.) Thirum., F. Kern & B.V. Patil	*Kweilingia divina* (Syd.) Buriticá
Endophyllum tuberculatum (Ellis & Kellerm.) Arthur & Fromme	*Pucciniosira tuberculata* (Ellis & Kellerm.) Buriticá & J.F. Hennen
Frommea obtusa (F. Strauss) Arthur	*Phragmidium potentillae* (Pers.) P. Karst.
Gymnosporangium distortum Arthur & Cummins	*Roestelia distorta* (Arthur & Cummins) F. Kern
Hamaspora benguetensis Syd.	*Hamaspora rubi-sieboldii* (Kawagoe) Dietel
Hemileia woodii Kalchbr. & Cooke	*Puccinia woodii* (Kalchbr. & Cooke) P. Syd. & Syd.
Jacksoniella holwayi (H.S. Jacks.) Kamat & Sathe	*Phragmidiella holwayi* (H.S. Jacks.) Buriticá
Kamatomyces narasimhanii (Thirum.) Sathe	*Masseeella narasimhanii Thirum.*
Kuehneola aliena (Syd., P. Syd. & E.J. Butler) P. Syd. & Syd. & E.J. Butler	*Phragmidiella aliena* (Syd., P. Syd. & E.J. Butler) Buriticá & J.F. Hennen
Kuehneola trichosanthis (Petch) T.S. Ramakr. & Sundaram	*Cerotelium trichosanthis* (Petch) Nag Raj, Govindu & Thirum.
Kuehneola vitis (E.J. Butler) P. Syd. & Syd.	*Chrysomyxa vitis* E.J. Butler
Melampsora laricis-epitea Kleb.	*Melampsora epitea* Thüm.
Nyssopsora schefflerae Ramachar, Bagyan., Subbal. & Hosag.	*Nyssopsora thwaitesii* (Berk. & Broome) Syd.
Ochropsora sorbi Dietel	*Ochropsora ariae* (Fuckel) Ramsb.
Oplophora cedrelae (Hori) Syd.	*Nyssopsora cedrelae* (Hori) Tranzschel
Phakopsora apoda (Har. & Pat.) Mains	*Angiopsora apoda* (Har. & Pat.) Aime & McTaggart.
Phakopsora gossypii (Lagerh.) Hirats. f.	*Phakopsora desmium* (Berk. & Broome) Cummins
Phakopsora grewiae (Pat. & Har.) Cummins	*Uredopeltis chevalieri* J. Walker & R.G. Shivas

Table 3 Continued.

Old Name	**New Name**
Phakopsora tecta H.S. Jacks. & Holw.	*Uromyces spegazzinii* (De Toni) Arthur
Phakopsora vignae (Bres.) Arthur	*Phakopsora pachyrhizi* Syd. & P. Syd.
Phakopsora ampelopsidis Dietel & P. Syd.	*Neophysopella ampelopsidis* (Dietel & P. Syd.) Jing X. Ji & Kakish.
Phragmidium disciflorum (Tode) J. James	*Phragmidium mucronatum* (Pers.) Schltdl.
Phragmidium rubi (Pers.) G. Winter	*Phragmidium bulbosum* (Fr.) Schltdl.
Puccinia absinthii DC.	*Puccinia chrysanthemi* Roze
Puccinia abutili Berk. & Broome	*Puccinia abutilonis* Berk. & Broome
Puccinia allii (DC.) F. Rudolphi	*Puccinia porri* (Sowerby) G. Winter
Puccinia artemisiella P. Syd. & Syd.	*Puccinia tanaceti* DC.
Puccinia arthraxonis (Henn.) Syd., P. Syd. & E.J. Butler	*Kuehneola loeseneriana* (Henn.) H.S. Jacks. & Holw.
Puccinia bullata (Pers.) J. Schröt.	*Puccinia angelicae* (Schumach.) Fuckel
Puccinia calcitrapae var. *centaureae* (DC.) Cummins	*Puccinia carthami* Corda
Puccinia carduorum Jacky	*Puccinia calcitrapae* DC.
Puccinia caricis Rebent.	*Puccinia dioicae Magnus*
Puccinia coronata f. *agrostidis* Erikss.	*Puccinia coronata* Corda
Puccinia coronata var. *himalensis* Barclay	*Puccinia coronata* Corda
Puccinia dispersa Erikss. & Henning	*Puccinia recondita* Roberge ex Desm.
Puccinia epilobii-tetragoni G. Winter	*Puccinia pulverulenta* Grev.
Puccinia extensicola Plowr.	*Puccinia dioicae* Magnus
Puccinia glumarum (J.C. Schmidt) Erikss. & Henning	*Puccinia striiformis* Westend.
Puccinia graminis var. *tritici* Erikss. & Henning	*Puccinia graminis* Pers.
Puccinia himalensis (Barclay) Dietel	*Chrysomyxa himalensis* Barclay
*Puccinia leptodermidis (*Barclay) Sacc.	*Coleosporium leptodermidis* (Barclay) P. Syd. & Syd.
Puccinia levis var. *panici-sanguinalis* (Rangel) Ramachar & Cummins	*Uromyces panici-sanguinalis* Rangel
Puccinia lolii E. Nielsen	*Puccinia coronata* Corda
Puccinia lycoctoni Fuckel	*Uromyces dactylidis* G.H. Otth
Puccinia maydis Bérenger	*Puccinia sorghi* Schwein.
Puccinia obtegens (Link) Tul.	*Puccinia suaveolens* (Pers.) Rostr.
Puccinia orientalis (Syd., P. Syd. & E.J. Butler) Arthur & Cummins	*Diorchidium orientale* Syd., P. Syd. & E.J. Butler
Puccinia orientalis (Syd., P. Syd. & E.J. Butler) Arthur & Cummins	*Diorchidium orientale* Syd., P. Syd. & E.J. Butler
Puccinia penniseti Zimm.	*Puccinia substriata* Ellis & Barthol.
Puccinia persistens Plowr.	*Puccinia recondita* Roberge ex Desm.
Puccinia poae-nemoralis G.H. Otth	*Puccinia brachypodii* G.H. Otth
Puccinia polygoni Alb. & Schwein.	*Puccinia polygoni-amphibii* Pers.
Puccinia prunicolor Syd., P. Syd. & E.J. Butler	*Puccinia purpurea* Cooke
Puccinia pruni-persicae Hori	*Leucotelium pruni-persicae* (Hori) Tranzschel
Puccinia pruni-spinosae Pers.	*Tranzschelia pruni-spinosae* (Pers.) Dietel
Puccinia pulsatillae Kalchbr.	*Puccinia ustalis* Berk.
Puccinia punctiformis (F. Strauss) Röhl.	*Puccinia suaveolens* (Pers.) Rostr.
Puccinia rubigo-vera var. *tritici* (Erikss.) Carleton	*Puccinia striiformis* Westend.
Puccinia rubigo-vera (DC.) G. Winter	*Puccinia recondita* Roberge ex Desm.
Puccinia saxifragae-micranthae Barclay	*Puccinia heucherae* (Schwein.) Dietel
Puccinia substriata var. *indica* Ramachar & Cummins	*Puccinia substriata* Ellis & Barthol.
Puccinia substriata var. *penicillariae* (Speg.) Ramachar & Cummins	*Puccinia substriata* Ellis & Barthol.
Puccinia taraxaci Plowr.	*Puccinia hieracii* (Röhl.) H. Mart.
Puccinia tricholaenae (Syd. & P. Syd.) T.S. Ramakr. & K. Ramakr.	*Diorchidium tricholaenae* Syd. & P. Syd.
Puccinia triticina Erikss.	*Puccinia recondita* Roberge ex Desm.

Table 3 Continued.

Old Name	New Name
Puccinia anomala Rostr.	*Puccinia hordei* G.H. Otth
Puccinia anthistiriae Barclay	*Puccinia graminis* Pers.
Puccinia baryi (Berk. & Broome) G. Winter	*Puccinia brachypodii* G.H. Otth
Puccinia brizae-maximae T.S. Ramakr.	*Puccinia graminis* Pers.
Puccinia bupleuri-falcati (DC.) G. Winter	*Puccinia bupleuri* F. Rudolphi
Puccinia cichorii Bellynck ex J. Kickx f.	*Puccinia hieracii* (Röhl.) H. Mart.
Ravenelia berkeleyi Mundk. & Thirum.	*Ravenelia cassiicola* G.F. Atk.
Ravenelia breyniae Syd. & P. Syd.	*Kernkampella breyniae* (Syd. & P. Syd.) Rajendren
Ravenelia breyniae-patentis Mundk. & Thirum.	*Kernkampella breyniae-patentis* (Mundk. & Thirum.) Rajendren
Ravenelia emblicae Syd. & P. Syd.	*Kernkampella emblicae* (Syd. & P. Syd.) G.F. Laundon
Ravenelia evernia Syd.	*Ravenelia fragrans* Long
Ravenelia kirganeliae Mundk. & Thirum.	*Kernkampella kirganeliae* (Mundk. & Thirum.) G.F. Laundon
Ravenelia phyllanthi Mundk. & Thirum.	*Kernkampella phyllanthi* (Mundk. & Thirum.) G.F. Laundon
Scopella aulica (Syd.) Mundk. & Thirum.	*Maravalia aulica* (Syd.) Y. Ono
Scopella echinulata (Niessl) Mains	*Maravalia echinulata* (Niessl ex Rabenh.) Y. Ono
Scopella fici Mundk. & Thirum.	*Maravalia fici* (Mundk. & Thirum.) Y. Ono
Scopella gentilis (Syd.) Mundk. & Thirum.	*Maravalia gentilis* (Syd.) Y. Ono
Scopella mimusops (Cooke) Cummins	*Maravalia mimusops* (Cooke) Y. Ono
Stakmania formosana (Syd. & P. Syd.) Sathe	*Phakopsora formosana* Syd. & P. Syd.
Teloconia rosae (Kuntze) Syd.	*Phragmidium kamtschatkae* (H.W. Anderson) Arthur & Cummins
Thekopsora gaultheriae (Syd. & P. Syd.) P. Syd. & Syd.	*Pucciniastrum gaultheriae* Syd. & P. Syd.
Trachyspora intrusa (Grev.) Arthur	*Trachyspora alchemillae* (Pers.) Fuckel
Tranzschelia punctata Arthur	*Tranzschelia pruni-spinosae* (Pers.) Dietel
Tunicopsora bagchii Suj. Singh & P.C. Pandey	*Kweilingia bagchii* (Suj. Singh & P.C. Pandey) Buriticá
Uredo artocarpi Berk. & Broome	*Physopella artocarpi* (Berk. & Broome) Arthur
Uredo bombacis Petch	*Calidion bombacis* (Petch) D.J. Soares & R.W. Barreto
Uredo callicarpae Petch	*Uromyces callicarpae* (Petch) Fujik. ex S. Ito
Uredo colebrookeae Barclay	*Olivea colebrookeae* (Barclay) Thirum. & Yadav
Uredo fici Castagne	*Cerotelium fici* (Castagne) Arthur
Uredo gaultheriae (Syd. & P. Syd.) Hirats. f.	*Pucciniastrum gaultheriae* Syd. & P. Syd.
Uredo ipomoeae Yadav	*Coleosporium ipomoeae* (Schwein.) Burrill
Uredo plumeriiae Pravenna, Nasheema & Balakrishna	*Coleosporium plumeriae* Pat.
Uredo tephrosiicola Henn.	*Ravenelia tephrosiicola* (Henn.) Hirats. f.
Uredo ziziphi Pat.	*Macabuna ziziphi* (Pat.) Buriticá & J.F. Hennen
Uredopeltis boswelliae (Patel, Payak & N.B. Kulk.) Sathe	*Dasturella boswelliae* Patel, Payak & N.B. Kulk.
Uredopeltis boswelliae (Patel, Payak & N.B. Kulk.) Sathe	*Dasturella boswelliae* Patel, Payak & N.B. Kulk.
Uromyces fabae (Pers.) de Bary	*Uromyces viciae-fabae* (Pers.) J. Schröt.
Uromyces leptodermus Syd. & P. Syd.	*Uromyces setariae-italicae* Yoshino
Uromyces linearis Berk. & Broome	*Puccinia peradeniyae* Demers & Castl.
Uromyces lycoctoni (Kalchbr.) Trotter	*Uromyces dactylidis* G.H. Otth
Uromyces phaseoli G. Winter	*Uromyces appendiculatus* (Pers.) Link
Uromyces pisi (DC.) G.H. Otth	*Uromyces pisi-sativi* (Pers.) Liro
Uromyces scillarum (Grev.) G. Winter	*Uromyces muscari* (Duby) Niessl
Uromyces scirpi Burrill	*Uromyces lineolatus* (Desm.) J. Schröt.
Uromyces sojae (Henn.) Syd. & P. Syd.	*Phakopsora pachyrhizi* Syd. & P. Syd.
Xenostele indica Thirum.	*Xenostele litseae* (Pat.) Syd. & P. Syd.

Discussion

This study provides an outline for rust fungi of India based on the literature. It provides complete information of Indian *Pucciniales* in one compilation as 69 genera and 640 species belonging to 16 families. Rust fungi are one of the extensively studied fungal groups of India, as evident from the number of researchers who have investigated these fungi since pre-independance. The outline presented in this study helps to better understand the taxonomy of Indian rust fungi. In addition to broadly studied fungal group of India, rust fungi possessed a broad host range and distribution too. As per earlier reports, rust fungi cause diseases on various plant hosts (Misra et al. 1975, Bisht & Srivastava 1990, Cummins & Hiratsuka 2003, Jiao et al. 2016). High relative humidity and dense forest cover might be the possible reasons to promote these rust fungi in these regions to cause diseases. The occurrence of 167 species of rust fungi belonging to 23 genera and 11 families on 170 plant species belonging to 52 families from Himachal Pradesh justified their diversity in this hilly state. Similarly, the broader host range from *Poaceae* with highest number of records followed by *Ranunculaceae, Rosaceae, Asteraceae, Polygonaceae, Fabaceae, Salicaceae, Acanthaceae, Lamicaeae, Pinnaceae, Apiaceae, Rubiaceae, Saxifragaceae, Cyperaceae, Euphorbiaceae, Berberidiaceae, Geraniaceae, Linaceae* and *Zinziberaceae* support a wide distribution of these fungi (Gautam & Avasthi 2019). The occurence of 12 rust genera with 35 species belonging to 7 families on large number of herbaceous, shrubby plants including climbers, grass and trees also support the diversity and distribution of rust fungi in Himalayan regions (Singh & Palni 2011). However, these fungi are not only limited to hilly regions of India; Mohanan (2010) documented a total of 95 rust fungi belonging to 25 genera associated with 117 forest plant species belonging to 80 host genera under 43 host families from the Western Ghats regions of Kerala. Similarly, the checklist of the rust genus *Uromyces* was documented by Gautam & Avasthi (2017b), also support broad diversity of these fungi on wide-ranging host range.

Besides the diversity and distribution, rust fungi cause very devastating diseases on various agricultural crops in India. Wheat rusts caused by three species of *Puccinia* namely, stripe rust (by *P. striiformis* f. sp. tritici Westend.), stem rust (by *P. graminis* Pers. f. sp. tritici Eriks. & Henn.) and leaf rust (caused by *P. triticina* Eriks.) pose a threat to global wheat production. The detection of Ug99 led the global community to work together to combat this disease, re-emerged as a threat and the establishment of the Borlaug Global Rust Initiative (BGRI, earlier Global Rust Initiative) in September 9, 2005. Pathotyping of rust pathogens and their identification are some important steps being deployed by researchers to find out management strategies of rust diseases. Emphasis is laid on evaluation of germplasm for rust resistance and development of various rust resistance varieties through various breeding programmes. In comparison to other crops, wheat has achieved a record high production in India during the current century. The development of rust resistance varieties has also progressed which played a vital role in protecting wheat from any epidemic threat (Tomar et al. 2014). The ICAR scientists cracked the whole genome of *Puccinia triticina* which is now proving very helpful in understanding the nature of this wheat rust pathogen (Kiran et al. 2016). Similarly, about 22 varieties of wheat which are are resistant to the deadly Ug99 fungal disease caused by *Puccinia graminis- tritici* are developed, of which, some of the varieties such as DBW 17, PBW 550, and Lok 1 are being cultivated in wheat-growing states in India (Bhardwaj et al. 2019).

Both morphological and molecular characterization of rust fungi is required to understand the natural classification and evolutionary relationship of rust fungi. Because with the difficulty of culturing of these fungi artificially, the success rate of culturing is also not so encouraging. The direct sequencing of rust fungi is also not so easy because of the isolation of DNA of other microbes associated with main rust pathogens. This may affects the quality and purity of DNA and ultimately the sequencing process and final identification. Due to all the above reasons, the information on molecular identification of Indian rust fungi is not adequate. Although a phylogeny of Indian rust fungi based on the sequence data of LSU and ITS available for corresponding rust fungi in GenBank (NCBI) is presented, the lack of molecular data for most of the rust fungi included requires the application of molecular techniques. Our phylogenetic studies based on LSU and ITS sequence data showed that few taxa of family *Pucciniaceae* include polyphetic taxa i.e. from *Puccinia* and

Uromyces. More studies are still required for the better understanding of their taxonomic placement at different levels. Hence, fresh collections are required to generate molecular data to understand their phylogenetic relationships. This study has set the foundation for the systematics and taxonomic studies of rust fungi in India at generic and species level.

Although 69 genera of Indian rust fungi were included in this study, very few of these are known to have DNA sequence data. Molecular studies of these fungi are still scanty and there is much scope for exploratory work on this fungal group. Due to the lack of molecular studies, many genera or species need to be recollected and epitypifed, in order to place them in their correct taxonomic position. Some Indian rust fungi require much attention as there is confusion in their correct taxonomic placement. Therefore, future works are likely to focus on reassessing the samples of rust fungi reported from India on both morphological and molecular characterization. Emphasis should also be given on understanding the relationship between rust pathogens and host preference to elaborate this fungal group more precisely. In addition, a digital web based platform should be developed which help the researchers to identify Indian *Pucciniales* and to provide all information on their diversity, distribution and host association.

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