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 *Colesporiaceae*, *Crossosporaceae*, *Gymnosporangiaceae*, *Melampsoraceae*, *Milesinaceae*, *Ochropsoraceae*, *Phakopsoraceae*, *Phragmidiaceae*, *Pileolariaeae*, *Pucciniaceae*, *Puccinistraceae*, *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
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, telemorphs 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. Pucciniales 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 Puccinales. 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 Telios-cl races 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 (1) 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, Thirumalchar & Cummins 1948, Thirumalchar & Mundkur 1949) played an important role in the taxonomic placement of rust fungi (Alexopoulos 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 Uredininae, Melampsorinae and Mikronergeriinae. The Uredininae includes species which produce the aecial stage on angiospermous host with pedicellate teliospores. Similarly, Melampsorinae comprises heteroecious, mostly macrocyclic rust species producing aecial stage on gymnosperms and producing sessile teliospores. Mikronergeriinae 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 Basidiomyces, 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, Mikronergeriaceae, Phakoposoraceae, Phragmidiaceae, Pileolariaeae, Pucciniaceae, Raveneliaceae and Sphaerophragmiaceae in order Pucciniales, class Pucciniomycetes and subphylum Puccinomyccotina 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 Puccinomyccotina 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. Thirumalacher laid down a pioneer contribution in the studies of rust and smut fungi as Ustilaginales of India (Mundkar & Thirumalacher 1952). Foundation of the Indian Phytopathological Society was also laid down by B. B. Mundkur along with S.R. Bose, both served 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 Thirumalacher in 1952 jointly published a consolidated list of Indian Ustilaginales. Similarly, Thirumalacher & 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. Narasimhan, 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” (Mohan 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 pragmatic 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 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 transformation environment: (http://sing.euvgio.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:

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<td>KX999000</td>
</tr>
<tr>
<td><em>Uromyces polygoni-avicularis</em></td>
<td>DAOM 181565</td>
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<td>KY764197</td>
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<td>BPI863744</td>
<td>KY575068</td>
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<td>KY575069</td>
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<tr>
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<td>HQ412651</td>
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<td>--</td>
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<td>--</td>
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<td>BRIP 60012</td>
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<tr>
<td><em>Uromyces trifolii</em></td>
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<tr>
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<td>AF426199</td>
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<td><em>Uromyces vignae</em></td>
<td>H92019</td>
<td>AB115731</td>
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<td>BRIP 60213</td>
<td>--</td>
<td>KX999906</td>
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<td><em>Taphrina pruni</em></td>
<td>CBS 358.35</td>
<td>MH855700</td>
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</table>

### Genus-wise literature of Indian rust fungi


Skierka: Chavan 1968, Gautam & Avasthi 2017c.

Sphaerophragmium: Cooke 1880a.

Stakmania: Sathe 1966c.


Uredopeltis: Ramachar et al. 1978, Sathe 1965e.


Xenostele: Ramakrishnan 1951a.

Zaghouania: Butler & Bisby 1931.

Pucciniales genera incertae sedis


Phragmotelium: Thirumalachar 1942b, Thirumalachar et al. 1943.

Tunicopsora: Suji. Singh & P.C.

**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), *Pucciniastriaceae* (19), *Melampsoraceae* (18), *Crossopsoraceae* (14), *Zaghouaniaceae* (13), *Gymnosporangiaceae* (7), *Milesinaeaceae* (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


*Pucciniales* Clem. & Shear


*Coleosporium* Lév. (19)

- *Coleosporium asterum* (Dietel) Syd. & P. Syd.
- *Coleosporium barclayense* Bagchee
- *Coleosporium bletiae* Dietel
- *Coleosporium campanulae* (Pers.) Tul.
- *Coleosporium clematidis* Barclay
- *Coleosporium datisciae* Tranzschel
- *Coleosporium inulae* Rabenh.
- *Coleosporium ipomoeae* (Schwein.) Burrill
- *Coleosporium himalayense* Durrieu
- *Coleosporium leptoderidis* (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 vittis 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 ampelopsisdis (Dietel & P. Syd.) Jing X. Ji & Kakish.
Neophysopella meliosmae (Kusano) Jing X. Ji & Kakish.
Neophysopella meliosmae-nyrianthae (Henn. & Shirai) Jing X. Ji & Kakish.

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

*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 dannosa* (Sacc.) Lind.

*Melampsora epitea* Thüm.

*Melampsora eucalypti* Rabenh.

*Melampsora euphorbiae* (Ficinus & C. Schub.) Castagne

*Melampsora euphorbiae-geniculatae* F. Kern & Thurist.

*Melampsora geniculatae* Ramachar & Bhagyan.

*Melampsora hypericorum* (DC.) J. Schröt.

*Melampsora lini* (Ehrenb.) Lév.

*Melampsora mundkuri* Thirum.

*Melampsora oblonga* Bagchee

*Melampsora populnea* (Pers.) P. Karst.

*Melampsora salicis-albae* Kleb.

*Melampsora salicis-wallichianae* Ulbr.

*Melampsora sancti-johannis* Barclay

*Melampsora stereoespermi* 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


*Ochropsora* Dietel (1)

*Ochropsora ariae* (Fuckel) Ramsb.

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 kирganeliae T.S. Ramakr. & K. Ramakr.
Phakopsora mangalarica T.S. Ramakr. & Sundaram
Phakopsora meibomiae (Arthur) Arthur
Phakopsora pachyrhizi Syd. & P. Syd.
Phakopsora odenae 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 kamschatae* (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


**Pileolaria** Castagne (2)

*Pileolaria indica* Syd.
*Pileolaria pistaciae* F.L. Tai & C.T. Wei


**Hyalopsora** Magnus (2)

*Hyalopsora orientalis* Chona & Munjal
*Hyalopsora polypodii* (Pers.) Magnus
**Melampsoridium** Kleb. (4)
- *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.


**Caéoma** Link (4)
- *Caéoma himalayense* Suj. Singh, S.N. Khan & B.M. Misra
- *Caéoma scopariae* K.N. Rao
- *Caéoma euphorbiae-geniculatae* Ramachar & Bhagyan.
- *Caéoma indicum* Rajendren

**Chrysocelis** Lagerh. & Dietel (1)
- *Chrysocelis butleri* (Dietel, Syd. & P. Syd.) G.F. Laundon

**Corbulopsora** Cummins (1)
- *Corbulopsora cumminsi*ii 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 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 mysorensis* 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 amphphilophidis Doidge
Puccinia angelicae (Schumach.) Fuckel
Puccinia anodae P. Syd. & Syd.
Puccinia antirrhini Dietel & Holw.
Puccinia api P. Syd. & P. Syd.
Puccinia arachidis Spec.
Puccinia arenariae (Schumach.) J. Schütz.
Puccinia argentata (Schultz) G. Winter
Puccinia aristidae Tracy
Puccinia aridicola Henn.
Puccinia arthraxonis-ciliaris Cummins
Puccinia arundinellae Barclay
Puccinia asterum (Schwein.) F. Kern
Puccinia atropuncta Peck & Clinton
Puccinia azanzia 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 calcitrata var. filicinae Barclay
Puccinia calcitrata 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 chrysanthehi 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 collettiata Barclay
Puccinia conclusa Thüm.
Puccinia congesta Berk. & Broome
Puccinia coronata Corda
Puccinia courtoisiana (Syd. & P. Syd.) Syd.
Puccinia crepidis-japonicae (Lindr.) Dietel
Puccinia crepidis-sibiricae Lindr.
Puccinia cressae Lagerh.
Puccinia ctenolepidis Ramachar & Bagyan.
Puccinia curculiginis Racib.
Puccinia curcuminæ 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 dessertorum Syd. & P. Syd.
Puccinia digitariae Ramachar & George
Puccinia digitariae-biformis P.B. Chavan & Hosag.
Puccinia digitariae-vestitae Ramachar & Cummins
Puccinia dioicae Magnus
Puccinia dioiscorae Kom.
Puccinia dovrensis A. Blytt
Puccinia drabeæ 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 chryspogononi 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 eulaliae Barclay
Puccinia eutela Syd.
Puccinia exhauiriens 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 fimbristyliidis Arthur
Puccinia fimbristyliidis-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 (Röhrl.) 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 inayattii 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 kraussii (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 launaea 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 luculentà (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 mysoensis Syd.
Puccinia melothricola 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 peradeniæ 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 pgonatheri Petch
Puccinia pollinae Barclay
Puccinia pollinae-quadrinervis Dietel
Puccinia polygoni-amphibii Pers.
Puccinia polygoni-veyrichii Miyabe
Puccinia polysora Underw.
Puccinia pori (Sowerby) G. Winter
Puccinia praecox Bubák
Puccinia praınıana Barclay
Puccinia prenanthis-purpureae (DC.) Lindr.
Puccinia princeps Syd. & P. Syd.
Puccinia propinqua Syd., P. Syd. & E.J. Butler
Puccinia prossii 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 rotboelliae P. Syd. & Syd.
Puccinia ruelliae Lagerh.
Puccinia rufipes Dietel
Puccinia sacchari Patel, Kamat & Y.A. Padhye
Puccinia sonchi Roberge ex Desm.
Puccinia sataresis P.B. Chavan & Bakare
Puccinia saüssureae 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 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 Finicus & C. Schub.
Puccinia thomasiana T.S. Ramakr. & K. Ramakr.
Puccinia thunbergiae Cooke
Puccinia thwaitesii Berk.
Puccinia tiliae-folia T.S. Ramakr. & Sundaram
Puccinia tragae Cooke
Puccinia tricholepidis Syd.
Puccinia trollii P. Karst.
Puccinia turgida P. Syd. & Syd.
Puccinia tweediana T.S. Ramakr. & K. Ramakr.
Puccinia unica var. dicha Cummins & S.M. Husain
Puccinia urticae Barclay
Puccinia ustalis Berk.
Puccinia verrucula 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 achrour Syd. & P. Syd.
Uromyces acontiiFuckel
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 elignyi Pat. & Har.
Uromyces clivialis 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 hobsontii 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 proeminenis (DC.) Lév.
Uromyces pseudarthriae Cooke
Uromyces ramacharii Ravinder & Bagyan.
Uromyces rotiboelliae 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 spagazzinii (De Toni) Arthur
Uromyces sphaeropleus Cooke
Uromyces sporgoni Clint & Peck. subsp. asiaticus
Uromyces striatus J. Schröt.
Uromyces strobilanthus Barclay
Uromyces superfluos P. Syd. & Syd.
Uromyces tenuicuts 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 valerianaes (Schumach.) Fuckel
Uromyces valerianaes-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.

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-patensis (Mundk. & Thirum.) Rajendren
Kernkampella.coinbatorica (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* (Niesl 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)

**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-pennatulae* Dietel
- *Ravenelia acaciae-pennatulae* Dietel
- *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.) Bagan. & Ravinder
Prospodium tirumalense Bagan., Ravinder & P. Ramesh

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

Sphaerophragmium Magnus (1)
Sphaerophragmium acaciae (Cooke) Magnus

Leucotelium Tranzschel (1)
Leucotelium pruni-persicae (Hori) Tranzschel
Tranzschelia Arthur (2)
Tranzschelia discolor (Fuckel) Tranzschel & M.A. Litv.
Tranzschelia pruni-spinosa (Pers.) Dietel

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. & Gopalkrishn.
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 dicrocephalae 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 inquisitense P. Henn.
Aecidium kamatii Sathe
Aecidium latifolium Massee
Aecidium leeae M.A. Salam & Ramachar
Aecidium lepidagathis Syd. & P. Syd.
Aecidium leucadimum Mitter
Aecidium lophanthi Henn.
Aecidium lophopetalii 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 microrhynchii 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 pavonieae-odoratae T.S. Ramakr., Sriniv. & Sundaram
Aecidium peristrophe 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 pulaiae 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 rhytismaeum Berk. & Broome
Aecidium salamii G.F. Laundon
Aecidium satarensae P.B. Chavan & S.K. Patil
Aecidium saussureae Johanson
Aecidium scutarensae 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 strobilanthis Barclay
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 uurgineae Henn. & Pole-Evans
Aecidium vanguardiae 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 mysorensense (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 chasalae** 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 ophiuri** Petch

**Uredo ophiuri** Syd., P. Syd. & E.J. Butler
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 Ravenelicia, Kernkampella clustered in a Raveneliaceae clade and Maravalia formed a distinct lineage. The Nyssopora belonging to Uredininae 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 with the use of all modern molecular methodologies, 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 Puccinales 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.

Synonym – 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).


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).


Equivalent to Urediniomycecidae (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.


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 Araucariomycetinae, Melampsorinae, Mikronegeriinae, Ravenelinae, Rogerpetsoniinae, Skierkineae, and Uredininae. There are now 18 families Araucariomycetaceae, Coleosporiaceae, Crossosporaceae, Gymnosporangiaceae, Melampsoraceae, Milesinaceae, Ochropsoraceae, Phakopsoraceae, Phragmidiaceae, Pileolariaceae, Pucciniaceae, Pucciniastraceae, Raveneliaceae, Rogerpetsoniaceae, 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, urediniospores, 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.


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 – Asteraeae, 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

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.


The family Gymnosporangiaceae consists of Group V (type 4) Spermogonia, bound 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. Uredinospores borne singly on 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).


Figs 2, 7, 9


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.

![Image of rust fungi](image)

**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


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 *Melampsorinae*. The important characters of this family include production of Group 1 (mostly type 1, also type 2 and 3) Spermogonia and colourless sori. Although urediniospores of *Naohidemyces* are orange in colour. The presence of peridermium-typeaecia (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*. 

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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 studies on Milesina and Uredinopsis are also required to demonstrate their correct taxonomic position.

The family Ochropsoraceae contains Group VI (type 7) spermogonia. Aecia are of acecidium-type, these states systemic in nature and overwintering as mycelium. Uredinia are of maluca-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.

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 acecidium-type) with aeciospores either verrucose or echinulate, borne singly or in chains. Uredinia lecithya 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. Ramkr. & K. Ramkr. still requires molecular studies, 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
*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 echinulate 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 echinulate urediospores 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.


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 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


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.


Notes – The genus *Caemora*, 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


**Raveneliaceae** consists Group VI (type 5, 7) spermogonia. The genera of this family produce typically uredo- (rarely acecidium-, caemora-, 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.


Host families – *Fabaceae*, *Oleaceae*, *Phyllanthaceae*, *Poaceae*, *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 characters. 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** 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 differentiated these from all other rust fungi. Urediniospores and teliospores are single-celled produced on sporogenous cells through a narrow sorus opening. Before emergence, 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 autecious 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.


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

Spermogonia are mostly lacking and unknown, Group V (type 4) in *Spheroorchidium*, if present. Aecia are aecidium-type and uredinia resembling aecia (leythea-type in *Spheroorchidium*). 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 autecious 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 morphological characters, and DNA based molecular studies are necessary.

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


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.


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

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produced without peridium (most often uredo-type) or weakly developed peridium in some cases and produce echinulate, singly borne urediniospores. 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 himalachensis 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. agrostidis* 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)

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<td><em>Uredo bombacis</em> Petch</td>
<td><em>Calidion bombacis</em> (Petch) D.J. Soares &amp; R.W. Barreto</td>
</tr>
<tr>
<td><em>Uredo callicarpae</em> Petch</td>
<td><em>Uromyces callicarpae</em> (Petch) Fujik. ex S. Ito</td>
</tr>
<tr>
<td><em>Uredo colebrookeae</em> Barclay</td>
<td><em>Olivea colebrookeae</em> (Barclay) Thirum. &amp; Yadav</td>
</tr>
<tr>
<td><em>Uredo fici</em> Castagne</td>
<td><em>Cerotelium fici</em> (Castagne) Arthur</td>
</tr>
<tr>
<td><em>Uredo gaultheriae</em> (Syd. &amp; P. Syd.) Hirats. f.</td>
<td><em>Pucciniastrum gaultheriae</em> Syd. &amp; P. Syd.</td>
</tr>
<tr>
<td><em>Uredo ipomoeae</em> Yadav</td>
<td><em>Colesporium ipomoeae</em> (Schwein.) Burrill</td>
</tr>
<tr>
<td><em>Uredo plumieriæ</em> Pravenna, Nasheema &amp; Balakrishna</td>
<td><em>Colesporium plumieriæ</em> Pat.</td>
</tr>
<tr>
<td><em>Uredo tephrosiicola</em> Henn.</td>
<td><em>Ravenelia tephrosiicola</em> (Henn.) Hirats. f.</td>
</tr>
<tr>
<td><em>Uredo ziziphi</em> Pat.</td>
<td><em>Macabuna ziziphi</em> (Pat.) Buriticá &amp; J.F. Hennén</td>
</tr>
<tr>
<td><em>Uromyces leptodermus</em> Syd. &amp; P. Syd.</td>
<td><em>Uromyces setariae-italicæ</em> Yoshino</td>
</tr>
<tr>
<td><em>Uromyces linearis</em> Berk. &amp; Broome</td>
<td><em>Puccinia peradenii</em> Demers &amp; Castl.</td>
</tr>
<tr>
<td><em>Uromyces lycocotni</em> (Kalchbr.) Trotter</td>
<td><em>Uromyces dactylidis</em> G.H. Otth</td>
</tr>
<tr>
<td><em>Uromyces phaseoli</em> G. Winter</td>
<td><em>Uromyces appendiculatus</em> (Pers.) Link</td>
</tr>
<tr>
<td><em>Uromyces pisi</em> (DC.) G.H. Orth</td>
<td><em>Uromyces pisi-sativi</em> (Pers.) Liro</td>
</tr>
<tr>
<td><em>Uromyces scillarum</em> (Grev.) G. Winter</td>
<td><em>Uromyces muscarï</em> (Duby) Niessl</td>
</tr>
<tr>
<td><em>Uromyces scripi</em> Burrill</td>
<td><em>Uromyces lineolatus</em> (Desm.) J. Schrödt.</td>
</tr>
</tbody>
</table>
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-independence. 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*, *Lamiaeae*, *Pinnaceae*, *Apiaceae*, *Rubiaceae*, *Saxifragaceae*, *Cyperaceae*, *Euphorbiaceae*, *Berberidiaceae*, *Geraniaceae*, *Linaceae* and *Zinziberaceae* support a wide distribution of these fungi (Gautam & Avasthi 2019). The occurrence 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. & Hoffm.) 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 *Pucciniales* 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 epitypified, 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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