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Current status of research on Rust fungi (*Pucciniales*) in India

Gautam AK[1], Avasthi S[2], Verma RK[3], Devadatha B [4], Sushma[5], Ranadive KR [6], Bhadauria R[2], Prasher IB[7] and Kashyap PL[8]

[1]School of Agriculture, Abhilashi University, Mandi, Himachal Pradesh, India
[2]School of Studies in Botany, Jiwaji University, Gwalior, Madhya Pradesh, India
[3]Department of Plant Pathology, Punjab Agricultural University, Ludhiana, Punjab, India
[4]Fungal Biotechnology Lab, Department of Biotechnology, School of Life Sciences, Pondicherry University, Kalapet, Pondicherry, India
[5]Department of Biosciences, Chandigarh University Gharuan, Punjab, India
[6]Department of Botany, P.D.E.A.'s Annasaheb Magar Mahavidyalaya, Mahadevnagar, Hadapsar, Pune, Maharashtra, India
[7]Department of Botany, Mycology and Plant Pathology Laboratory, Panjab University Chandigarh, India
[8]ICAR-Indian Institute of Wheat and Barley Research (IIWBR), Karnal, Haryana, India

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Abstract

Rust fungi show unique systematic characteristics among all fungal groups. A single species of rust fungi may produce up to five morphologically and cytologically distinct spore-producing structures thereby attracting the interest of mycologist for centuries. In India, the research on rust fungi started with the arrival of foreign visiting scientists or emigrant experts, mainly from Britain who collected fungi and sent specimens to European laboratories for identification. Later on, a number of mycologists from India and abroad studied Indian rust fungi and contributed a lot to knowledge of the rusts to the Indian Mycobiota. The establishment of Imperial Agricultural Research Institute (IARI) at Pusa (Bihar) in 1905 was the key achievement of pre-independent India which laid the foundation for many useful research on Indian rust fungi and in producing many renowned mycologists. This study presents the history of the study of rust fungi in India with complete information from various journals, books, websites and institutions involved. Detailed information of decadal publication records of rust fungi in India published in various journals have been included. Apart from the addition of a complete list of literature on Indian rust fungi, the future scope of research on rust fungi in India along with problems and challenges are also discussed. In a nutshell, this compendium will be quite useful for mycologists, especially beginners to find all available information on Indian rust fungi in one document.

Key words – fungi – history – Indian Mycology – mycological institutes – mycological websites and journals

Introduction

Fungi are valuable organisms which play an important ecological and economic role in decomposing, nutrients recycling and symbiotic association with higher plants. Endophytic as well as mycorrhizal fungi that help in growth and development inhabit almost every plant found on earth. Apart from beneficial aspects, fungi are among the major pathogens that cause many diseases

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Corresponding Author: Ajay K. Gautam – e-mail – a2gautam2006@gmail.com

in plants. The pathogenic fungi adopt a variety of strategies to colonize plants tissues and cause diseases. These plant pathogenic fungi later lead to enormous economic losses in agriculture, horticulture and forestry all over the world. Many fungi are well-known plant-pathogens as they cause very destructive diseases on host plants (Agrios 2005, Doehlemann et al. 2017). Rust fungi are among the dominant causal agents of plant diseases. These fungi are considered as successful plant pathogens that attract interest among researchers who studying these organisms. The rust fungi cause massive destruction on host plants especially in agricultural and horticultural crops, resulting in huge losses in terms of quality and quantity of produce. In addition, these fungi exhibit a wider diversity and broader host range and their infection are not only limited to agricultural crops but also to non-agricultural plants including medicinal herbs, shrubs, trees, and even weeds. Hence, these fungi can be considered as a limiting factor for the successful cultivation, plantation and growth of agricultural crops and forestry plants. Besides, rust fungi are one of the most speciose and the most complex group of plant pathogens. It can be confirmed that majority of these plant pathogenic rust fungi belongs to a single order *Pucciniales* (formerly *Uredinales*) of subdivision *Pucciniomycotina* (Aime 2006, Aime & McTaggart 2020, Gutam et al. 2021).

The rust fungi are obligate plant parasites which share relatively similar life cycles, morphology, and biology. Generally, the majority of rust fungi require two unrelated, specific plant hosts to complete their life cycle i.e. heteroecious type. The fungi comprise a broader host range extending from lower plants like ferns to higher plants including angiosperms and gymnosperms. These fungi appear commonly as yellow-orange or brown powdery mass on healthy and vigorously growing plant parts such as leaves, petioles, tender shoots, stem and fruits. These fungi possess several unique systematic characteristics (Duplessis et al. 2011). A single species of rust fungi may produce distinct spore-producing structures (up to five) during their life cycle. The diverse structures *viz*., Spermogonia, aecia, uredinia, telia, and basidia produced in successive stages of reproduction during the infection process and it may vary from species to species (Cummins & Hiratsuka 2003, Duplessis et al. 2011).

Along with distinctive appearances, rust fungi adopt specific agro-climatic conditions to initiate infraction of hosts. Although, rust fungi can grow well in almost all types of environmental conditions, the average temperature of 35°C and relative humidity of 50-60% is considered as ideal for initiation and development of infection by these fungi. As the infection advances, rust infected plants show chlorosis (tissue yellowing) or discolouration with stunted growth. However, the main disease symptoms include coloured (orange, yellow, brown, black or white) pustules, witches brooms, stem canker, hypertrophy of the affected tissues or formation of galls. A high degree of host specificity is another notable feature which becomes very useful in the identification process (Savile 1971, Cummins & Hiratsuka 2003, Duplessis et al. 2011).

The infection by rust fungi may often reduce the vigour of the plant. However, the infected plant may be killed in extreme cases (Peterson 1974, Cummins & Hiratsuka 2003, Mohanan 2010). Some of the rust fungi are among the most destructive and devastating pathogens of agricultural crops causing severe diseases such as stem rust, yellow (stripe) rust in wheat, Asian soybean rust, coffee rust and many more with huge annual crop losses every year (Cummins & Hiratsuka 2003, Leonard & Szabo 2005, Dean et al. 2012). Due to these facts, the study of these fungi became equally important as on other phytopathogenic fungi and continuously receives a lot of attention from mycologists and plant pathologists all over the globe.

The diversity of rust fungi is vast in India because of the availability of favourable agro-climatic conditions required during infection initiation and disease development. Like other countries of the world, the rust fungi cause many devastating diseases on a variety of agricultural and non-agricultural crops in India. Epidemiology of wheat rusts (black stem rust & yellow stripe rusts) is one of the major threats in India which causes a major loss to crop yield (Joshi et al. 1985, Tomar et al. 2014, Bhardwaj et al. 2019). Similarly, soybean rust has now become a serious and economically important disease of the country which results in 20- 100% yield losses (Sharma & Gupta 2006, Devaraj et al. 2016). Coffee leaf rust is another important disease, along with other major rust diseases, being investigated by Indian mycologists and pathologists (McCook 2006,

Narayana 2012, 2013). However, the mycologists of India have not only limited their study on the rust of agricultural and horticultural crops, but they have also investigated weeds and forest trees. The research on rust fungi is gaining momentum with the involvement of a number of researchers. Modern scientists are now engaged in genotyping and pathotyping of rust fungi. Therefore, it becomes very necessary to compile the status of all information pertaining to research on rust fungi in India.

This study is an initiative taken in order to present the status of research on rust fungi from the beginning. We have compiled this study in detail in different sections as follows:

1) In first section, we provided comprehensive information on the history of research on rust fungi in India. Method of compilation and layout of the paper is also provided in this section along with information of various journals, books, websites and institutions involved.
2) Second section covers the main output of this compilation in a table with a general overview of rust fungi in India. Detailed information of publication records since the beginning have been provided here in order to understand the yearly trend of publications.
3) This section contains a list of selected literature on Indian rust fungi.
4) Brief information on the future scope of research on rust fungi in India along with problems and challenges is provided in last section.

Attempts have been made to include all available information on rust fungi, still this information cannot be considered as fully updated. This updating is a regular process. New additions and any literature not included in this paper will surely be presented in the future compilations.

History of rust fungi in India: past to present

India is a biodiversity rich country that occupies most of the South Asian continent with a total area of about 3,287,263 square kilometers. It is situated north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude. The diverse climatic conditions of the country range from temperate and alpine in the northern Himalaya, to tropical in the south, supporting rich flora and fauna. There are four seasons determined by monsoons as dry, cool winter season (December through March); hot spring season (April and May); the rainy summer season (June through September); less-rainy autumn season (October and November). Rainfall for the entire country has an average of 105 cm (41 inches) while; temperature reaches an average high of 38° to 40°C and an average low of 10°C. The diversified forest cover (about 23.68%) of India leads to very high biological diversity (Singh & Kushwaha 2008). This variability in climatic conditions and biological diversity plays a vital role in the growth and development of various plant pathogenic fungi including rust fungi.

The beginning of research on fungi in India began with the arrival of foreign visiting scientists or emigrant experts, mainly from Britain, who collected fungi and sent specimens to European laboratories for identification. Barclay (1890a, b, d) contributed a lot to the knowledge of the rusts occurring in the vicinity of Shimla during the exploration of Himalayan fungi. Sir Edwin John Butler (1874–1943), in a real sense, contributed a lot to initiate and organize large–scale mycological and phytopathological research in India. It was as the result of his great efforts that the Imperial Agricultural Research Institute established at Pusa (Bihar) in 1905 where he became the Imperial Mycologist in India. He also laid down the foundation of the Herbarium Cryptogamae Indiae Orientalis (HCIO), a national fungal herbarium facility Pusa, Bihar in 1905, later shifted to the Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi. Because of his contributions in the field of mycology, Butler is aptly referred to as the Father of Indian Mycology (Raychaudhuri et al. 1972).

However, the mycological contribution of the pre-Butler period cannot be ignored. This contribution chiefly comes from overseas mycologists. The name of Mordecai Cubitt Cooke (1825–1914) who was an English botanist and mycologist is known in Indian mycological history.

He carried out his research on Indian fungi including rust fungi (The genus *Ravenelia*). He particularly stressed on the Himalayan fungi during his studies. Similarly, studies of David Douglas Cunningham (1843-1914) who contributed to Order *Uredinales* along with *Mucorales* and *Ustilaginales* and Arthur Barclay (1852–1891) made noteworthy contributions to our knowledge of the *Uredinales*. They laid down the foundation on which discipline of mycology developed in India. Many more mycologists got involved in post-Butler period with time. Most of the Indian mycologists followed the research laid down by E.J. Butler after his departure from India. The rust fungi along with smuts received special attention from Balchandra Bhavanishankar Mundkur (1896-1952) and Mandayam Jeersannidhi Thirumalachar (1914-1999). The studies on rust and smut fungi as Ustilaginales of India (Mundkar & Thirumalachar 1952) go to their credit. The foundation of the Indian Phytopathological Society was laid down by B. B. Mundkur and S. R. Bose who was appointed as its first president. Likewise, Thirumalachar (1914–1999) investigated the life cycle of cereal rusts in India and conducted exhaustive studies on rust and smut of India, and developed several methods for controlling plant diseases in India. In his research, he also reported a new rust disease of *Cardamom* (Thirumalachar 1943a) and two new species of rusts namely *Masseeëlla breyniae* and *Masseeëlla narasimhanii* for Indian mycobiota (Thirumalachar 1943b, c).

Dr. Karam Chand Mehta of the 20th century investigated the possible causes of recurrence of rust in the plains of India. He also added to the knowledge of linseed and wheat rust epidemiology. Paul Sydow (1851–1925) and his son Hans Sydow (1879–1946) contributed immensely in understanding the Himalayan fungi including rust fungi. They have covered very important rust genera with respect to systematics and taxonomy. The major rust genera they studied include *Aecidium, Caeoma, Gymnosporangium, Monosporidium, Peridermium, Phragmidium, Puccinia, Roestelia, Uredo* and *Uromyces*. Joseph Charles Arthur (1850–1942), a pioneer American plant pathologist and mycologist is well known for his work with the parasitic rust fungi of Himalayas (*Pucciniales*). Arthur named 29 genera and 309 species throughout the world including North Western Himalayas in India during his career. The relationship of *Kuehneola* was one of the major studies carried out by him (Arthur 1917). Krishna Das Bagchee (1898–1973), another Indian mycologist established a laboratory for forest diseases at Forest Research Institute, Dehra Dun. During his mycological studies, he conducted pioneering work on the biology, taxonomy and control of rust fungi on Indian conifers. While studying rusts, he discovered *Peridermium himalayensis* Bachee on *Pinus latifolia*, *Cronatium ribicola* Fischer and *Peridermium indicum* Colley & Tayler, *Peridermium brevius* (Barel.) Sacc. and *Melampsora oblonga* on *Pinus excels* wall (Bagchee 1933, Bagchee 1950a, b, c).

Another mycologist George Baker Cummins (1904–2007), a distinguished American mycologist who was considered as an authority of the rust fungi, along with some other mycologists investigated Uredinales of North Western Himalayas especially *Scopella* and *Puccinia* (Arthur & Cummins 1936, Cummins 1943, 1950, 1953). Many contributions to Indian rust fungi were made by two renowned mycologists namely, Ram Lal Munjal (1920–2008) and BL Chona, who jointly published a series of papers entitled "Notes on Miscellaneous Indian Fungi" documenting a large number of fungi from India. They also published the fungi of Delhi and rusts on ferns and sugarcane from India. Another group of mycologists including S T Ahmad, VC Sinha, KG Nema, MM Payak and DP Mishra investigated rust fungi of agricultural crops in India. "Physiologic specialization in *Puccinia coronata* Corda in India" (Payak & Mishra 1963), "The *Uredinales* of Jabalpur, Madhya Pradesh" (Nema & Mishra 1965) and "Addition to the wheat rust races in India, race 14 & 38 of *Puccinia recondita* identified during 1965" (Ahmad et al. 1969) are some of their major contributions made. The names of TS Ramakrishnan and K Ramakrishnan are remembered among Indian mycologists who have contributed a lot to Indian mycology including rust fungi. The "additions to rust fungi of Madras" and "notes on some fungi from South India" are two popular series published by them. Some other mycologists associated with them and who published their research on rust, were G Rangaswamy, KV Shrinivasan and NV Sundaram. Similar important literature on "fungi of Bombay" was published by Patel et al. (1949), parasitic fungi

collected in the vicinity of Banaras by Payak (1949) and contribution to the knowledge of *Uredineae* of Bihar" by Yadav (1953). Dr. AV Sathe is a well-known name who contributed enormously to rust fungi of India especially Maharashtra. He revised *Masseeëlla narasimhansii* Thirum. (Sathe 1965b), and also added the rust fungi of Maharashtra (Sathe 1965c), some new or revised species of *Physopella* (Sathe 1965d), some new reports of *Aecidium* from India (Sathe 1966 a, b), *Stakmania* and *Peridospora* - two new genera of Uredinales from India (Sathe 1966c, 1969b) and nomenclature of common rust fungi affecting sugarcane (Sathe 1971). Likewise, SD Patil studied rust of Mahabaleshwar (Patil 1966a) and the genus *Revenelia* Berk. in Maharashtra (Patil 1966b). Similarly, PB Chavan also contributed a lot to the rust fungi of Maharashtra. During the years 1985 to 1994, Prof. G Bagyanarayana added many new rust fungi *viz*. a new species of *Kuehneola* (Bagyanarayana & Rao 1985), *Uromyces* (Bagyanarayana et al. 1987a, Bagyanarayana and Ravinder 1994), *Puccinia hydrabadensis* (Bagyanarayana & Ravinder 1987), *Puccinia microspora* (Bagyanarayana & Ravinder 1988a), *Prospodium tirumalensis* (Bagyanarayana et al. 1999) and *Nyssopsora schefflerae* (Bagyanarayana et al. 1987b). In addition to this, spermogonial and aecial stages of *Kernkamepella kiragnelliae* were reported (Bagyanarayana & Ramachar 1985). Studies on the rusts from Hyderabad were given (Bagyanarayana & Ramachar 1986) with notes on two Indian species of *Ravenelia* provided (Bagyanarayana & Ravinder 1988b, Bagyanarayana 1989). Hosagoudar VB carried out detailed studies on mycology of Kerala and discovered *Elaeocarpus tuberculatus* (Hosagoudar 1984), *Aecidium painavuensis* (Hosagoudar 1987) as a new record to India and new species of *Uredo* and *Olivea* (Hosagoudar & Nair 1985, Hosagoudar 1989). It is not possible to discuss every mycologist who contributed significantly to the development of research on rust fungi in India. The mycological notes of rust fungi are also provided by many mycologists (Chona & Munjal 1955, Chona et al. 1956, Dube 1958, Bakshi & Singh 1960, Bahekar 1966, Chavan & Patil 1972, Chavan & Bakare 1974). Therefore, we are providing here only their names as without mentioning them this document cannot be considered complete. The contribution of great Indian mycologists namely, K.D. Bagchee, T.S. Ramakrishnan, J.H. Mitter, K.J. Narsimhan, S.N. Das Gupta, R.N. Tandon, R. Prasad, T.S. Sadasivan, C.V. Subramaniam, R. C. Sharma, Sanjeev Sharma, R.K. Sharma, S.N. Sachan and many more cannot be ignored.

While discussing the studies on rust fungi carried out after 2001, "mycology of Kerala", a monumental work of Dr. C. Mohanan cannot be neglected as he worked on the Biodiversity of Plant Pathogenic Fungi of the Western Ghats and published a book entitled "Rust Fungi of Kerala, India" (Mohanan 2010). Simultaneously, *Plumeria alba* as a new host of *Uredo plumeriae* was reported by Praveena et al. (2001), while, rust of *Dalbergia sisoo* from North-Eastern hill region of India was studied by Bag & Bhowmik (2001). Bag (2008) also reports rust on two ground orchids from India. *Uromyces muscari* as a new rust record from India was added by Agarwal (2001). Herbarium Cryptogamae Indiae Orientalis (HCIO) has a rich collection of rusts, smuts, powdery mildews and meliolales fungi and has more than 3500 "Type specimens". A comprehensive checklist of *Puccinia* species of India along with herbarium photographs and brief descriptions was compiled by Kamil et al. (2013). Later on, Ajay Kumar Gautam and associates initiated the studies on rust fungi of Himachal Pradesh, a hilly state in North-western Himalaya. During their studies, they published a plethora of articles including checklists of genus *Puccinia* (Gautam & Avasthi 2016a), a checklist of *Uromyces* (Gautam & Avasthi 2017c) and a complete checklist of rust fungi from Himachal Pradesh (Gautam & Avasthi 2019). In addition, some new species of rust fungi along with few new records were also added (Gautam &Avasthi 2016b, 2017a, b, 2018). A major scientific breakthrough of ICAR Scientists leads to the decoding of genomes of 15 strains of wheat rust fungus *Puccinia triticina*. Similarly, some of the Indian scientists carried out their research on finding out new pathotypes of different rust fungi (Nayar et al. 2004, Prashar et al. 2007, Bhardwaj et al. 2009, 2011, Aggarwal et al. 2018a, b) and in new rust-resistant genotypes (Chand et al. 2004, 2006, Rai et al. 2011), genetic variability and molecular markers (Uppalapati et al. 2013, Singh et al. 2015, Aggarwal et al. 2017, Savadi et al. 2018b, Gangwar et al. 2019a, b). To understand the

contribution of various scientists and researchers involved in research since beginning, we are providing here a complete detail of each in the literature section (Table 3).

Method of compilation and layout of the paper

The paper is based on critical analyses of data obtained from different sources such as our collections and data from literature i.e. published research papers, books, monographs, scientific reports and even from various useful websites. In this section along with complete information various journals, books, websites consisting and providing information and institutions involved.

First of all, a comprehensive list of journals on the research on Indian rust fungi that have been published or are still in process is prepared and several research papers published in them is also calculated. Here, various books and scientific reports containing information on this group of fungi also provided. This will not only help the researchers to learn about various scientific journals, books and reports but, also in choosing appropriate journals for publishing their research. In addition, information from various institutions and websites related to rust fungi is also provided.

A detailed outline of rust fungi of India has also been provided in this paper to understand the placement of all fungal genera at the level of class, order and family as well as to find out the total number of species in a genus. The outline presented in this study will help in understanding the overview of Indian rust fungi.

A complete list of literature on Indian rust fungi after the outline is provided in this compilation to save valuable time of active researchers engaged in investing rust fungi in India. This article will help in finding out the available literature in one place and also to understand the year wise trend of publications. Therefore, with the use of this list, a publication statistics of articles since the beginning has been provided. The decade wise as well as pre and post-independence publication statistics are provided to elaborate this information.

An attempt has been made to summarize present compilation with respect to the scope of research on this particular group in India. The different problems which mycologists face in conventional fungal taxonomy research including rust fungi are provided in this compilation. This will not only make aware the young researchers but awaken decision takers and policymakers also to fund the projects in this field to conserve basic mycology and mycologists for the future.

Journals, Institutions and websites

A number of institutes like Indian Type Culture Collection (ITCC) New Delhi; National Fungal Culture Collection of India (NFCCI) Pune, Maharashtra; CSIR-IMTECH Chandigarh, NBAIM Mau, Uttar Pradesh, National Collection of Industrial Microorganisms (NCIM) Pune, and many more are actively engaged in the research on fungal taxonomy and other related aspects and in providing facilities for molecular characterization of fungi including rust fungi in India. Besides these, there is only a single website “Fungi from India” that deals with compilation and regular updating of the diversity of distribution of rust fungi in India (Ranadive et al. 2017). However, some international websites namely, Index Fungorum, Mycobank, Outline of fungi, One Stop Shop and Faces of Fungi were also found useful during the compilation of this study. Going through the published literature, information of the major journals that publish manuscripts related to mycology (rust fungi mainly) and those published in English was compiled (Table 1). This information revealed that more than 106 research journals and many books and scientific reports published and provided the research information on Indian rust fungi. Of the total journals, 11 mainstream journals are devoted to publishing various aspects of fungi. The highest number of publication on rust fungi was published by Indian Phytopathology (141) followed by Current Science (52), Proceeding of Indian Academy of Sciences (42), Journal of Maharashtra Agriculture University (20), Journal of Mycology and Plant Pathology (33), Sydowia (17), Mycologia (17), Annals of Mycology (14), Journal of Indian Botanical Society (15), Science and Culture (11), Maharashtra Vigyan Mandir Patrika (10). Rest of the journals was found with the number of publications on Indian rust fungi had less than ten. In addition to research journals, some books, magazines/ bulletins/ proceedings also published information on Indian rust fungi. A book series entitled

"Fungi of India" published by a number of publishers in different years (Fungi of India 1931, 1960, 1975, 1981, 1982, 1986, 1991, 1996, 2004) played a key role in compilation and conservation of most of the literature on Indian fungi including rust fungi. Other books like Diseases of Crop Plants in India, Taxonomy and Ecology of Indian Fungi, Additions to new fungal disease in India: An update from 2001 to 2011 and many more also published important information on rust fungi. Besides books, numbers of annual publications of ICAR, conference proceedings (e.g. Indian Science Congress, abstract in Indian Phytopathology, etc.), annual reports and bulletins of various national agencies also documented useful information on these fungi. There are a number of websites also which are providing information on fungi, including rust on a digital platform (Table 1).

Table 1 List of institutes, societies and websites involved and providing information on Indian rust fungi

Name of Institute/ Societies	Websites
1. Indian Type Culture Collection (ITCC), IARI, New Delhi	1. https://www.iari.res.in
2. National Fungal Culture Collection of India (NFCCI) Pune, Maharashtra, India	2. http://nfcci.aripune.org/
3. National Collection of Industrial Microorganisms (NCIM) Pune	3. https://www.nclindia.org/files/NCIM/Default.aspx
4. CSIR-IMTECH Chandigarh	4. https://www.imtech.res.in/
5. NBAIM Mau, Uttar Pradesh	5. http://nbaim.org.in/
6. Fungi from India	6. http://www.fungifromindia.com/
7. Index Fungorum	7. http://www.indexfungorum.org/
8. MycoBank	8. www.mycobank.org
9. Outline of fungi	9. https://www.outlineoffungi.org/
10. One Stop Shop	10. https://onestopshopfungi.org/
11. Faces of Fungi	11. http://www.facesoffungi.org/
12. Indian Phytopathological Society (IPS)	12. http://www.ipsdis.org/
13. Indian Society of Mycology and Plant Pathology (ISMPP)	13. https://www.ismpp.org.in/
14. Mycological Society of India (MSI)	14. https://www.fungiindia.co.in/
15. Indian Mycological Society	15. https://www.imskolkata.org/

General overview of rust fungi in India

A general overview of Indian rust fungi with respect to phyla, class, order, families and genus is provided by following Aime & McTaggart (2020) for a higher-rank classification and He et al. (2019) and Wijayawardene et al. (2020) for a general outline. All generic names taken previously from published literature were also searched in MycoBank (www.mycobank.org)/ Species Fungorum (www.speciesfungorum.org) websites. In addition, standard literature on rust fungi were also consulted to confirm their scientific entity i.e. some generic/species names have been updated with currently accepted names (Cummins & Hiratsuka 2003, Aime 2006, Aime et al. 2018, Aime & McTaggart 2020). After complete verification, accepted taxa of rust fungi of Basidiomycota up to genus level with a number of species are mentioned in details. The results of outline compilation revealed that 69 genera and 640 species of rust fungi belonging to 16 families have been reported from India. Highest numbers of species were reported from *Puccinia* (279), followed by *Uromyces* (89), *Ravenelia* (33), *Phakospora* (25), *Coleosporium* (19), *Phragmidium* (18), *Melampsora* (17), *Maravalia* (11). While comparing the rust families, the highest number of species of rust fungi were found in *Pucciniaceae* (393) followed by *Raveneliaceae* (62), *Phakopsoraceae* (50), *Coleosporiaceae* (32), *Phragmidiaceae* (27), *Pucciniastraceae* (19), *Melampsoraceae* (18), *Zaghouaniaceae* (13), *Crossopsoraceae* (14), *Gymnosporangiaceae* (7), *Milesinaceae* (5), *Skierkaceae* (3), *Tranzscheliaceae* (3), *Pileolariaceae* (2), *Ochropsoraceae* (1), *Sphaerophragmiaceae* (1). The species rust fungi with the uncertain taxonomic position are placed

in *incertae sedis.* The detailed overview of Indian rust fungi obtained after literature review is presented in Table 2.

Table 2 Overview of phyla, class, order, family and genus of rust fungi of India

Phyllum: *Basidiomycota* **Class:** *Pucciniomycetes* **Order:** *Pucciniales*	
Family (Number of spp.)	**Genus (Number of spp.)**
Coleosporiaceae (32)	*Coleosporium* (19)
	Chrysomyxa (7)
	Cronartium (4)
	Goplana (1)
	Stakmania (1)
Crossopsoraceae (14)	*Angiopsora* (2)
	Crossopsora (3)
	Dasturella (3)
	Kweilingia (2)
	Neophysopella (2)
	Physopella (2)
Gymnosporangiaceae (7)	*Gymnosporangium* (3)
	Peridiopsora (1)
	Roestelia (3)
Melampsoraceae (18)	*Ceropsora* (1)
	Melampsora (17)
Milesinaceae (5)	*Milesina* (3)
	Uredinopsis (2)
Ochropsoraceae (1)	*Ochropsora* (1)
Phakopsoraceae (50)	*Arthuria* (2)
	Bubakia (1)
	Cerotelium (7)
	Macabuna (1)
	Masseeëlla (6)
	Monosporidium (3)
	Phakospora (25)
	Phragmidiella (3)
	Pucciniostele (1)
	Uredopeltis (1)
Phragmidiaceae (27)	*Hamaspora* (2)
	Kuehneola (6)
	Phragmidium (18)
	Trachyspora (1)
Pileolariaceae (2)	*Pileolaria* (2)
Pucciniastraceae (19)	*Hyalopsora* (2)
	Melampsoridium (4)
	Peridermium (7)
	Pucciniastrum (6)
Pucciniaceae (393)	*Caeoma* (4)
	Chrysocelis (1)
	Corbulopsora (1)
	Endophyllum (8)
	Gambleola (1)
	Hapalophragmium (4)
	Kernella (1)
	Puccinia (279)
	Pucciniosira (1)
	Ramakrishnania (1)

Table 2 Continued.

Phyllum: *Basidiomycota* **Class:** *Pucciniomycetes* **Order:** *Pucciniales*	
Family (Number of spp.)	**Genus (Number of spp.)**
	Trochodium (2)
	Uromyces (89)
	Xenostele (1)
Raveneliaceae (62)	*Chaconia* (1)
	Didymopsorella (1)
	Diorchidium (3)
	Gymnopuccinia (1)
	Kernkampella (6)
	Maravalia (11)
	Scopella (1)
	Olivea (3)
	Prospodium (2)
	Ravenelia (33)
Skierkaceae (3)	*Skierka* (3)
Sphaerophragmiaceae (1)	*Sphaerophragmium* (1)
Tranzscheliaceae (3)	*Leucotelium* (1)
	Tranzschelia (2)
Zaghouaniaceae (13)	*Cystopsora* (1)
	Elateraceium (1)
	Hemileia (10)
	Zaghouania (1)
Pucciniales	*Aecidium* (96)
genera incertae sedis (169)	*Nyssopsora* (3)
	Phragmotelium (2)
	Tunicopsora (1)
	Uraecium (1)
	Uredo (66)

Available literature on Indian rust fungi

Sir E. J. Butler conducted large scale mycological and phytopathological research in India. With this, research on rust fungi in India had also been started, although, research records on these fungi also found in Pre Butler era. Various journals namely, Grevillea, Indian Forester, Journal of Royal Microscopic Society, Journal of Bombay Natural Society, Journal of Asiatic Society of Bengal, Journal of Botany, Linnaeus Botany, Hedwigia and Journal of Asiatic Society of Bengal published the literature on rust fungi during this era. However, the establishment of Indian mycological journals and publication of a number of mycological books was still waiting. With the foundation of Herbarium Cryptogamae Indiae Orientalis (HCIO), a national fungal herbarium facility Pusa, Bihar in 1905, later shifted to the Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi, the research on Indian mycology and plant pathology geared up. This had opened the way to establish renowned international and national journals of repute publish research of Indian researchers. Besides this, Butler and his associates compiled 'The Fungi of India', Butler & Bisby (1931) which has been revised several times and further updated by Vasudeva et al. 1960, Parndekar 1964, Mukerji & Juneja 1974, Sarbhoy et al. 1975, 1982,1986, 1996, Bilgrami et al. 1979, Bilgrami et al. 1981, 1991, Jamaluddin et al. 2004. Several research-article series have been published by Indian researcher's time to time. Some of the important series are as 'Some Indian fungi', 'Fungi Indiae Orientalis', 'Fungus flora of Allahabad', 'Fungi of Nainital', 'Fungi Indici', 'The fungi of Bombay', 'Notes on Indian fungi', 'Some noteworthy rusts', 'Additions to rust fungi of Madras', 'Some fungi from Assam', 'Additions to rust fungi of Madras', 'Genera of rusts', 'Some new and interesting fungi', 'Additions to the fungi of Bombay', 'Notes on some fungi from South India', 'Notes on the miscellaneous fungi', 'Fungi of Ajmer (Rajasthan)',

'Fungi causing plant diseases at Jabalpur (M.P.)', 'Fungi causing plant disease at Jabalpur (M.P.)', 'Fungi of medicinal and aromatic plants of North Western Himalayas', 'Fungi on medicinal and aromatic plants of North West Himalayas', 'Additions to fungal flora of Assam', 'Notes on Fungi of Jammu and Kashmir', 'Parasitic fungi from North India', 'Some noteworthy rusts', 'New rust from India', 'Fungi of Delhi', 'Studies on rusts of Maharashtra', 'Fungi of Gorakhpur' and many more in the form of checklists. The information on selected literature published on Indian rust fungi from 1876 to date is presented in Table 3.

Table 3 Selected literature on Indian rust fungi

Literature	Reference
Some Indian fungi	Cooke (1876a, b)
Some parasites of *Coniferae*	Cooke (1877)
Some Indian fungi	Cooke (1878a, b)
The Fungi of India	Cooke (1880a)
The genus *Ravenelia*	Cooke (1880b)
Aecidium esculentum n. sp. on *Acicia eburnean*	Barclay (1890a)
List of *Uredineae* occurring in neighbourhood of Simla	Barclay (1890b)
History of a Himalayan *Gymnosporangium* (*G. cunninghamianum* n.sp.)	Barclay (1890c)
Life history of *Uridineae* on *Rubia cordifolia* nov.sp.	Barclay (1890d)
Life history of *Puccinia gerani-sylvatici* Karst. var. *himalensis*	Barclay (1890e)
Uredineae from the neighbourhood of Simla	Barclay (1891)
Fungi Indiae Orientalis	Sydow & Butler (1901), Sydow et al. (1907, 1911a, b, 1912)
Indian forest fungi	Butler (1906)
Indian Wheat rusts	Butler & Hayman (1906)
Revision of the genus *Hemileia* Berk	Massee (1906)
A new genus of *Uridinaceae*	Butler (1910)
The Caster rust (*Melampsorella ricini* de Toni)	Ajrekar (1912)
The rust of wildvines in India	Butler (1912)
Notes on some rusts in India	Butler (1914)
The genus *Kuehneola*	Arthur (1917)
Notes on South Indian Fungi	Mcrae (1917)
Novae fungporum species	Sydow & Sydow (1917)
Death of Chir (*Pinus longifolia*) plantations in Kashmir	Champion (1922)
Life history of *Uromyces aloes* (Cke) Magn	Ajrekar & Tonapy (1923)
Cronartium ribicola on *Rubrum*	Hafeezkhan (1928)
Fungi flora of Allahabad, India	Mitter & Tandon (1930), Saksena (1930), Mitter & Tandon (1937a)
The fungi of India	Butler & Bisby (1931)
Fungus flora of Nainital	Mitter &Tandon (1932, 1938)
Infestation of *Peridermium himalayensis* on *Pinus latifolia* and *Cronarium himalayensis* on *Swertia* sp.	Bagchee (1933)
Fungi Indici	Sydow & Mitter (1933, 1935), Sydow et al. (1937)
The fungi of Bombay	Uppal et al. (1935)
Rusts of the North Western Himalayas	Arthur & Cummins (1936)
Fungi of Mussoorie	Mitter & Tandon (1937b)
Fungi of India – Supplement -I	Mundkar (1938)
On a new *Ravenelia* from India	Mundkar & Prasad (1938)
Fungi Himalayensis	Sydow (1938)
Cereal rust in India	Mehta (1940)
Occurrence of *Darluca filum* (Biv.) Cast. on Cereal rusts in South India	Ramakrishnan & Narasimhalu (1941)
A new species of *Puccinia* on *Ocimum adscendens*	Thirumalachar (1941a)
Melampsora parasite on *Lobelia trigona* Roxb.	Thirumalachar (1941b)
Morphology and parasitism of *Trochodium*	Thirumalachar (1942a)
Phragmotelium mysorensis on Indian Raspberry	Thirumalachar (1942b)
Uredinales from North Western Himalayas	Cummins (1943)

Table 3 Continued.

Literature	Reference
A new species of *Cystopus* on *Evolvulus alsinoides* L.	Damle (1943)
Indian species of *Phakopsora* and *Bubakia*	Mundkar (1943)
Dasturella a new genus of *Uredinales*	Mundkar & Kheshwala (1943)
Notes on Indian fungi	Padwick & Merh (1943), Padwick & Khan (1944), Padwick (1945a, b)
Rust disease of *Cardamom*	Thirumalachar (1943a)
Masseeella breyniae as a new rust species	Thirumalachar (1943b)
Masseella narasimhanii as new species of rust on *Flugea leucopyrus* Willd	Thirumalachar (1943c)
Contribution to the flora of Nandi Hills	Thirumalachar et al. (1943)
Life history and morphology of *Trochodium ajreki*	Gharse (1944)
Two new genera of rust on *Bignoniaceae*	Mundkar & Thirumalachar (1945)
Some noteworthy rusts	Thirumalachar (1945, 1947, 1950c)
Revisions and additions to Indian Fungi	Mundkar & Ahmad (1946)
Additions to rust fungi of Madras	Ramakrishnan & Ramakrishnan (1946, 1947a, 1948a, b, 1949, 1950a, b, c), Ramakrishnan (1951a, b, 1952), Ramakrishnan et al. (1952a, b), Ramakrishnan & Sundaram (1953a, 1955a, b)
Rust on *Premna mucornata*	Ramakrishnan & Soumini (1946a)
Hemileia wrightiae on *Wrightia tinctoria* & *W. tomentosa*	Ramakrishnan & Soumini (1946b)
Hemileia jasmine on *Jasminium ritchiei* Clarke.	Krishnamurthy & Rangaswamy (1947)
Morphology and spore forms and heteroecism in *Dasturella divina*	Thirumalachar & Gopalkrishan (1947)
Morphology and parasitism of *Hemileia* species	Thirumalachar & Narsimhan (1947)
Uredostage connected with the aecidia found on *Berberis* spp.	Prasada (1947)
A new rust on *Dalbergia paniculata* Roxb.	Ramakrishnan & Ramakrishnan (1947b)
Some fungi from Assam	Chowdhary (1948)
Studies on rust fungi of some wild grasses occurring in Himalayas	Prasad (1948)
Studies on lentil rust, *Uromyces fabae*	Prasad & Verma (1948)
Uromyces acori Ramakrishnan and Rangaswamy on *Acorus calamus*	Ramakrishnan & Rangaswamy (1948)
Fungi of Bombay	Patel et al. (1949)
Parasitic fungi of the vicinity of Banaras	Payak (1949)
Investigation of cereal rusts. *Puccinia purpurea* Cooke	Soumini (1949)
Critical notes on some plant rusts	Thirumalachar (1949a)
Preliminary notes on heteroecism of *Puccinia versicolor*	Thirumalachar (1949b)
Genera of rusts	Thirumalachar & Mundkar (1949)
Morphology, cytology and biology of Indian coniferous rust observations on the *Cronatium ribicola* Fischer and *Peridermium indicum* on *Pinus excelsa* in India	Bagchee (1950a)
Morphology, cytology and biology of Indian coniferous rust observations on the *Peridermium brevius* (*Coleosporium barclayense* on *Senecio refinervis* DC) and *Melampsora oblong* on needles of *Pinus excela*	Bagchee (1950b)
Puccinia kuehnii (Krueg.) Butler on Sugarcane in India	Chona & Munjal (1950)
The *Scopella* of the *Uredinales*	Cummins (1950)
Puccinia on sugarcane in Bombay	Patel et al. (1950)
Rusts of South India	Ramakrishnan (1950)
Rust disease on *Garcinia indica*	Sunderam & Rao (1950)
Some new and interesting rust fungi	Thirumalachar (1950a,b,c)
Genera of rusts	Thirumalachar & Mundkar (1949)
Alternation of generation and heteroecism in *Puccinia versicolor*	Thirumalachar & Narsimhan (1950a)
Cytology and life history of a bisporidial *Endophyllum*	Thirumalachar & Narsimhan (1950b)

Table 3 Continued.

Literature	Reference
Kulkarniella – a new genus of rust	Gokhle & Patel (1951)
Additions to the fungi of Bombay	Patel et al. (1951a)
Additions to the fungi of Bombay	Patel et al. (1951b)
Rust on wild grasses	Prasada (1951)
Two new rusts from South India	Ramakrishnan (1951c)
New and noteworthy *Ravenelia* from India	Sanwal (1951a)
Taxonomic notes on tropical fungi	Sanwal (1951b)
Critical notes on some plant rusts	Thirumalachar (1951)
Revision of and addition to Indian fungi	Thirumalachar & Mundkar (1951), Mundkar & Thirumalachar (1952)
About *Uromyces cicer-arietini* on *Cicer arietinum*	Asthana (1952)
Indian wild linseed (*Linum mysorense* Heyne) a possible collateral host of the rust infecting cultivated linseed (*Linum usitatissimum*) in the hills	Lele (1952)
Fungi of India- a second supplement	Ramakrishnan & Subramanian (1952c)
A new rust on *Antidesma* in India	Ramakrishnan & Sundaram (1952a)
Notes on some fungi from South India	Ramakrishnan & Sundaram (1952b, 1953b, 1954a, b)
Fungi of Assam	Bhattacharya & Baruah (1953)
Parasitic *Puccinia* spp. on Andropogonaceae	Cummins(1953)
A new species of *Arthuria*	Gokhle & Patel (1953)
Morphological and cytological studies of a bisporidial species of *Endophyllum*	Thirumalachar & Govindu (1954)
Contribution to the *Uredineae* of Bihar	Yadav (1953), Yadav & Thirumalachar (1955), Yadav (1963a, b,1964a)
Puccinia polysora underwood in the Indian ocean area	Orian (1954)
Rusts of Hyderabad	Ramachar & Salam (1954)
Endophyllum sp. on *Elaegnus latifolia*	Gokhle et al. (1955)
Mycoflora Kanpurensis	Gupta & Shukla (1955)
Rusts fungi on some of the important conifers	Puri (1955)
Decline of Cheshewnut	Ramakrishnan (1955)
Additions to the rust fungi of Hydrabad	Salam & Ramachar (1955)
Rust on grape fruit	Vaheeduddin (1955)
Puccinia tumidepes on *Lycium europaeum*	Dalela (1956)
Curvularia pallescena on *Aecidium urgineae*	Ramachar (1956)
The life history of *Puccinia blepharidis* P. Henn.	Ramakrishnan & Sundaram (1956a)
The life history of *Puccinia romagnoliana* Nair & Sacc.	Ramakrishnan & Sundaram (1956b)
Two new records of *Uromyces* from India	Saksena (1956)
Additions to the rust fungi of Hydrabad	Salam & Ramachar (1956)
List of Indian Fungi 1952-56	Subramaniam & Ramakrishnan (1956)
Complete life cycle of *Puccinia rufipes*	Sunderam (1956)
Additions to the fungi of Bombay	Thirumalachar et al. (1956)
The pycnia, flexuous hyphae, and nuclear migrations in the aecia of *Scopella gentilis*	Payak (1956)
Notes on some fungi from South India	Ramakrishnan (1957a, b, 1959, 1960)
Puccinia kuehinii (Krueg) Butler on *Erianthus munja*	Sharma (1957)
Notes on fungi of Assam	Chaudhari (1958)
The fungi of Delhi	Chona et al. (1958), Behera & Mukerji (1974)
Taxonomic studies on *Uromyces indigoferae* in India	Joshi & Reddy (1958)
Fungi of Ajmer, Rajasthan	Joshi (1958), Joshi &Vashiist (1959)
Uromyces indigoferae as the rust pathogen of *Indigofera liniolla*	Joshi & Reddy (1959)
Puccinia erianthi Padwick & Khan on cultivated sugarcane	Kanadswamy & Vijyalakshmi (1959)
A new host for *Melampsora heliscopiae* (Pers.) Went from Kashmir	Kaul (1959)

Table 3 Continued.

Literature	Reference
Fungi of India	Vasudeva (1960)
Fungi causing plant disease at Jabalpur (M.P.)	Nema & Agarwal (1960)
Spore dispersal of *Hemileia vestratrix* by certain species of thrips occurring on *Coffea arabica* in South India	Ananth & Chokanna (1961)
Rusts of Indian trees	Bakshi & Singh (1961)
A new host of *Puccinia kanmorensis* Cummins from India	Khanna (1961)
Two fern rusts from India	Munjal & Kapoor (1961)
Ravenelia esculenta an edible rust fungus	Narasimhan & Thirumalachar (1961)
Notes on some fungi from South India	Sunderam (1961)
Diseases of important medicinal and aromatic plants of J&K	Ganguly & Pandotra (1962)
Fungi collected from Kulu Valley, Punjab	Pandotra &Ganguly (1962)
Life history and relationship of *Uromyces clignyi*	Patil & Thirumalachar (1962)
Gram rust in uredial stage on *Trigonella polycerata* L. in Simla hills	Payak (1962)
Two new rusts from Rajasthan	Prasad et al. (1962)
A new Aecial host of *Puccinia aristidae* Tracy.	Singh (1962)
Fungi of India	Vasudeva (1962)
Rust on *Solanum xanthocarpum* Schrad & Wendl.	Wakhloo (1962)
Fungi of medicinal and aromatic plants of NW Himalayas	Ganguly & Pandotra (1963)
Bromus japonicas Thumb. susceptible to wheat rust under natural conditions	Joshi & Merchand (1963)
Berberis Aecidium in Lahul Valley of Western Himalayas	Joshi & Payak (1963)
A new physiologic race of Indian rust	Mishra (1963)
Rust on *Muechlenbergia hugelii* Trin., in the Simla hills	Mishra & Lele (1963)
A new race of *Puccinia recondite* Roxb. ex. Desm. in India	Mishra & Sharma (1963)
Physiologic specialization in *Puccinia coronata* Corda in India	Payak & Mishra (1963)
New host record for *Puccinia citrulli* Syd. & Butler.	Sunderam (1963)
Fungi causing plant diseases at Jabalpur (M.P.).	Agarwal & Sahni (1964)
Physiologic specialization on *Puccinia penniseti* Zimm.	Dalela & Sinha (1964)
Studies in the crown rust of Oat in India	Mishra et al. (1964)
Oxalis corniculata, the alternate host of *Puccinia sorghi* in India	Mishra & Sharma (1964)
Telial stage of rust on *Sesbania aegyptiaca* Poir.	More & Moniz (1964)
Fungi on medicinal and aromatic plants of North West Himalayas	Pandotra & Ganguly (1964a, b)
A new host of *Puccinia versicolor*	Patil & Thirumalachar (1964)
A perfect stage of *Uredo treminalie* P. Henn.	Patwardhan (1964)
Rust of Castor	Ravindra Nath & Narahari Reddy (1964)
Additions to fungal flora of Assam	Roy (1964)
A new physiologic race of *Puccinia striiformis* West in India	Sharma & Singh (1964)
Physiologic specialization in *Uromyces leptodermus* Syd.	Sunderam (1964)
Uredo thelypteridis: a new species addition to India	Yadav (1964b)
Rust on *Schizandra grandiflora*	Singh & Jalan (1965)
Puccinia graminis and *P. striformis* on *Lolium perenne*	Mishra et al. (1965)
The *Uredinales* of Jabalpur M.P.	Nema & Mishra (1965)
Berberis as aecial host of *Puccinia brachypodii* in Simla hills	Payak (1965)
Taxonomy of *Puccinia penniseti*	Ramachar (1965)
The species of *Puccinia* on Paniceae	Ramachar & Cummmins (1965)
Some fungi from South India	Ramakrishnan (1965)
Sugarcane rust in India	Sahni & Chona (1965)
New species of *Dasturella* (Uredinales) from India	Sathe (1965a)
Revision of *Masseella narasimhansii* Thirum. (Uredinales)	Sathe (1965b)
Some additions to rust fungi of Maharashtra	Sathe (1965c)
New or revised species of *Physopella* (*Uredinales*) from India	Sathe (1965d)
Uredopeltis boswelliae Sathe from India	Sathe (1965e)
Nuclear condition on *Aecidium* of *Puccinia cocao* Mcalp.	Yadav & Yadav (1965)
Fungi of Gwalior and Indore region	Jain et al. (1966)
Studies on host range of *Uromyces fabae*	Kapooria & Sinha (1966)

Table 3 Continued.

Literature	Reference
A new species of *Uredo* on *Hygrophila*	Laundon & Ponappa (1966)
Status of Linseed rust races and their resistance in India	Mishra & Prasad (1966)
Fungi of Jammu and Kashmir	Pandotra (1966)
Rust of Mahabaleshwar	Patil (1966a)
The genus *Revenelia* Berk. in Maharashtra	Patil (1966b)
Parasitic fungi from North India	Pavgi & Upadhyay (1966)
A new species of *Caeoma* from India	Rajendran (1966)
Species of *Phakopsora* and *Physopella* on tribe *Peniceae*	Ramachar (1966)
Some new reports of *Aecidium* from India	Sathe (1966a)
Stakmania- a new genus of *Uredinales* form India	Sathe (1966b)
Possibility of new collateral hosts for the rusts of gram	Bahadur & Sinha (1967)
Uromyces sp. on *Euphorbia dracunculoides* in Rajasthan, India	Mathur (1967)
Narenga porphyrocoma – a new host *Puccinia helianthi*	Sohi et al. (1967)
Notes on rust fungi of Maharashtra, India	Chavan (1968)
Alternation of *Helicortichum* rust with *Thakictrum*	Mishra et al. (1968)
New physiologic race of *Puccinia graminis – tritici* in Maharashtra	Mutkekar et al. (1968)
Life history and heteroecism of *Uromyces commellinae*	Patil & Thirumalachar (1968)
Fungi of South India	Rangaswamy et al. (1968)
Fungi of India (1962–1967)	Tilak & Rao (1968)
Additions to fungal flora of Assam	Roy (1968)
Addition to the Wheat rust races in India-I. Race 12, 14,38 & 61 of *Puccinia recondita* identified during 1965 &66	Ahmad & Singh (1969), Ahmad et al. (1969)
The *Uredinae* of Jabalpur (M.P.)	Mishra (1969)
Screening of *Lathyrus* germplasm collection against rust *Uromyces fabae* (Pers.) de Bary	Mishra & Khare (1969)
Fungi on medicinal and aromatic plants of North West Himalayas	Pandotra & Sastry (1969a)
Notes on the fungi of Jammu and Kashmir	Pandotra & Sastry (1969b)
Morphology of Pycnia of some *Ravenelia* species	Pavgi & Singh (1969)
Rust of *Pennisetum typhoides*	Sathe (1969a)
Peridospora- a new genus of *Uredinales* from India	Sathe (1969b)
Uredinales of Maharashtra State, India	Sathe (1969c)
Abnormal phenomenon during germination of teliospores in the rust *Scopellopsis dalbergiae*	Rajendren (1969)
Two unrecorded races and a new biotype of *Puccinia recondite*	Payak & Khanna (1970)
Kernkampella: A new genus in the Uredinales	Rajendran (1970)
Fungi from Rajasthan, India	Goyal et al. (1971)
Noteworthy rusts from Maharashtra, India	Patil & Thirumalachar (1971)
Nomenclature of common rust fungi affecting sugarcane	Sathe (1971)
Puccinia helianthi on *Helianthus cucumerifolius* in India	Siddiqui (1971)
Tunicospora, a new rust genus on bamboo	Singh & Pandey (1971)
Germination of the teliospores of *Ravenelia hobsoni*	Nair (1971)
Diseases of important native and exotic forest trees in India	Bakshi et al. (1972)
Suceptibility of exotic pine to *Cronartium himalayense*	Bakshi & Singh (1972)
Puccinia deodikarii sp. nov. from India, Uredinales	Gopinathnair (1972)
Aecidium vernoniae – cinereae Patch in India	Goswami (1972)
Indian species of *Ravenelia* on *Abrus* and *Albizia*	Kapoor & Agarwal (1972)
Identity and nomenclature of soybean rust from India	Sathe (1972a)
Taxonomic studies of the genus *Cerotelium* (Uredinales)	Sathe (1972b)
rust on groundnut (*Arachis hypogea*) in Calcutta, W.B.	Sharma & Mukerji (1972)
Diseases of sunflower (*Helianthus annus*) in India	Siddiqui (1972)
New *Melampsoridium* on *Mangolia*	Singh & Pandey (1972)
Morphographic studies on genus *Ravenelia* occurring in Rajasthan	Tyagi & Prasad (1972)
Rust infection of Sorghum	Balasubramanian (1973)
New rust from India	Chavan & Bakare (1973a, b)
Rust disease of Tejpat	Goswami & Bhattacharjee (1973)
Uredinales of North East India	Goswami & Singh (1973)

Table 3 Continued.

Literature	Reference
Telial stage of the rust *Cerotelium fici* (Cast.) Butl. in Maharashtra	Pawar & Kulkarni (1973)
Occurrence of groundnut rust in India	Ramakrishna & Subbayya (1973)
Helianthus cucumerifolius as host for sunflower rust in India	Siddiqui (1973)
Hiratsukamyces – a new genus of *Pucciniastreae*	Thirumalachar et al. (1973)
Fungi of Eastern Himalaya (India)	Dewan & Kar (1974)
Indian species of *Ravenelia* on *Acacia*	Kapoor & Agarwal (1974)
Occurrence of rust of groundnut (*Puccinia arachidis*) in Madhra Pradesh	Khosla et al. (1974)
Gall formation by *Puccinia thwasitesii* on *Gendarussa vulgaris*	Unni & Philip (1974)
Fungi of India. Supplement to the list of Indian Fungi	Mukerji & Juneja (1974)
Fungi of Maharashtra, India	Chavan (1975)
Groundnut (*Arachis hypogaea* L.) rust from Maharashtra state, India	Chavan & Bhambure (1975)
Groundnut rust in Bihar	Mishra & Mishra (1975)
Some rust fungi from Simla hills	Mishra et al. (1975)
Some foliicolous fungi	Sharma (1975)
Groundnut rust (*Puccinia arachidis* Speg.) from U.P.	Yadav et al. (1975)
Uredinae of Jabalpur, Madhya Pradesh	Mishra & Nema (1976), Mishra et al. (1976)
Polygonum demetorum as host for *Puccinia polygoni- abphibii*	Munshi (1976)
Nomenclatural changes in some *Uredinales*	Ramachar & Bhagyanarayana (1976)
A new rust on *Polygonum glabrum* from India	Sathe & Rahalkar (1976)
Rust of Cowpea cuased by *Uromyces phaseoli* var. *vignae*	Sokhi & Sohi (1976)
Sunflower rust (*Puccinia helianthi*) in Madhya Pradesh	Shukla & Singh (1976)
Sehima nervosum- a new host of *Puccinia versicolor*	Ahmad (1977)
Rust fungi of western Maharashtra, India	Chavan & Bakare (1977)
Phytopathogenic fungi of Meerut	Dublish & Singh (1977)
Annotated list of fungi from Faizabaad	Kanaujia (1977), Kanaujia & Kishore (1981)
Studies on rusts of Maharashtra	Patil (1977)
A new species of *Revenelia* Berk. from Maharashtra	Patil & Date (1977)
Melampsora sp. from Andhra Pradesh	Ramachar & Bhagyanarayana (1977a)
Mycological notes on some rust fungi from India	Ramachar & Bhagyanarayana (1977b)
Rust on garlic	Singh & Sharma (1977)
Pink disease and rust of plums in India	Waraitch & Khatri (1977)
Puccinia xanthi – a report from India	Jadhav & Somani (1978)
Rust of *Xanthium strumarium* L.	Khulbe & Verma (1978)
Fungal flora of Amboli (Ratanagiri)	Patil & Thite (1978)
Additions to rust (*Uredinales*) from Hydrabaad (India)	Ramachar et al. (1978)
Some new *Ravenelias* from Rajasthan	Tyagi & Prasad (1978)
Fungi of Gorakhpur	Kamal et al. (1979), Kamal & Singh (1981)
Groundnut rust in Nainital Tarai region of Uttar Pradesh	Kolte & Awasthi (1979)
Brachy *Puccinia* on *Cnicus arvensis*	Sharma et al. (1979)
New species of *Puccinia* on *Cyondon*	Somani (1979)
Fungi causing plant diseases at Jounpur UP	Srivastava (1979, 1980)
Physiological changes in *Phyllanthus emblica* by *Ravenelia emblicae*	Nagaraja (1980)
Puccinia xanthi on *Xanthium strumarium* in India	Deoraj (1980)
Puccinia and *Uromyces* from Maharashtra	Patil & Date (1980)
Rusts from Nagaland and Arunachal Pradesh	Ahmad (1981)
Phakaopsora grewiae on *Grewia asiatica* from Jabalpur	Sharma & Jain (1981)
Rust fungi from Kedarnath Valley	Srivastava (1982)
Rust fungi from Chamoli, Garhwal	Kala & Gaur (1983)
Virulence analysis system of brown rust of wheat (*Puccinia recondita* f. sp.*tritici*)	Nagarajan et al. (1983)
Contribution to *Urediales* of Rajasthan	Tyagi et al. (1984)
Rust of *Elaeocarpus tuberculatus* Roxb. from Iduki, Kerela, India	Hosagoudar (1984)

Table 3 Continued.

Literature	Reference
Vulpia myuros and *Briza minor* in the perpetuation of Black rust of Oats in the Nilgiri hills	Joshi & Lele (1984)
Rust disease of *Prunus puddum*	Bist et al. 1985
Uromyces coronatus on *Zizania latifolia*	Nagachan & Verma (1984)
Uromyces dactylidis on *Poa annua*	Saini & Chand (1984)
Spermogonial and aecial stages of *Kernkamepella kiragnelliae*.	Bagyanarayana & Ramachar (1985)
Kuehneola on *Gymnosporia Montana* from India	Bagyanarayana & Rao (1985)
Leaf rust of *Barlaria prionitis*	Barde & Thakare (1985)
Outbreak of rust on Oak (*Quercus acusissima*) in Manipur	Chakravorty et al. 1985
Uredo Pers. on *Dalbergia latifolia* Roxb. from Kerala	Hosagoudar & Nair (1985)
Nyssospora thirumalachari – a new rust from India	Nagachan & Goswami (1985)
Rust disease of ray ambala (*Phyllanthus phyllanthi*)	Patel et al. (1985)
Puccinia ctenolepidis - a new rust on *Ctenolepis* (Cucurbitaceae)	Ramachar et al. (1985)
Uredinae of the Punjab state	Sokhi et al. (1985)
Aecidium hartwegii Thuen.: an addition to Indian Mycoflora	Yadava & Saran (1985)
Monitoring of wheat rusts in the Indian sub-continent	Joshi et al. (1985)
Nyssopsora thirumalachari- a new rust from India	Nagachan & Goswami (1985)
Rust diseases of Mahova (*Bassia latifolia*)	Solanki et al. (1985)
Aecidium hartwegiae Thuem., an addition to Indian Mycoflora	Yadav & Saran (1985)
Uromyces pontederiae- a new record from India	Agarwal & Sarbhoy (1986)
Fungi from North Eastern region of India	Ahmad (1986)
New rusts from Hyderabad	Bagyanarayana & Ramachar (1986)
Occurrence of rust on Japanese plum	Bhardwaj & Shyam (1986)
New fungal records from Garhwal hills	Gaur et al. (1986)
Rust fungi from Himalaya	Sharma (1986)
Plant diseases of India	Mukerji & Bhasin (1986)
Puccinia hydrabadensis, a new graminaceous rust from India	Bagyanarayana & Ravinder (1987)
A new species of *Uromyces* on *Atylosia* from India	Bagyanarayana et al. (1987a)
Nyssopsora schefflerae sp. nov. from India	Bagyanarayana et al. (1987b)
Seedling disease of *Gmelina arborea* in Kerela – new record	Florence & Snakaran (1987)
Aecidium painavuensis sp. nov. from Kerela	Hosagoudar (1987)
Noteworthy records of fungi on Indian conifers	Singh et al. (1987)
Amomum subulatum, a new host for *Phakopsora elletariaei* from Sikkim	Srivastava & Verma (1987)
Tranzschelia discolor f. sp. *dulcis* rust on Almond in India	Sharma et al. (1987)
Puccinia microspore, a new record Andhra Pradesh	Bagyanarayana & Ravinder (1988a)
Notes on two Indian species of *Ravenelia*	Bagyanarayana & Ravinder (1988b)
Uromyces pisi in India	Bharti et al. (1988)
Garlic rust from Punjab state, India	Singh & Basandrai (1988)
Safflower rusts in India	Singh & Khare (1988)
Uredinales of Kerala	Hosagoudar (1988)
Taxonomic survey of rust fungi of North Eastern region of India	Ahmad (1989)
A new species of *Olivea* Arth. from India	Hosagoudar (1989)
Severe rust on Jasmine (*Jasminum auriculatum* Vahl.) by *Uromyces hobsoni* Vize. in Andhra Pradesh	Rao et al. (1989)
Fungal diseases of some medicinal plants from North Eastern region of India	Ahmad (1990)
Rust on black zira in Himachal Pradesh	Bhardwaj & Sharma (1990)
Uromyces trifol*ii* (DC) Lev. on *Trifolium resupinatum* L	Hooda & Sani (1990)
Rust of florist *Geranium*	Singh & Rao (1990)
Rust fungi from Maharashtra	Patil (1991)
Prevalence and distribution of pea rust in Himachal Pradesh	Chauhan et al. (1991)
Dasturella divinia – a new record on *Bambusa aurndinacea* from India	Bhat (1992)
Launea pinnatalifida, a new host for *Coleosporium asterum*	Sinha & Singh (1992)
Rust on perpetual strawberry	Singh & Sinha (1993)
Fungal diseases of *Pistacia integerrima* from Himachal Pradesh	Bhardwaj & Sharma (1994)
Uromyces on *Ocimum* in India	Bagyanarayana & Ravinder (1994)

Table 3 Continued.

Literature	Reference
Rust of *Oxalis* – a new record from India	Bhattacharyya & Saikia (1994)
Puccinia polyspora rust of maize in India	Payak (1994)
Pistachio nut rust – a new disease from Himachal Pradesh	Bhardwaj (1995)
Soybean rust in Madhya Pradesh	Sharma & Mehta (1996)
Addition to fungi of Kashmir	Dar & Ghani (1997)
Puccinia oxalidis Dietel. et. Ellis – a new record from India	De. (1997)
Pea specific strains in *Uromyces fabae*	Chand et al. (1997)
New fungi from North East India	Borah et al. (1998)
Cerotelium fici – a pathogen of mulberry rust in West Bengal	Gangwar & Qadri (1998)
Wheat rust infection on rye	Sharma & Paul (1998)
Rust disease of French bean	Sharma (1998)
Prospodium tirumalensis: a new species from India	Bagyanarayana et al. (1999)
Puccinia cannacearum, a new rust taxon on *Canna indica*	Bagyanarayana & Ramesh (1999)
Diseases of buckwheat (*Fagopyrum* sp.) in Himachal Pradesh	Paul & Sud (1999)
Rust fungi (*Uredinales*) of India Central Himalaya	Palni et al. 2000
Uromyces muscari: a new record from India	Agarwal (2001)
Rust of *Dalbergia sisoo* from North-Eastren hill regions of India	Bag & Bhowmik (2001)
Rust of *Plumeria alba* – a new host of *Uredo plumeriae*	Praveena et al. (2001)
New records of rust fungi from India	Agarwal (2002, 2004 a,b)
Rust species (*Uredinales*) from Andhra Pradesh	Bagyanarayana et al. (2003)
Trichothecium roseum, a hyperparasite on rust of *Plumeria alba*	Praveena et al. (2003)
Rust disease of *Canna indica* in India	Maji (2003)
Phakopsora pachyrhizi - soybean rust from Rajasthan	Gupta & Kaur (2004)
Leaf rust (*Melampsora ciliata*) of Poplar in Himachal Pradesh	Khan et al. (2004)
Soybean rust in Chhattisgarh	Verma et al. (2004)
Melampsora medusae rust in India	Paul et al. (2004)
Queensland arrowroot (*Canna edulis*) rust caused by *Puccinia thaliae*	Jeeva et al. (2004)
Pea (*Pisum sativum* L.) genotypes against *Uromyces fabae*	Chand et al. (2004)
Melampsora ciliate on new host in India	Sah et al. (2006)
Rust of *Justicia gendarussa* from central India	Yadav & Sharma (2006)
Aeciospores in outbreaks of Pea (*Pisum sativum*) Rust (*Uromyces fabae*)	Kushwaha et al. (2006)
Fungi of Kerala	Hosagoudar et al. (2006)
Pathotypic evolution in *Puccinia striiformis* in India during 1995-2004	Prashar et al. (2007)
Ravenelia aloii rust on *Aloe vera* in plains of India	Dubey & Pandey (2007)
Rust of *Acorus calamus* from Chhattisgarh	Nirmalkar et al. (2007)
Coleosporium plumeriae on *Plumeria alba* in India	Baiswar et al. (2008)
Rust on *Artemisia dracunculus* L. in Himachal Pradesh	Bharat (2008)
New pathotypes 5 R 45, 7 R 29 93R45 and 49R45 of *Puccinia triticina*	Jain et al. (2008), Bhardwaj et al. (2009)
Coleosporium plumeirae Lev., rust new to the Maharashtra state	Kavale & Patil (2009)
Puccinia jabalpurensis on *Lagascea mollis* from India	Bhanu (2009)
Wheat stripe rust in Kashmir	Khan et al. (2009)
Yellow rust of wheat from Jharkhand	Lal et al. (2009)
Rust Fungi of Kerala	Mohanan (2010)
Occurrence of teak (*Tectona grandis* L.) rust (*Olivea tectonae* (Racib) Thirum) in Bihar	Dayaram (2010)
Leaf rust of *Acorus calamus* caused by *Uromyces acori* from Kerala	Golda et al. (2011)
Aonla leaf rust caused by *Phakopsora phyllanthi* in Himachal Pradesh	Jarial et al. (2011)
Rust of maize from Jharkhand	Lal et al. (2011)
Wheat diseases in India with a special reference to stripe rust	Sharma & Saharan (2011)
Diversity and distribution of rust fungi in central Himalayan region	Singh & Palni (2011)
Molecular mapping for resistance to pea rust caused by *Uromyces* fabae (Pers.) de-Bary	Rai et al. (2011)
Aloe vera rust (*Uromyces aloës*): A new record from Madhya Pradesh	Soni et al. (2011)
Garlic rust in Shimla district of Himachal Pradesh	Bharat & Gupta (2011)

Table 3 Continued.

Literature	Reference
Ug99 races of the stem rust fungus is a threat to world wheat production	Singh et al. (2011)
Pathotypes 125R28 and 93R37 of *Puccinia triticina* on wheat from India	Bhardwaj et al. (2011)
Rust situation and pathotypes of *Puccinia* species in Leh Ladakh in relation to recurrence of wheat rusts in India	Bhardwaj et al. (2012)
Studies on epidemiology of lentil rust	Joshi & Tripathi (2012)
Management of Coffee leaf rust disease in India	Narayana (2013)
Characterization and evaluation of genetic variability of *Puccinia emaculata* for rust resistance	Uppalapati et al. (2013)
Puccinia thaliae rust on *Canna indica* in Sikkim	Gopi et al. (2014)
Puccinia melanocephala: first report from Punjab, India	Prasher et al. (2015)
Chrysanthemum white rust *Puccinia horiana* in India	Dheepa et al. (2015)
Fungal diseases of trees in forest nurseries of Indore, India	Pathak et al. (2015)
Validation of SSR markers associated with rust (*Uromyces fabae*) resistance in pea (*Pisum sativum* L.)	Singh et al. (2015)
Prevalence of rust disease of pea (*Pisum sativum*.) in Uttarakhand and Uttar Pradesh	Upadhyay et al. (2015)
Puccinia horiana causing white rust of *Chrysanthemum* in India	Sriram et al. (2015)
Puccinia himachalensis – a new rust fungus from Himachal Pradesh	Gautam & Avasthi (2016b)
Checklist of rust fungi in the genus *Puccinia* from Himachal Pradesh	Gautam & Avasthi (2016a)
Coleosporium sp. on *Clematis gouriana* in India	Hande et al. (2016)
Solidago canadensis, a new host record for *Coleosporium asterum*	Thite et al. (2016)
Rust disease on wild Coffee (*Psychotria nervosa*) caused by *Puccinia mysuruensis* sp. nov	Mahadevakumar et al. (2016)
Rust Frangipani (*Plumeria*) Caused by *Coleosporium* sp. in Haryana	Kumar & Paul Khurana (2016)
Puccinia tiliaefolia (Pucciniales) in northwestern Himalayas, India	Gautam & Avasthi (2017a)
Rust fungi associated with *Pistacia integerrima* in India	Gautam & Avasthi (2017b)
Checklist of *Uromyces* in India	Gautam & Avasthi (2017c)
PCR-based marker to detect *Puccinia striiformis* f. sp. *tritici*	Aggarwal et al. (2017)
Dissection of genomic features and variations of three pathotypes of *Puccinia striiformis* through whole genome sequencing	Kiran et al. (2017), Ranadive et al. (2017)
First online documentation of fungi from India.	
Molecular characterization of Indian pathotypes of *Puccinia striiformis* f. sp. *tritici*	Aggarwal et al. (2018a)
Use of URP and RAPD markers in molecular characterization of predominant Indian wheat rust pathotypes	Aggarwal et al. (2018b)
Puccinia duthiae on *Dichanthium foveolatum* from India	Pawar et al. (2018)
Puccinia graminis tritici detected in Indian subcontinent (2009–2015)	Prasad et al. (2018)
Temporal transcriptional changes in SAR and sugar transport-related genes during wheat and leaf rust pathogen interactions	Savadi et al. (2018a)
Molecular breeding technologies and strategies for rust resistance in wheat (*Triticum aestivum*) for sustained food security	Savadi et al. (2018b)
Rust fungi of North Western Himalayas (Himachal Pradesh), India	Gautam & Avasthi (2018)
Puccinia horiana Henn. on *Chrysanthemum* in Himachal Pradesh	Chandel et al. (2019)
Physiologic specialization and shift in *Puccinia triticina* pathotypes on wheat in Indian subcontinent during 2013–2016	Bhardwaj et al. (2019)
Characterization of three new Yr9 virulences and identification of sources of resistance	Gangwar et al. (2019a)
Virulence and molecular analysis of atypical pathotypes of yellow rust pathogen	Gangwar et al. (2019b)
Morphology of *Puccinia horiana* rust occurred in West Bengal	Mondal & Singh (2019)
Mycoparasitic fungi *Sphaerellopsis paraphysata* on *Puccinia substriatain*	Ashmitha et al. (2019)
Rust disease caused by *Puccinia oxalidis* on *Oxalis latifolia* from India	Verma et al. (2020)
Taxonomic outline of Indian *Pucciniales*	Gautam et al. (2021)

Publication indices

The year wise, decade wise and era wise indices of mycological publications on Indian rust fungi is presented here in this section of the paper (Table 4, Fig. 1). From 1876-1900, there were only 18 research papers published on rust fungi in India. Of the 16 publications, 8 were published during 1876-1880, 9 in 1890 and only 1 in 1891. This number was 6 (1901-1910), 10 (1911-1920), 6 (1921-1930) and 16 (1931-1940). The situation appears to have improved with respect to increase in the number of publication as 63 (1941-1950), 77 (1951-1960), 101 (1961-1970), 89 (1971-1980), 75 (1981-1990) and 29 (1991-2000). Total 489 research papers have been published during the 20th century. Thereafter, about 82 research papers have been published to date and this process is still in continuation. Besides these statistics, about 86 research papers were published in pre-independence era while, nearly 485 in the post-independence period. If we compare the year wise publications, the highest number of 24 publications were published in 1985 followed by 18 (1950 and 1966), 17 (1964), 14 (1965 and 1977), 13 (1969 and 1972), 12 (1956 and 1963), 11 (1951 and 1955) and 10 (1973). Total number of publications was less than 10 in all remaining years. If we talk about research journals, nearly 107 scientific journals were involved and are still publishing research on Indian rust fungi. In addition, a number of books and scientific reports were published.

Table 4 Year wise number of publications on rust fungi in India in international and national journals

Year	Number of Publications	Year	Number of Publications	Year	Number of Publications
1876	02	1948	07	1985	24
1877	01	1949	07	1986	08
1878	02	1950	18	1987	08
1879	01	1951	11	1988	06
1880	02	1952	09	1989	06
1890	09	1953	07	1990	06
1891	01	1954	05	1991	03
1901	01	1955	11	1992	03
1905	01	1956	12	1993	01
1906	02	1957	04	1994	06
1907	01	1958	07	1995	02
1910	01	1959	07	1996	02
1911	01	1960	04	1997	03
1912	03	1961	06	1998	05
1914	01	1962	08	1999	03
1916	01	1963	12	2000	01
1917	03	1964	17	2001	04
1918	01	1965	14	2002	01
1922	01	1966	18	2003	03
1923	01	1967	03	2004	09
1928	02	1968	07	2005	01
1930	02	1969	13	2006	04
1931	01	1970	03	2007	04
1932	01	1971	07	2008	03
1933	02	1972	13	2009	04
1935	02	1973	10	2010	03
1936	02	1974	08	2011	11
1937	03	1975	09	2012	02
1938	03	1976	09	2013	02
1939	01	1977	14	2014	01
1940	01	1978	05	2015	04
1941	03	1979	08	2016	04
1942	02	1980	06	2017	06
1943	09	1981	05	2018	07
1944	02	1982	03	2019	07
1945	04	1983	04	2020	01

Table 4 Continued.

Year	Number of Publications	Year	Number of Publications	Year	Number of Publications
1946	04	1984	05	2021	01
1947	07				
Total Number of publications = 571		Total Number of publications = 86			
In 20th century = 489		(Pre- independence)			
In 21st century = 82		Total Number of publications = 485			
		(Post- independence)			

Current problems of research on rust fungi

What exactly came out after the whole compilation of available Indian literature is the majority of research pertaining to the identification of these fungi is based on morphological characters, that is the morphology of certain spore stages. However, with the introduction of the modern tools and molecular-based techniques of fungal taxonomy, specifically DNA-based, very few studies are based on the use of them. The basic reasons for lagging in the use of molecular methods in taxonomic research of rust fungi are same as the case of all other fungi. The non-availability of required facilities, funds and expensive services provided by different agencies are some important problems faced by mycologists during the study of fungi including rust fungi. The detailed explanation of these problems is provided below:

1. When we talk about funds, it has now become very common to fund applied research (e.g. biotechnology preferably) and to obtain funds for basic inventorying and identification of fungi, it is not so easy. Due to the lack of sufficient funds, laboratories involved in taxonomic research on fungi remained devoid of in modern tools (used in DNA isolation, amplification (PCR) and sequencing).
2. Most of the universities and scientific institutions across the world now use impact factors as a basis for evaluating a scientist's performance or appraising whether they should be promoted. Yet the journals with impact factors generally asked for the use of molecular techniques as basic criteria in fungal taxonomy research to publish any research article.
3. This is unfortunate, despite the fact that fungal taxonomy is relatively inexpensive to fund in comparison to applied research, basic fungal research is not in preference of funding nowadays. The decision-makers should fund the research projects based on inventorying and identification of fungi to upgrade infrastructure involved laboratories with modern equipment.
4. If the mycologists opted for the use of services provided by various agencies/ institutions of national and international repute, the charges of molecular techniques are so high and not in the reach of every mycologist, particularly the researchers working on self-finance basis.

All the above-discussed issues are ultimately leading to the decreased interest of mycologists in fungal taxonomy, which is ultimately decreasing the number of fungal taxonomists.

Indian rust fungi – the future

The present study provides the current status of research on rust fungi in India with respect to comprehensive history, complete information of various journals, books, websites constructing information, institutions providing mycological services, the outline of Indian rust fungi, complete list of literature with publication indices and basic problems mycologists are facing to carry out the taxonomic type of research. All attempts have been made to include all available information on Indian rust fungi, still, this information cannot be considered fully updated. Valuable suggestions and new additions are most welcome to the corresponding author. However, at the end of the compilation, the following points have come out which are to be addressed in the future:

1. Rust fungi are widely surveyed and investigated, but many still need to be explored.

2. The molecular data for most of the Indian rust fungi is not available which open a potential field of research interest for current and future mycologists.
3. Many rust fungi reported in India are still with the uncertain taxonomic position, hence placed in *incertae sedis*. The names of genera such as *Angiopsora*, *Scopella*, *Trochodium* etc. are now changed. Their Indian collections are identified only on the basis of morpho-taxonomic characters. Similarly, the type species of *Ramakrishnania* (*Ramakrishnania ixorae* Ramachar & Bhagyan) is also based on morpho-taxonomy solely. The use of modern techniques will provide a good opportunity for young and emerging researchers to investigate them for resolving their taxonomical placement.
4. Some generic names have been transferred to new genera, but either their types or records from India still need to be revised. They should be recollected and reassessed. The plant pathologists working on Indian rust fungi have a great opportunity to explore these fungi and place them in their correct taxonomic positions.

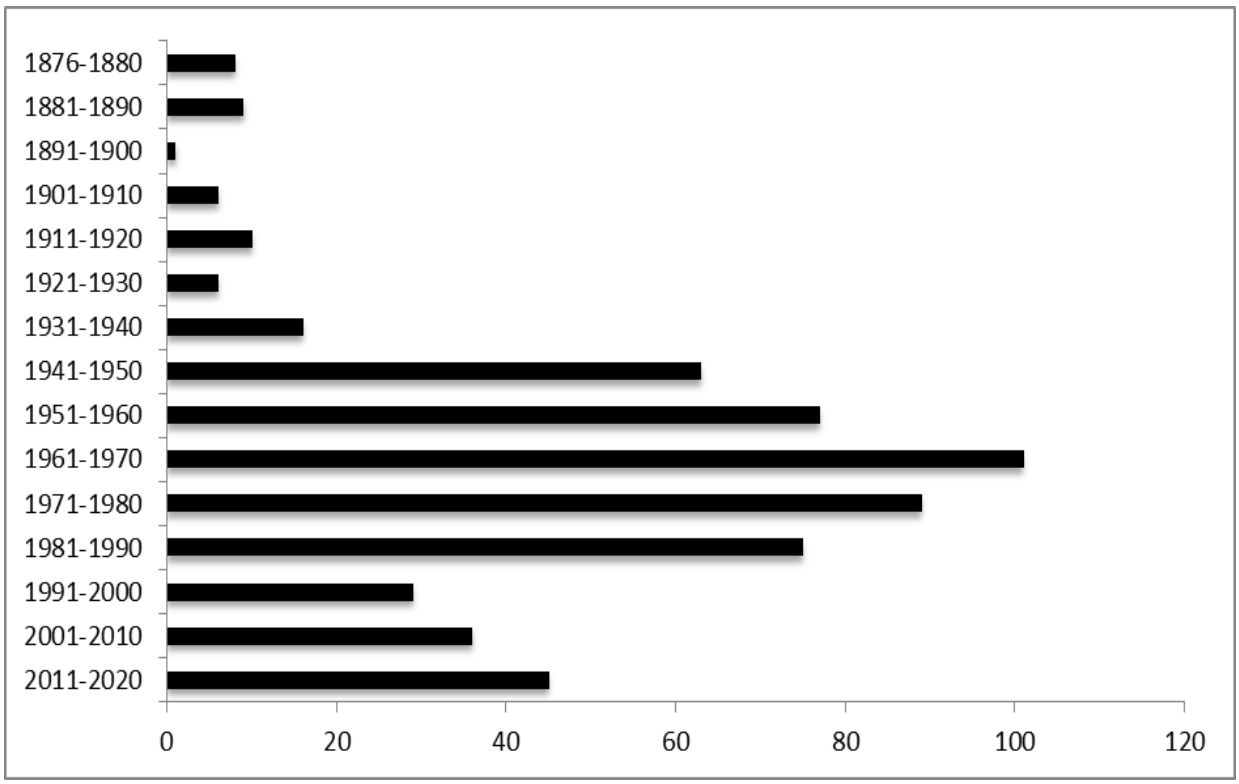

Fig. 1 – Decadal publication record of rust fungi in India published in various journals.

Overall, the use of molecular fungal taxonomy will be helpful to reclassify Indian rust fungi and place them in their correct taxonomic position. Although, a lot of scope is still present in investigating rust fungi, the current level of productivity in fungal systematics is disappointing. Whatever the reason may be, the decrease in the number of mycologists is alarming. At present, very few countries have active mycologists. Therefore, it is important that seniors and currently active mycologists and governments should promote fungal research financially and academically so that future mycologists can be prepared and their decreasing numbers can be controlled well in time.

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