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A CHECKLIST OF RUST FUNGI FROM HIMACHAL PRADESH, INDIA

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Abstract: An updated analysis of the diversity of rust fungi in Himachal Pradesh is provided herein as a product of field surveys, of mycological analysis, and of all forms of published documentation and literature. The results of all forms of analysis revealed that Himachal Pradesh has 167 species of rust fungi belonging to the class Pucciniomycetes. The class is represented by 11 families, 23 genera with 167 species. The *Pucciniaceae* (96 species) followed by *Phragmidiaceae* (14 species) are the largest families of rust fungi reported from the state. Rest of the families were found associated with 1–10 species of rust fungi. The rust fungi (19 species) with uncertain placement are placed in incertae sedis. The rust genera reported from Himachal Pradesh so far are *Aecidium*, *Chrysomyxa*, *Coleosporium*, *Frommea*, *Gymnosporangium*, *Kuehneola*, *Kweilingia*, *Melampsora*, *Monosporidium*, *Ochrospora*, *Peridermium*, *Phakopsora*, *Phragmidium*, *Pileolaria*, *Puccinia*, *Pucciniastrum*, *Pucciniostele*, *Ravenelia*, *Skierka*, *Uredinopsis*, *Uredo*, *Urocystis*, and *Uromyces*.

Keywords: Basidiomycota, checklist, Himachal Pradesh, Pucciniales, Pucciniomycetes.

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Author contribution: AKG performed the survey, data collection and finalized the manuscript. SA compiled the published literature and contributed in manuscript writing.

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INTRODUCTION

Rust fungi are highly specialized obligate plant parasites having several unique morphological and microscopic features. These fungi commonly appear as yellow orange or brown powder on a variety of host plants and plant parts. Unlike other plant pathogens, rusts usually affect healthy and vigorously growing plants; the infection is limited to plant parts, such as leaves, petioles, tender shoots, stem, and fruits. The group is considered as one of the most harmful plant pathogens in agriculture, horticulture and forestry. These fungi are of major concern because they act as limiting factors for the successful cultivation, plantation and growth of agricultural crops and forestry plants. A wider diversity and broader host range is exhibited by this fungal group and their infection is not only limited to agricultural crops but also non-agricultural plants including medicinal herbs, shrubs, trees, and even weeds. An estimated 168 rust genera and approximately 7,000 species exist on various plant hosts, more than half of which belong to the genus *Puccinia* (Mohan 2010).

Rust fungi show unique systematic characteristics among all fungal groups. A single species may produce up to five morphologically and cytologically distinct spore-producing structures, viz., spermatogonia, aecia, uredinia, telia, and basidia, in successive stages of reproduction during the infection process. The presence of these successive stages may vary from species to species. To initiate and develop infection, rusts require an average temperature up to 35°C along with 50–60 % relative humidity. The rust infected plants may appear stunted, chlorotic (yellowed), or otherwise discoloured, whereas, disease symptoms includes coloured pustules, witches brooms, stem canker, hypertrophy of the affected tissues or formation of galls (Cummins & Hiratsuka 2003). Unlike other fungi, rusts exhibit one of the most important characteristics of their exceptionally high degree of host specificity.

Among all reported rust fungi, some are among agriculture's most destructive and devastating pathogens, causing diseases such as wheat stem rust, wheat yellow (stripe) rust, Asian soybean rust, coffee rust and many more. These rust fungi cause annual crop losses in billions every year worldwide. This loss can be greater in developing world where growers are not aware about diseases caused by rust fungi and often cannot afford fungicides. Owing to their economic importance, the rusts have been studied extensively in regular mycological surveys in Himachal Pradesh, but no single-source compiled literature is available. Therefore,

this study facilitates the access to scattered Himalayan literature with reference to rust fungi to the students and plant pathologists of national and international community.

STUDY AREA

Himachal Pradesh is one of the northern states of India that lies between 30.377– 32.21 North and 75.74 – 79.07 East. It is a mountainous state with very high mountains to grasslands in plain (Figure 1). Great variations in elevation ranging from about 350m (1,148 ft) to 7,000m (22,966 ft) are found in the state. The variations are also observed in the climatic conditions. Hot and sub-humid tropical conditions were found in the southern tracts while, cold, alpine and glacial conditions in the northern and eastern mountain ranges with more elevation. The variability in rainfall was observed in the range of 1,500–3,000 mm. These variations in geo-climatic conditions of the state lead to greater biodiversity in the state. A total 66.52% of the area is covered with very dense evergreen to deciduous forests types. While, alpine shrub and meadows are found distributed in the west and northeastern Himalaya; alders, birches, rhododendrons, and moist alpine shrubs are regional vegetation. The plant pathogens including bacteria, fungi and viruses are also found due to these changeable geographical and climatic conditions of the state which are quite favourable for their growth and development.

MATERIALS AND METHODS

The information on rust fungi was gathered by investigating the following data sources: (1) mycological survey conducted on rust fungi from Himachal Pradesh during the years 2014 to 2018, and (2) all forms of published documentation and literature (Bilgrami et al. 1991; Jamaluddin et al. 2004). The names of some taxon in the obtained data have been replaced by currently accepted names as they were of out-of-date. The current usage of names was checked using the Index Fungorum (<http://www.indexfungorum.org/>) to adopt the generic and specific taxonomy in Species Fungorum (<http://www.speciesfungorum.org/>).

The plant samples found infected with rust fungi were collected during a mycological survey of various localities of Himachal Pradesh. Field observations of rust fungi on host plants and their photographs were

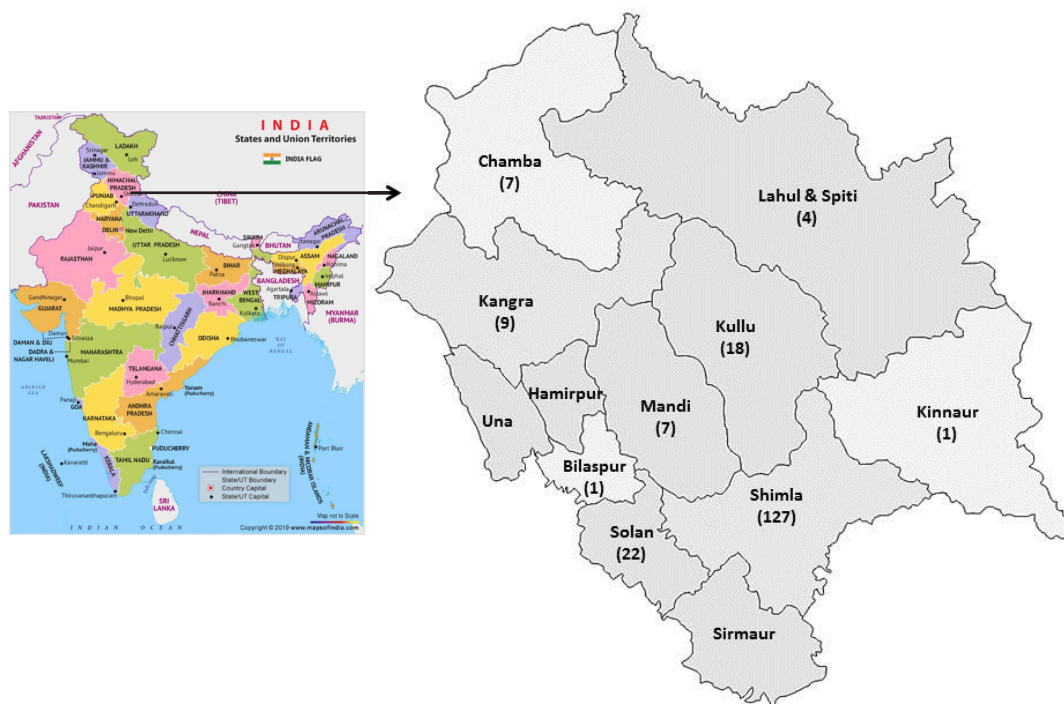


Figure 1. Himachal Pradesh showing district wise number of reports of rust fungi.

taken in natural conditions. Collected specimens were packed in paper bags and taken to the laboratory for further analysis. A few disease samples were used for morphological analysis of the rust fungi and the rest of the materials were dried for future microscopic studies. The air dried specimens were preserved in standard size herbarium packets and deposited at the Abhilashi University Mycological Herbarium (AUMH).

The microscopic mounts were prepared from fresh samples by brushing the rust powder into a drop of distilled water and lactophenol on microscopic slides, which were covered with cover slip and gently heated. The microscopic slides were analysed for spore dimensions like size, shape and ornamentations.

Both macro- and micro-morphological characters obtained from the laboratory were only used for taxonomic studies of the collected fungi. The fungal specimens were identified and their distribution records were checked by using standard literature (Cummins & Hiratsuka 2003; Mukerji & Manoharachary 2010). Illustrations are photographed under microscope equipped with digital camera.

RESULTS

As per the results obtained in the present study and from all sources of information, Himachal Pradesh has 167 species of rust fungi belonging to 23 genera and 11 families (Table 1). The largest family is Pucciniaceae (95 species) followed by *Phragmidiaceae* (14 species). Other families were reported to have species of rust fungi up to ten. However, 19 species of rust fungi with uncertain placement are placed in taxonomic group incertae sedis. *Aecidium*, *Chrysomyxa*, *Coleosporium*, *Frommea*, *Gymnosporangium*, *Kuehneola*, *Kweilingia*, *Melampsora*, *Monosporidium*, *Ochrospora*, *Peridermium*, *Phakopsora*, *Phragmidium*, *Pileolaria*, *Puccinia*, *Pucciniastrum*, *Pucciniostele*, *Ravenelia*, *Skierka*, *Uredinopsis*, *Uredo*, *Urocystis*, and *Uromyces* are the rust genera reported so far from Himachal Pradesh.

Present studies revealed that 170 plant species belonging to 52 families were found infected with rust fungi throughout the state. Thirty-five hosts of family Poaceae were highest to be found infected with these fungi followed by Ranunculaceae (16), Rosaceae (15), Asteraceae (11), Polygonaceae (7), Fabaceae, Salicaceae, Acanthaceae & Lamiaceae (6 each), Pinnaceae & Apiaceae (5 each), Rubiaceae (4), Saxifragaceae, Cyperaceae & Euphorbiaceae (3 each), and Berberidiaceae, Geraniaceae, Linaceae & Zinziberaceae

Table 1. Number of species of rust fungi in the families and genera in Himachal Pradesh.

Family	Genera	Number of species
Coleosporiaceae	<i>Chrysomyxa</i>	03
	<i>Coleosporium</i>	06
Cronartiaceae	<i>Peridermium</i>	06
	<i>Uredo</i>	07
Melampsoraceae	<i>Melampsora</i>	08
	<i>Ochrospora</i>	01
Phakopsoraceae	<i>Monosporidium</i>	02
	<i>Phakopsora</i>	02
	<i>Pucciniosteles</i>	01
	<i>Kweilingia</i>	01
Phragmidiaceae	<i>Frommea</i>	01
	<i>Kuehneola</i>	01
	<i>Phragmidium</i>	09
Pileolariaceae	<i>Pileolaria</i>	02
	<i>Skierka</i>	01
Pucciniaceae	<i>Gymnosporangium</i>	01
	<i>Puccinia</i>	80
	<i>Uromyces</i>	16
Pucciniastraceae	<i>Pucciniastrum</i>	01
	<i>Uredinopsis</i>	01
Raveneliaceae	<i>Ravenelia</i>	02
Urocystidaceae	<i>Urocystis</i>	01
Total (10)	21	148
Incertae sedis	<i>Aecidium</i>	12
	<i>Uredo</i>	07
Grand Total (11)	23	167

(2 each). The rest of the plant species were reported to be infected with a single rust fungus. The area-wise results revealed that most of the rust fungi (about 127) were reported from Shimla and nearby regions followed by Solan (22), Kullu (18), Kangra (9), Chamba & Mandi (7 each), Lahul & Spiti (4), and Kinnaur & Bilaspur (1 each).

The checklist of rust fungi from Himachal Pradesh, a hilly state of northern India.

Fungi

Basidiomycota Whittaker ex Moore

Pucciniomycetes Pucciniomycetes R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw.

Pucciniales Clem. & Shear

1. Family: *Coleosporiaceae* Dietel.

Genus: *Chrysomyxa* Unger., Beitr. vergleich. Pathologie: 24 (1840)

Type species: *Chrysomyxa abietis* (Wallr.) Unger (1840)

Chrysomyxa deformans (Diet.) Jacz., (Dietal 1890)

On *Pinaceae*—leaves of *Picea morinda*

Distribution: Shimla & Dalhausie

Chrysomyxa piceae Barclay, (Barclay 1890)

On *Pinaceae*—leaves of *Picea morinda*

Distribution: Narkanda & Mashobra

Chrysomyxa himalensis Barclay, (Butler 1905)

On *Ericaceae*—leaves of *Rhododendron arboreum*

Distribution: Shimla

Genus: *Coleosporium* Lév., Annl. Sci. Nat., Bot., sér. 3 8: 373 (1847)

Type species: *Coleosporium tussilaginis* (Pers.) Lév. (1849)

Coleosporium barclayense Bagchee, (Bagchee 1950; Sehgal et al. 1989; Puri 1955)

On *Pinaceae*—Fallen needles of *Pinus roxburghii* and *Pinus excelsa*

Distribution: Kullu and Shimla

Coleosporium campanulae (Pers.) Tul., (Barclay 1890; Sehgal et al. 1989)

On *Campanulaceae*—Leaves of *Campanula colorata*, needles of *Pinus roxburghii*

Distribution: Kasauli and Shimla

Coleosporium clematidis Barclay, (Barkley 1856; Sydow & Butler 1912)

On *Ranunculaceae*—leaves of *Clematis montana* and *Clematis buchnania*

Distribution: Shimla

Coleosporium leptodermidis (Barclay) P. Syd. & Syd., (Sydow & Butler 1912)

On *Ranunculaceae*—leaves of *Clematis montana*

Distribution: Shimla

Coleosporium plectranthi Barclay, (Cummins 1943)

On *Lamiaceae*—leaves of *Plectranthus geradianus*

Distribution: Shimla

Coleosporium senecionis (Pers.) Fr., (Sydow & Mitter 1933)

On *Asteraceae*—leaves of *Senecio graciliflorus*

Distribution: Shimla

2. Family: *Cronartiaceae* Dietel.

Genus: *Peridermium* (Link) J.C. Schmidt & Kunze,

Type species: *Peridermium californicum* Arthur & F. Kern (1914)

Peridermium brevius (Barclay) Sacc., (Barclay 1890)

On *Pinaceae*—Needles of *Pinus excelsa*

Distribution: Shimla

Peridermium cedri (Barclay) Sacc., (Barclay 1890)

On *Pinaceae*—needles of *Cedrus libani* var. *deodar*

Distribution: Shimla

Peridermium malayense Bagchee, (Sydow & Butler 1901)

On *Pinaceae*—branches of *Pinus longifolia*

Distribution: Shimla

Peridermium orientale Cooke., (Sydow & Butler 1901)

On *Pinaceae*—Needles of *Pinus longifolia*

Distribution: Shimla, Kangra, Kasauli (Solan)

Peridermium piceae (Barclay) Sacc., (Sydow & Butler 1901)

On *Pinaceae*—leaves of *Picea morinda*

Distribution: Shimla

Peridermium thomsonii (Berk.) Berk., (Cooke 1878)

On *Pinaceae*—leaves of *Picea morinda*

Distribution: Mahasu (Shimla), Kullu

3. Family: *Melampsoraceae* Dietel.

Genus: *Melampsora* Castagne (Image 1)

Type species: *Melampsora euphorbiae* (Ficinus & C. Schub.) Castagne (1843)

Melampsora ciliata Barclay, (Barclay 1891, Khan et al. 2004)

On *Salicaceae*—on leaves of *Populus ciliata*

Distribution: Shimla

Melampsora populnea (Pers.) P. Karst., (Syn. *Melampsora aecidioides* (DC) Schroet., *Melampsora rostrupii* G. Wagner) (Barclay 1891; Butler & Bisby 1931; Cummins 1943; Sharma & Sharma 2000)

On *Salicaceae*—on leaves of *Populus alba*, *Populus ciliata*

Distribution: Shimla

Melampsora euphorbiae (Ficinus & C. Schub.) Castagne, (Syn. *Melampsora helioscopiae* (Pers.) Vint.) (Sydow & Butler 1901)

On *Euphorbiaceae*—*Euphorbia pulcherrima* Wild. Ex. Klotz. and *Euphorbia helioscopia*

Distribution: Kangra

Melampsora hypericorum (DC.) J. Schröt., (Patil & Nayar

1936)

On *Hypericaceae*—leaves of *Hypericum* sp.

Distribution: Shimla

Melampsora caprearum Thüm., (syn. *Melampsora laricis-caprearum* Kleb.) (Sydow & Butler 1907)

On *Salicaceae*—leaves of *Salix daphnoides* and *Salix elegans*

Distribution: Dalhausie (Chamba) and Shimla

Melampsora lini (Ehrenb.) Lév., (Mishra 1963b, Mishra & Prasada 1966)

on *Linaceae*—leaves and stem of *Linum mysorensense* and *Linum grandiflorum*.

Distribution: Flowerdale, Shimla

Melampsora medusae Thum., (Paul et al. 2004).

On *Salicaceae*—leaves of *Populus deltoids*

Distribution: Kangra

Melampsora oblonga Bagchee, (Ranadive et al. 2012).

On *Pinaceae*—leaves of *Pinus excelsa*

Distribution: Mandi (Central H.P.)

Melampsora salicis-albae Kleb., (Sydow & Butler 1901)

On *Salicaceae*—Leaves of *Salix alba*

Distribution: Suket, Mandi

Melampsora rostrupii G. H. Wagner, (Syn. *M. aecidioides*, *M. populnea*) (Rehill & Puri 1980)

On *Salicaceae*—leaves of *Populus alba*

Distribution: Shimla.

Genus: *Ochrospora* Diet.

Type species: *Ochrospora sorbi* (G. Winter) Dietel (

Ochrospora sorbi (Oudem) Diet., (Arthur & Cummins 1933)

On *Ranunculaceae*—*Anemone* sp.

Distribution: Alwas (Chamba)

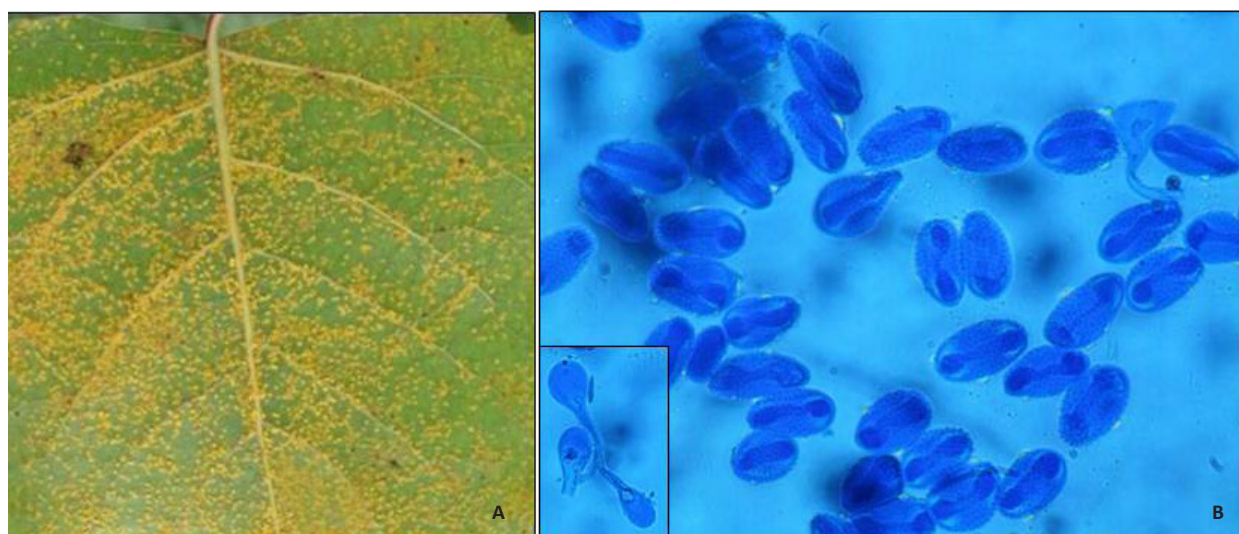


Image 1. *Melampsora populnea* on *Populus alba*: A—symptoms | B—urediniospore with paraphyses. © Ajay Kumar Gautam.

4. Family: Phakopsoraceae Cummins & Y. Hirats. f.,**Genus: Monosporidium Barclay**

Type species: *Monosporidium euphorbiae* Barclay ex Sacc. (1891)

Monosporidium andrachnes Barclay, (Barclay 1890)

On *Phyllanthaceae*—leaves of *Andrachne cordifolia*,

Distribution: Shimla & Kasuli (Solan)

Monosporidium euphorbiae Barclay ex Sacc., (Barclay 1890)

On *Euphorbiaceae*—leaves of *Euphorbia pilosa*

Distribution: Shimla

Genus: Kweilingia Teng

Type species: *Kweilingia bambusae* (Teng) Teng (1940)

Kweilingia divina (Syd.) Buriticá (Gautam & Avasthi 2018)

On *Poaceae*—leaves of *Dendroclamus strictus*

Distribution: Bilaspur

Genus: Phakopsora Dietel

Type species: *Phakopsora punctiformis* (Barclay & Dietel) Dietel (1898)

Phakopsora cronartiiformis Dietel, (Butler 1912)

On *Vitaceae*—leaves of *Vitis himalayana*

Distribution: Nachar, bashahr (Shimla)

Phakopsora punctiformis (Barclay & Dietel) Dietel, (Dietel 1890)

On *Rubiaceae*—leaves of *Galium aparine*

Distribution: Shimla

Genus: Pucciniostele Tranzschel & K.L. Kom.

Type species: *Pucciniostele clarkiana* (Barclay) Tranzschel & K.L. Kom. (1899)

Pucciniostele clarkiana (Barclay) Tranzschel & K.L. Kom., (Barclay 1890)

On *Saxifragaceae*—leaves of *Astilbe rivularis*

Distribution: Shimla

5. Family: Phragmidiaceae Corda**Genus: Frommea Arthur**

Type species: *Frommea obtusa* (F. Strauss) Arthur (1917)

Frommeella tormentillae (Fuckel) U. Braun, (syn.

Frommea obtusa (Str.) Arth.)

(Godre & Patwardhan 1965)

On *Rosaceae*—leaves of *Potentilla fragariae*

Distribution: Shimla

Genus: Kuehneola Magnus

Type species: *Kuehneola albida* (J.G. Kühn) Magnus (1898)

Kuehneola loeseneriana (Henn.) H.S. Jacks. & Holw., (syn. *Puccinia arthroxonis* (P. Henn.) Syd., P. Syd. & E.J.

Butler, (Golatkar 1976; Sharma & Sachan 1994)

On *Poaceae*—*Arthraxon prionodes*

Distribution: Kasauli Solan (H.P.).

Genus: Phragmidium Link (Image 2)

Type species: *Phragmidium mucronatum* (Pers.) Schltld. (1824)

Phragmidium kamtschatkae (H.W. Anderson) Arthur & Cummins, (syn. *Pucciniaroseae* Barclay; *Trolliomyces rosae* (Barclay) Ulbrich, *Teloconia rosae* (Barclay) Syd.) (Mundkar 1938; Pandotra & Ganguly 1964; Ulbrich 1939)

On *Rosaceae*—leaves and branches of *Rosa macrophylla*

Distribution: Shimla

Phragmidium barclayi Dietel, (Sydow & Butler 1907)

On *Rosaceae*—leaves of *Rubus lasiocarpus*

Distribution: Shimla

Phragmidium mucronatum (Pers.) Schltld., (syn. *Phragmidium disciflorum* (Tode) James.) (Cooke 1978)

On *Rosaceae*—*Rosa* sp.

Distribution: Kalatop forest, Chamba

Phragmidium incompletum Barclay, (Sydow & Butler 1901)

On *Rosaceae*—leaves of *Rubus paniculatus*

Distribution: Shimla

Phragmidium kamtschatke (Anders.) Arthur & Cummins, (Pandotra & Gaungly 1964)

On *Rosaceae*—leaves of *Rosa macrophylla*

Distribution: Narkanda, Shimla

Phragmidium laceianum Barclay, (Barclay 1891)

On *Rosaceae*—leaves of *Potentilla argrophylla*

Distribution: Narkanda, Bushahr (Shimla), Kullu

Phragmidium nepalense Barclay (Barclay 1891)

On *Rosaceae*—on leaves of *Potentilla nepalensis*,

Distribution: Mathiana, Shimla

Phragmidium octoloculare Barclay, (Barclay 1891)

On *Rosaceae*—leaves of *Rubus rosaefolius*

Distribution: Shimla

Phragmidium quinqueloculare Barclay, (Barclay 1890)

On *Rosaceae*—leaves of *Rubus biflorus*

Distribution: Shimla

Phragmidium rose-moschatae Dietel, (Mitter & Tandon 1938)

On *Rosaceae*—leaves of *Rosa moschata*

Distribution: Shimla & Kasauli

6. Family: Pileolariaceae Cummins & Y. Hirats.**Genus: Pileolaria Castagne (Image 3)**

Type species: *Pileolaria terebinthi* (DC.) Castagne (1842)

Pileolaria indica Syd., (Sydow 1938)

On *Anacardiaceae*—leaves of *Pistacia integerrima*



Image 2. *Phragmidium* sp. on *Rosa* sp.: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Distribution: Wangtu, Bushahr (Shimla)

Pileolaria pistaciae F. L. Tai & C. T. Wei, (Gautam & Avasthi 2017b)

On *Anacardiaceae*—leaves of *Pistacia integerrima*

Distribution: Balt (Mandi)

Genus: *Skierka* Racib. (Image 4)

Type species: *Skierka canarii* Racib. (1900)

Skierka himalayensis A. K. Gautam & S. Avasthi, (Gautam & Avasthi 2017b)

On *Anacardiaceae*—leaves of *Pistacia integerrima*

Distribution: Mandi

7. Family: *Pucciniaceae* Chevall.

Genus: *Gymnosporangium* R. Hedw. ex DC.,

Type species: *Gymnosporangium fuscum* DC. (1805)

Gymnosporangium cunninghamianum Barclay, (Barclay 1890)

On *Rosaceae*—leaves of *Pyrus pashia* and *Pyrus vasiocola*

On *Cupressaceae*—*Cupressus torulosa*

Distribution: Shimla

Genus: *Puccinia* Pers. (Images 5–11)

Type species: *Puccinia graminis* Pers. (1794)

Puccinia agrostidis Plowr., (Barclay 1891)

On *Ranunculaceae*—*Aquilegia vulgaris*

Distribution: Shimla

Puccinia ahmadiana Syd., (Sydow 1938)

On *Asteraceae*—*Pterotheca falconeri*

Distribution: Puti Ruhi, Lahul, Kullu Valley of Himachal Pradesh.

Puccinia porri (Sowerby) G. Winter, (syn. *Puccinia allii* (DC.) F. Rud.) (Butler & Bisby 1931; Singh & Sharma 1977, Bharat & Gupta 2011)

On *Amaryllidaceae*—*Allium sativum*

Distribution: Kullu, Shimla

Puccinia andropogonis Schwein., (Barclay 1890)

On *Poaceae*—*Andropogon tristis*

Distribution: Shimla

Puccinia graminis Pers., (syn. *Puccinia anthistiriae* Barclay) (Sydow & Butler 1912)

On *Poaceae*—*Anthistiria anathera*

Distribution: Shimla

Puccinia apii Desm., (Barclay 1890)

On *Apiaceae*—*Apium graveolens*

Distribution: Shimla

Puccinia arenariae (Schumacher) J. Schröt., (Barclay 1891)

On *Caryophyllaceae*—*Stellaria paniculata*

Distribution: Narkanda (Shimla)

Puccinia atropuncta Peck & Clint., (Chona et al. 1956)

On *Asteraceae*—*Prenanthes brunoniana*

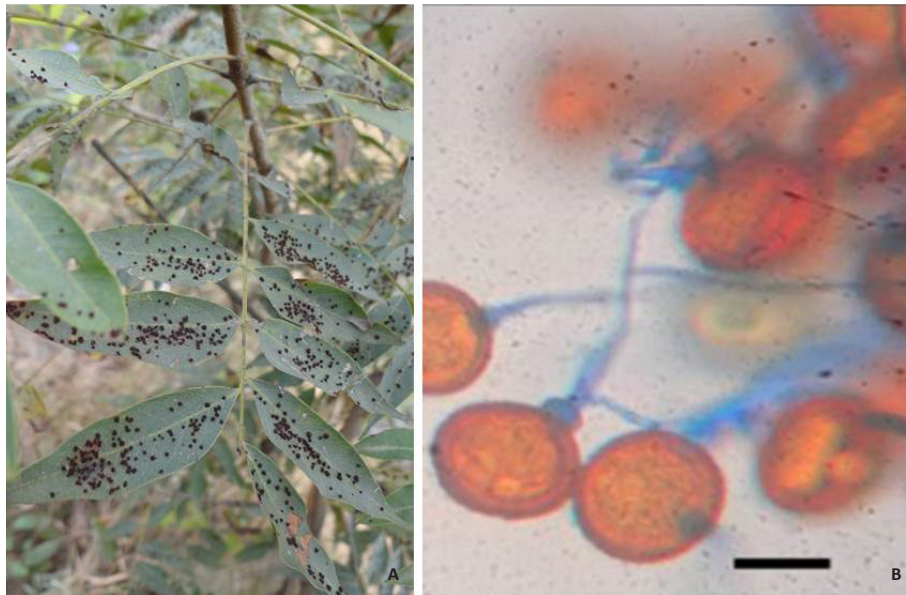


Image 3. *Pileolaria pistaciae*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.



Image 4. *Skierka himalayensis*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Distribution: Shimla

Puccinia bulbocastani (A. Cumino) Fuckel., (Bhardwaj & Sharma 1990)

On *Apiaceae*—on *Bunium persicum*

Distribution: Solan

Puccinia bistortae (F. Strauss.) DC., (Sydow 1938)

On *Polygonaceae*—*Polygonum viviparum*

Distribution: Losar, Spiti (Lahul & Spiti)

Puccinia brachypodii G.H. Otth., (Payak 1965)

On *Berberidaceae*—*Berberis aristata*

Distribution: Shimla

Puccinia bupleuri (Opiz) Rudolphi, (syn. *Pucciniabupleuri-falcati* (DC.) G. Wint. (Barclay 1890)

On *Apiaceae*—*Bupleurum falcatum*

Distribution: Shimla

Puccinia calthae Link, (Arthur & Cummins 1933; Chona et al. 1956)

On *Ranunculaceae*—*Caltha palustris* var. *alba*

Distribution: Dhramshala (Kangra); Rohtang pass (Kullu)

Puccinia caricis var. *himalayensis* Barclay, (Butler & Bisby 1931; Padwick & Khan 1944)

On *Cyperaceae*—*Carex setigera*

Distribution: Shimla

Puccinia caricis-filicinae Barclay, (Mitter & Tandon 1938)

On *Cyperaceae*—*Carex filicina*

Distribution: Shimla

Puccinia caricis-nubigenae Padwick & A. Khan, (Mitter & Tandon 1938)

On *Cyperaceae*—*Carex nubigena*

Distribution: Kufri, Shimla

Puccinia carthami Corda, (Sydow & Butler 1901)

On *Asteraceae*—*Carthamus oxycantha*

Distribution: Kangra

Puccinia chrysopogoni Barclay, (Barclay 1890; Sydow &

- Butler 1907)
 Oleaceae—*Jasminum humile*
 Poaceae—*Chrysopogon gryllus*
 Distribution: Shimla
Puccinia circaeae Pers., (Barclay 1890)
 On *Onagraceae*—*Circaea alpina*
 Distribution: Shimla
Puccinia colletiana Barclay, (Barclay 1890; Ganguly & Pandotra 1963)
 On *Rubiaceae*—*Rubia cordifolia*
 Distribution Shimla, Kasauli (Solan), Naggar (Kullu)
Puccinia coronata Corda, (syn. *Puccinia coronata* var. *avenae* P. Syd. & Syd.) (Mishra et al. 1964)
 On *Poaceae*—*Avena sativa*
 Distribution: Shimla
Puccinia cousiniae P. Syd. & Syd., (Padwick 1945)
 On *Poaceae*—*Coursinia thomsoni*
 Distribution: Spiti (Lahul & Spiti)
Puccinia cynodontis Lacroix ex Desm., (Sharma & Sachan 1994)
 On *Poaceae*—*Cynodon dactylon*
 Distribution: Solan
Puccinia dactylidina Bubák, (Sydow & Butler 1912)
 On *Poaceae*—*Dactylis glomerata*
 Distribution: Shimla
Puccinia dioscoreae Kom., (Pandotra & Ganguly 1962)
 On *Dioscoreaceae*—*Dioscorea deltoidea*
 Distribution: Manali
Puccinia duthiei Ellis & Tracy, (Sydow & Butler 1911)
 On *Poaceae*—*Andropogon pertusus*
 Distribution: Kasauli (Solan)
Puccinia ellisii De Toni, (Barclay 1891)
 On *Apiaceae*—*Angelica glauca*
 Distribution: Phagu, Shimla
Puccinia eremuri Kom., (Barclay 1891)
 On *Xanthorrhoeaceae*—*Eremurus himalaicus*
 Distribution: Kullu
Puccinia erianthi Padwick & A. Khan, (Padwick & Khan 1944)
 On *Poaceae*—*Erianthus fulvus*
 Distribution: Shimla
Puccinia eulaliae Barclay, (Butler & Bisby 1960)
 On *Poaceae*—*Pollinia japonica*
 Distribution: Reported from Shimla (H.P.) only.
Puccinia excelsa Barclay, (Barclay 1891)
 On *Lamiaceae*—*Phlomis bracteosa*
 Distribution: Mahasu & Huttoo Peak, Shimla
Puccinia fagopyri Barclay, (Barclay 1890)
 On *Polygonaceae*—*Fagopyrum esculentum*
 Distribution: Shimla, Sangla valley (Kinnaur)
Puccinia flavipes Syd. & P. Syd., (Barclay 1890)
 On *Rosaceae*—*Fragaria vesca*
 Distribution: Shimla
Puccinia gentianae (F. Strauss.) Link, (Barclay 1890)
 On *Gentianaceae*—*Gentiana kurroo*
 Distribution: Shimla
Puccinia geranii-silvatici P. Karst., (Barclay 1890)
 On *Geraniaceae*—*Geranium nepalense*
 Distribution: Shimla
Puccinia striiformis Westend, (syn. *Puccinia glumarum* (Schw.) Eriks & P. Henn.) (Prasada 1948)
 On *Poaceae*—*Brachypodium sylvaticum*
 Distribution: Shimla
Puccinia graminis Pers., (Barclay 1890a)
 On *Poaceae*—*Festuca gigentia*
 Distribution: Shimla, Kullu
Puccinia graminis-agropyri P.R. Mehta & R. Prasad, (Prasada 1948)
 On *Poaceae*—*Agropyron semicostatum*
 Distribution: Shimla
Puccinia graminis-poa Erikss. & Henning, (Prasada 1948)
 On *Poaceae*—*Poa nemoralis*
 Distribution: Shimla
Puccinia himalensis (Barclay) Dietel, (Padwick 1946; Sydow & Butler 1906 & 1907)
 On *Poaceae*—*Festuca gigentia*
 Distribution: Shimla
Puccinia himachalensis A.K. Gautam and S. Avasthi, (Gautam & Avasthi 2016a)
 On *Ranunculaceae*—*Clematis grata*
 Distribution: Mandi
Puccinia invenusta Syd. & P. Syd., (Sharma & Sachan 1994)
 On *Poaceae*—*Phramites karka*
 Distribution: Solan
Puccinia iridis Wallr., (Sydow & Butler 1912)
 On *Iridaceae*—*Iris florentina*
 Distribution: Shimla
Puccinia komarovii Tranzschel ex P. Syd. & Syd., (Khanna 1961)
 On *Balsaminaceae*—*Impatiens amphorata*
 Distribution: Shimla
Puccinia leptodermidis Barclay, (Barclay 1890; Sydow & Butler 1912)
 On *Rubiaceae*—*Leptodermis lenceolata*
 Distribution: Shimla, Kasauli (Solan)
Puccinia menthae Pers., (Pandotra & Ganguly 1964; Sydow & Butler 1912; Sydow 1938)
 On *Lamiaceae*—*Mentha longifolia*
 Distribution: Busher, Shimla, Kasauli, Kullu
Puccinia minutissima Arthur, (Munjel & Gill 1962)

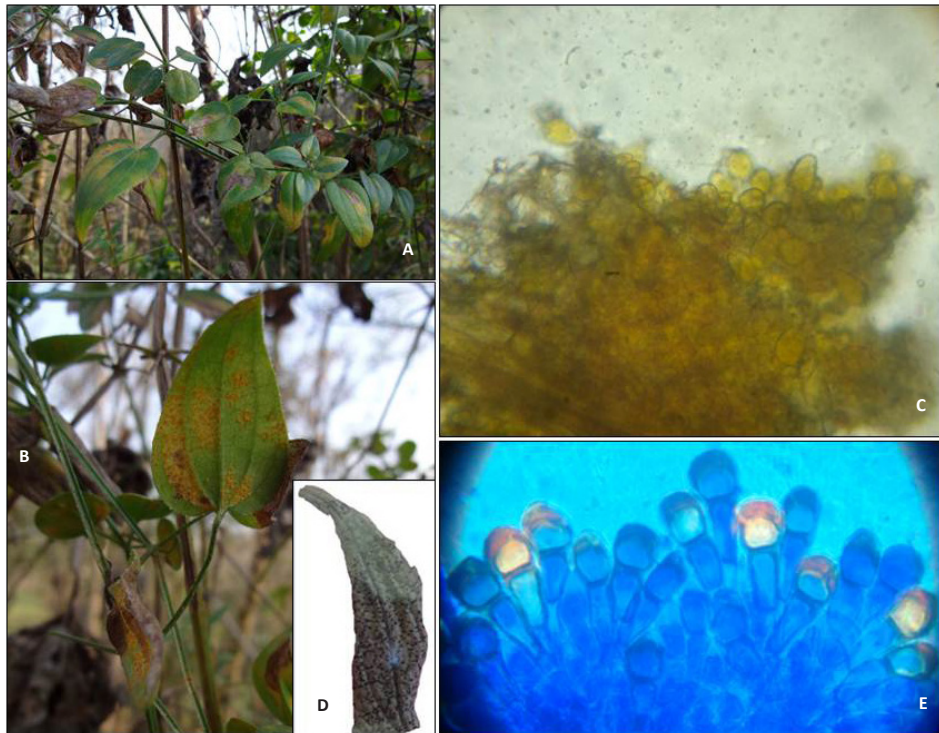


Image 5. *Puccinia collettiana*: A—habitat of host | B, C—symptoms | D—urediniospores | E—teliospores. © Ajay Kumar Gautam.

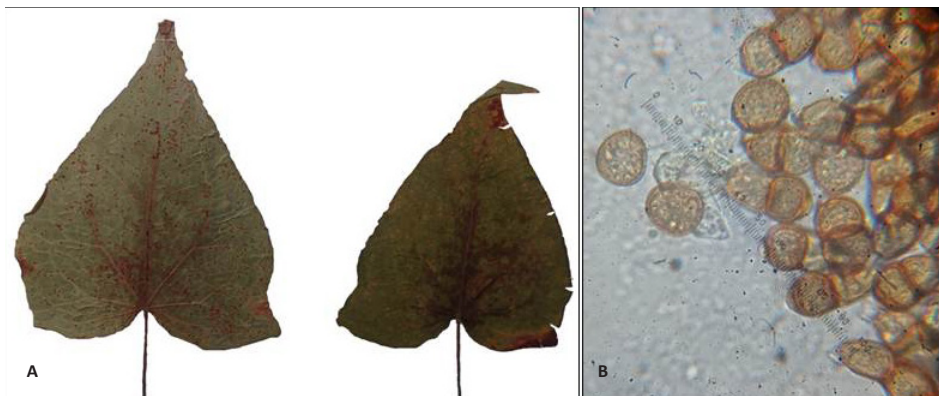


Image 6. *Puccinia fagopyri*: A—symptoms | B—urediniospores & teliospores. © Ajay Kumar Gautam.

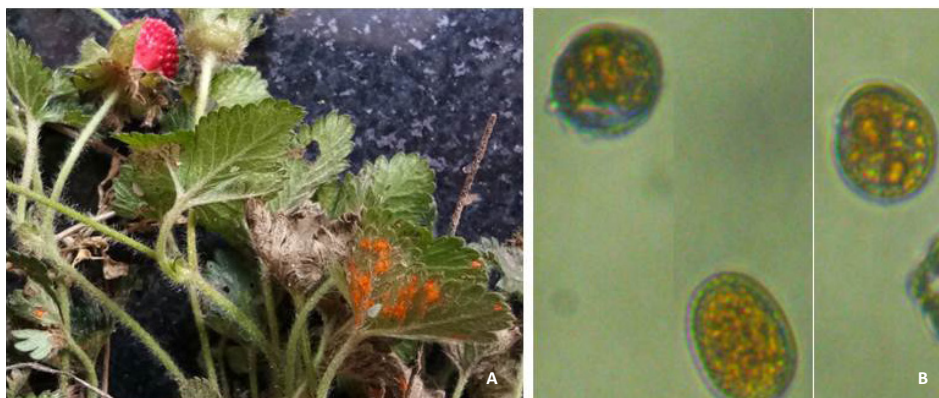


Image 7. *Puccinia flavipes*: A—symptoms | B—urediniospores. © Ajay Kumar Gautam.

On *Poaceae*—*Saccharum officinarum*

Distribution: Manali

Puccinia nepalensis Barclay & Dietel, (Barclay 1890; Ramakrishnan 1952)

On *Polygonaceae*—*Rumex nepalensis*

Distribution: Shimla and Kasauli

Puccinia neyraudiae Syd. & P. Syd., (Sharma & Sachan 1994)

On *Poaceae*—*Neyraudia arundinacea*

Distribution: Solan

Puccinia nitida (F. Strauss) Barclay, (Sydow & Butler 1912)

On *Polygonaceae*—*Polygonum amplexicaule*

Distribution: Mashobra, Shimla, Rohtaang Pass

Puccinia opizii Bubák, (Arthur & Cummins 1933)

On *Asteraceae*—*Lactuca decipiens*

Distribution: Alwas (Chamba)

Puccinia pacifica Blasdale ex Arthur, (Chona et al. 1956)

On *Plantaginaceae*—*Plantago tibetica*

Distribution: Shimla

Puccinia recondita Roberge ex Desm., (syn.

Pucciniapersistens Plowr., *Pucciniarubigo-vera* (DC.) G. Winter) (Arthur & Cummins 1933; Barclay 1890; Jain et al. 1966)

On *Ranunculaceae*—*Aquilegia vulgaris*, *Thalictrum javanicum*, *Thalictrum minus*

Distribution: Shimla, Dharamshala, Chamba, Kote, Keylog, Kullu

Puccinia pimpinellae (F. Strauss) Link, (Barclay 1890)

On *Apiaceae*—*Pimpinella diversifolia*

Distribution: Shimla

Puccinia polliniae Barclay, (Barclay 1890)

On *Acanthaceae*—*Pollinia nuda*

Distribution: Shimla

Puccinia pogonatheri Petch, (Sharma & Sachan 1994)

On *Poaceae*—*Pogonatherum paniceum*

Distribution: Solan

Puccinia polygoni-amphibii Pers., (Syn. *Pucciniapolygone* Alb. & Schw.)(Ganguly & Pandotra 1963, Mishra & Sharma 1964)

On *Polygonaceae*—*Polygonum orientale*

Distribution: Shimla, Katrain (Kullu)

Puccinia prainiana Barclay, (Barclay 1890)

On *Smilacaceae*—*Smilax aspera*

Distribution: Shimla

Puccinia punctata Link, (Barclay 1890)

On *Rubiaceae*—*Galium aparine*

Distribution: Shimla

Puccinia purpurea Cooke, (Sharma & Sachan 1994)

On *Poaceae*—*Sorghum halepense*

Distribution: Solan

Puccinia pusilla Syd. & P. Syd., (Sharma & Sachan 1994)

On *Poaceae*—*Cappilipedium assimite*

Distribution: Solan

Puccinia recondita var. *simlensis* A.P. Misra, S.T. Ahmad & Sheodh. Singh, (Gupta 1977)

On *Ranunculaceae*—*Thalictrum javanicum*,

On *Poaceae*—*Helicotrichon virens*

Distribution: Shimla

Puccinia roscoae Barclay, (Gupta 1977)

On *Zingiberaceae*—*Roscoea alpina*, *Roscoea procera*

Distribution: Shimla

Puccinia saviculae Grev., (Barclay 1890)

On *Apiaceae*—*Savicula europea*

Distribution: Shimla

Puccinia saxifragae-cilliatiae Barclay, (Barclay 1890)

On *Saxifragaceae*—*Saxifraga ligulata*

Distribution: Shimla

Puccinia heucherae (Schweinitz) Dietel, (syn. *Puccinia saxifragae-micranthae* Barclay) (Barclay 1891)

On *Saxifragaceae*—leaves of *Saxifraga micrantha*

Distribution: Bushar & Shimla

Puccinia sonchi Roberge ex Desm., (Sydow 1938)

On *Asteraceae*—*Sonchus* sp.

Distribution: Kullu

Puccinia sorghi Schwein., (Anonymous 1950; Mishra 1963a)

On *Poaceae*—*Zea maize*

On *Oxalidaceae*—*Oxalis conriculata*

Distribution: Mashobra & Shimla

Puccinia striiformis Westend., (Vasudeva 1958; Joshi & Merchand 1963; Mishra et al. 1965, 1975; Ahmad et al. 1969)

On *Poaceae*—*Muehlenbergia huegelii*; *Bromus japonicus* and *Lolium perenne*

Distribution: Shimla

Puccinia striiformis f. *muehlenbergii* Misra & Lele., (Mishra & Lele 1963)

On *Poaceae*—*Muehlenbergia huegelii*

Distribution: Shimla

Puccinia tanacetii DC., (Sharma & Sachan 1994; Bharat 2008)

On *Asteraceae*—*Artemisia nilagirica*

Distribution: Solan

Puccinia thlaspeos Ficus & C. Schub., (Arthur 1934; Arthur & Cummins 1933)

On *Brassicaceae*—*Draba lanceolata*

Distribution: Hunan Nallah, Pangi & Chamba

Puccinia tiliaefolia T.S. Ramakr. & Sundaram, (Gautam & Avasthi 2017c)

On *Malvaceae*—*Grewia tiliifolia*

Distribution: Mandi

Puccinia tricholepidis Syd., (Sydow 1938)

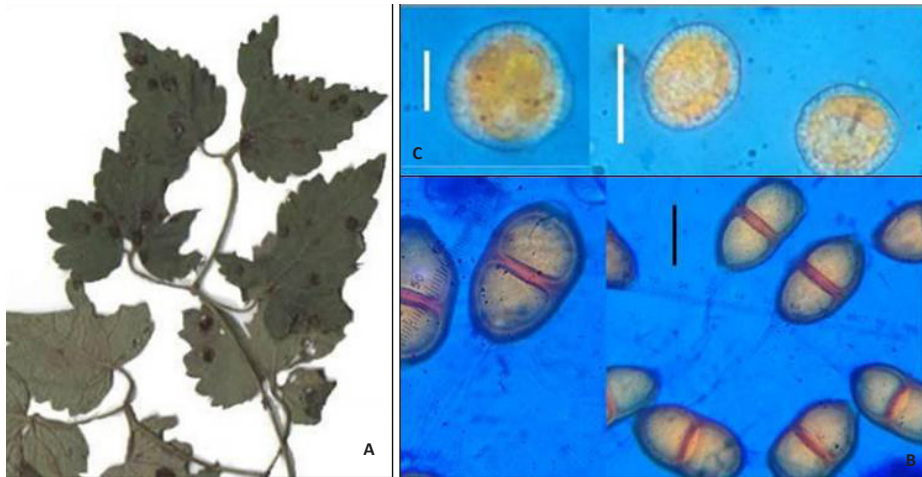


Image 8. *Puccinia himachalensis*: A—symptoms | B—teliospores | C—urediniospores. © Ajay Kumar Gautam.

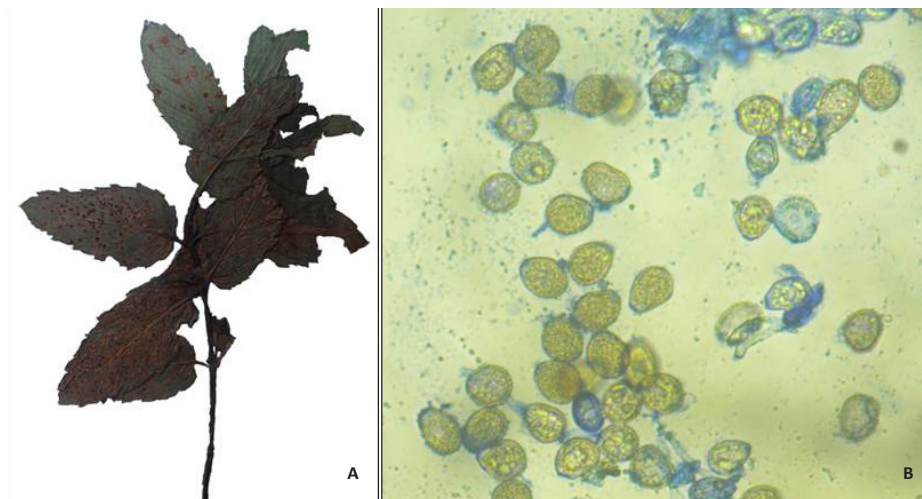


Image 9. *Puccinia menthae*: A—symptoms | B—urediniospores. © Ajay Kumar Gautam.

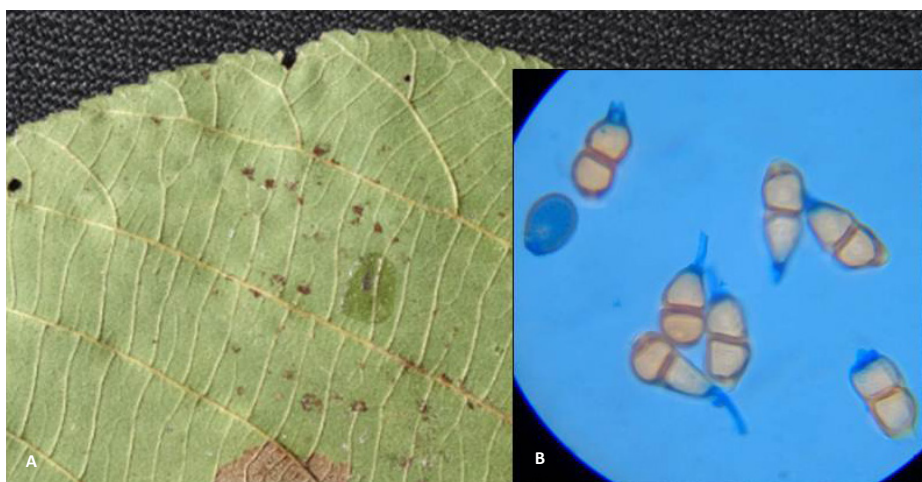


Image 10. *Puccinia tiliaefolia*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

On Asteraceae—*Tricholepis elongata*
 Distribution: Saharan & Bushar
Puccinia trifolii R. Hedw., (Arthur & Cummins 1933)
 On Ranunculaceae—*Anemone polyanthes*
 Distribution: Alwas, Chamba
Puccinia tweediana T.S. Ramakr. & K. Ramakr., (Chona & Munjal 1955;
 Ramakrishnan & Ramakrishnan 1948)
 On Acanthaceae—*Dicliptera* sp., *D. bupleuroides*
 Distribution: Kullu, Shimla
Puccinia urticae Barclay, (Barclay 1890)
 On Urticaceae—*Urtica parviflora*
 Distribution: Shimla & Kasauli
Puccinia ustalis Berk., (Berkeley 1856)
 On Ranunculaceae—leaves of *Ranunculus hirtellus*
 Distribution: Mathana, Shimla
Puccinia violae (Schumach.) DC., (Bilgrami 1963)
 On Violaceae—*Viola serpens*.
 Distribution: Shimla
Puccinia wattiana Barclay, (Sharma & Sachan 1994)
 On Ranunculaceae—*Clematis gouriana*
 Distribution: Shimla

Genus: *Uromyces* (Link) Unger (Image 12)

Type species: *Uredo appendiculata* Pers. (1796)
Uromyces trifolii (R. Hedw.) Lév., (Syn. *Uromyces flectens* Lagerh., *Uromyces nerviphilus* (Grognot) Hotson) (Gautam & avasthi 2017a)
 On Fabaceae—leaves of *Trifolium repens* L.,
 Distribution: Chail Chowk, Mandi
Uromyces viciae-fabae (Pers.) J. Schröt. (syn. *Uromyces fabae* (Pers.) de Barry. (Kulshreshtha et al. 1998)
 On Fabaceae—leaves of *Vigna radiata* (L.)
 Distribution: Shimla
Uromyces agropyri Barclay, (Barclay 1891)
 On Poaceae —*Agropyron* sp.
 Distribution: Bushahr (Shimla)
Uromyces dactylidis G.H. Otth (Syn. *Puccinia lycoctoni* Fuckel) (Sydow & Butler 1907)
 On Ranunculaceae—*Aconitum lycoctonum*
 Distribution: Shimla
Uromyces ciceris-arietini (Grognot.) Jacz. & G. Boyer, (Payak 1962)
 On Fabaceae—*Trigonella polyerata*
 Distribution: Shimla
Uromyces appendiculatus (Pers.) Link, (Sydow & Butler 1912)
 On Fabaceae—*Vigna vexillata*
 Distribution: Dhramshala
Uromyces macintirianus Barclay, (Sydow & Butler 1938)
 On Acanthaceae—leaves of *Hemigraphis latebrosa*



Image 11. *Puccinia wattiana*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

Distribution: Shimla
Uromyces hobsonii Vize, (Sydow & Butler 1907)
 On Oleaceae—leaves of *Jasminum grandiflorum*
 Distribution: Shimla
Uromyces polygoni-avicularis var. *polygoni-avicularis* (Pers.) P. Karst., (Sydow 1938)
 On Polygonaceae—leaves of *Polygonum cogatum*
 Distribution: Lahul Valley (L&S), Kullu
Uromyces rottboelliae Arthur, (Sydow & Butler 1938)
 On Poaceae—*Rottboellia speciosa*
 Distribution: Shimla
Uromyces sommerfeltii Hyl., Jorst. & Nannf., (Barclay 1890)
 On Asteraceae—*Solidago virgaurea*
 Distribution: Shimla
Uromyces strobilanthis Barclay, (Mitter & Tandon 1938)
 On Acanthaceae—*Strobilanthes dalhausianus*
 Distribution: Shimla
Uromyces valerianae-wallichii (Dietel) Arthur & Cummins, (Arthur & Cummins 1933)

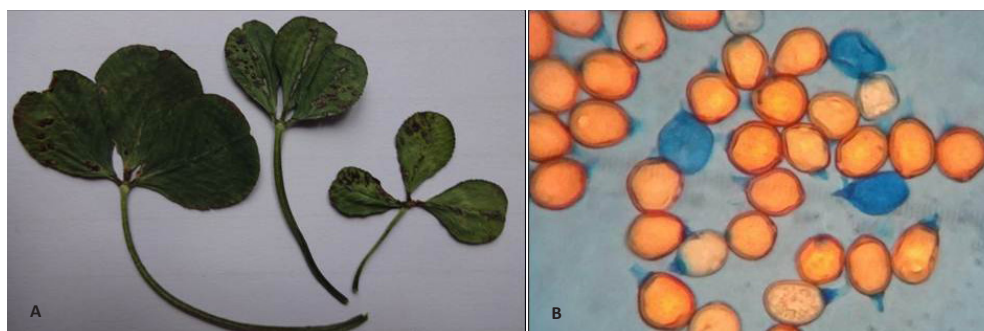


Image 12. *Uromyces trifolii*: A—symptoms | B—teliospores. © Ajay Kumar Gautam.

On *Caprifoliaceae*—leaves of *Valeria nawallichii*,

Distribution: Shimla

Uromyces vignae Barclay, (Barclay 1891)

On *Fabaceae*—*Vigna vexillata*

Distribution: Shimla

Uromyces vossiae Barclay, (Barclay 1890)

On *Poaceae*—*Vossia speciosa*

Distribution: Shimla

Genus: *Haplotelium* Syd.

Type species: *Haplotelium amoenum* (Syd. & P. Syd.) Syd. (1922)

Haplotelium ambiens (Cooke) Syd., (syn. *Uromyces ambiens* Cooke) (Barclay 1891, Sydow 1913)

On *Buxaceae*—*Buxus sempervirens*

Distribution: Bushahr (Shimla)

8. *Pucciniastraceae* Gäum. ex Leppik 1972

Genus: *Pucciniastrum* G.H. Otth

Type species: *Pucciniastrum epilobii* (Pers.) G.H. Otth (1861)

Pucciniastrum agrimoniae (Dietel) Tranzschel, (Sydow & Butler 1901; Sydow & Butler 1912)

On *Rosaceae*—leaves of *Agrimonia eupatoria*

Distribution: Shimla

Genus: *Uredinopsis* Magnus

Type species: *Uredinopsis filicina* (Niessl) Magnus (1893)

Uredinopsis syngammes Munjal & J.N. Kapoor., (Munjal & Kapoor 1961)

On *Pteridaceae*—Leaves of *Syngamme fraxiana* Bedd.

Distribution: Narkanda

9. *Urocystidaceae* Begerow, R. Bauer & Oberw.

Genus: *Urocystis* Rabenh. ex Fuckel

Type species: *Urocystis occulta* (Wallr.) Rabenh. (1867)

Urocystis sorosporioides Körn. ex Fuckel, (Mundkar & Thirumalachar 1952)

On *Ranunculaceae*—leaves and stem of *Delphinium*

denudatum

Distribution: Shimla

10. *Raveneliaceae* Leppik

Genus: *Ravenelia* Bark.

Type species: *Ravenelia glanduliformis* Berk. & M.A. Curtis (1874)

Ravenelia mitis Syd. & P. Syd. (Sydow & Sydow 1904-21)

On *Fabaceae*—leaves of *Tephrosia purpurea*

Distribution: Solan

Ravenelia tandonii Syd. (Bakshi & Singh)

On *Fabaceae*—leaves of *Acacia catechu*

Distribution: Solan.

Incertae sedis

Genus: *Aecidium* Pers.

Type species: *Aecidium berberidis* Pers. ex J.F. Gmel. (1792)

Aecidium cunninghamianum Barclay, (Barclay 1891)

on *Rosaceae*—leaves of *Cotoneaster bacillaris* Wall.

Distribution: Shimla

Aecidium flavescens Barclay, (Barclay 1891)

on *Asteraceae*—leaves of *Senecio rufinervis* DC.

Distribution: Mashobra, Shimla

Aecidium infrequens Barclay, (Sydow & Butler 1912)

on *Geraniaceae*—leaves of *Geranium nepalense*

Distribution: Shimla

Aecidium leucospermum DC., (Barclay 1890)

on *Ranunculaceae*—leaves of *Anemone rivularis*

Distribution: Shimla

Aecidium lophanthi P. Henn., (Arthur & Cummins 1933)

on *Lamiaceae*—leaves of *Mentha* sp.

Distribution: Chamba

Aecidium montanum E.J. Butler, (Arthur & Cummins 1933)

On *Berberidaceae*—leaves of *Berberis lyceum*

Distribution: Kangra

Aecidium mori Barclay, (Barclay 1890)

On *Moraceae*—leaves of *Morus alba*

Distribution: Shimla

Aecidium myriactidis (Barclay) Syd. & P.Syd., (Barclay 1890)

On *Asteraceae*—leaves of *Myriactis nepalensis*

Distribution: Mashobra (Shimla)

Aecidium orbiculare Barclay, (Barclay 1891)

On *Ranunculaceae*—leaves of *Clematis grata*

Distribution: Shimla

Aecidium peristrophes Syd. & P. Syd., (Sydow & Butler 1912)

On *Acanthaceae*—leaves of *Peristrophe* sp.

Distribution: Kangra

Aecidium plectranthi Barclay, (Barclay 1890)

On *Lamiaceae*—leaves of *Plectranthus coetsa*

Distribution: Shimla

Aecidium withaniae Thuem., (Sydow & Butler 1912)

On *Solanaceae*—leaves of *Withania coagulans*

Distribution: Shimla

Genus: *Uredo* Pers.

Type species: *Uredo betae* Pers. (1801)

Uredo apludae Barclay, (Barclay 1890)

On *Poaceae*—leaves of *Apluda aristata*

Distribution: Shimla

Uredo duetziae Barclay, (Butler & Bisby 1960)

On *Hydrangeaceae*—leaves of *Deutzia corymbosa*

Distribution: Shimla

Uredo lebrookiana Barclay, (Watt), (Butler & Bisby 1960)

On *Lamiaceae*—leaves of *Colebrookea oppositifolia*,

Distribution: Suni, near Simla

Uredo gomphrenae Barclay, (Sydow & Butler 1907)

On *Amaranthaceae*—leaves & stem of *Gomphrena globosa*

Distribution: Shimla

Uredo ignobilis Syd. & P. Syd., (Pedwick & Khan 1944)

On *Poaceae*—leaves of *Sporobolus indicus*

Distribution: Shimla

Uredo pileae Barclay, (Barclay 1891)

On *Poaceae*—leaves of *Sporobolus trinervia*

Distribution: Shimla

Uredo valerianae-wallichii Dietel, (Barclay 1891)

On *Caprifoliaceae*—leaves of *Valeriana wallichii*,

Distribution: Shimla

DISCUSSION

The present study provides the checklist of rust fungi from Himachal Pradesh, a northwestern Himalayan State of India. A remarkable diversity of rust fungi have been reported from the state which has an area of 55,673 km². The state exhibits marked variations in climate and vegetation and so far in fungal diversity. The available information about rust fungi from the state is in general meager and there is much scope for exploratory work on the taxonomy, diversity and ecological aspects of these fungi. There are about 167 species, 23 genera belonging to 11 families recorded from this hilly Himalayan state, with great variations in host infected (about 171 plant species belonging to 121 genera and 52 families). This distinguished diversity of rust fungi may be due to the fact that rust fungi tend to prefer humid habitats, which is one of the major characteristic features of the state. Being obligate parasites, rust fungi are associated with spreading and development of nutrient plants and are found in many belts, both on herbaceous plants, and on trees and shrubs.

After compilation of literature it is observed that most of the rust fungi were reported from Shimla and nearby regions. Although, these fungi are also reported from other districts of the state but the scope of exploration of these fungi and their host range is still there.

Two checklists on two major rust genera namely, *Puccinia* (Gautam & Avasthi 2016b) *Uromyces* (Gautam & Avasthi 2017a) have recently been published from this hilly state. Two new species of rust fungi namely *Puccinia himachalensis* (Gautam & Avasthi 2016a) and *Skierka himalayensis* (Gautam & Avasthi 2017b) have been reported from the state which are new to science. Whereas, *Pileolaria pistaciae* (Gautam & Avasthi 2017b), *Kweilingia divina* (Gautam & Avasthi 2018) are the new additions to the mycobiota of the state while, *Puccinia tiliaefolia* (Gautam & Avasthi 2017c) has been rediscovered after 46 years from India. During the literature survey we did not come across any molecular studies conducted on rust fungi from the state. As per greater phytodiversity of the state, studies on the rust fungi are inadequate and there is vast scope to conduct studies and fill the data gaps. Molecular studies of rust fungi are still required besides morphological taxonomy, which will not only help in revision and reassessment of the existing fungal species, but also to find their correct taxonomic position. The knowledge generated by the work is of immense utility as it is a key to revealing the diversity and ecology of rust fungi from Himachal Pradesh Himalaya.

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Announcement

The Sally Walker Conservation Fund -- an appeal for support
– P. 14787

Communications

Complementary bat (Mammalia: Chiroptera) survey techniques uncover two new country records for Nigeria

– Iroro Tanshi, Anthony Ekata Ogbeibu & Paul Jeremy James Bates, Pp. 14788–14801

Bone fractures in roadkill Northern Tamandua *Tamandua mexicana* (Mammalia: Pilosa: Myrmecophagidae) in Costa Rica

– Randall Arguedas, Elisa C. López & Lizbeth Ovaes, Pp. 14802–14807

***Barilius torsai* (Teleostei: Cypriniformes: Cyprinidae), a new freshwater fish from the Brahmaputra drainage, India**

– Kavita Kumari, Manas Hoshalli Munivenkatappa, Archana Sinha, Simanku Borah & Basanta Kumar Das, Pp. 14808–14815

Butterfly diversity throughout Midnapore urban area in West Bengal, India

– Surjyo Jyoti Biswas, Debarun Patra, Soumyajit Roy, Santosh Kumar Giri, Suman Paul & Asif Hossain, Pp. 14816–14826

Plant and fungi diversity of Devi Pindiyan Valley in Trikuta Hills of northwestern Himalaya, India

– Sajjan Thakur, Harish Chander Dutt, Bikarma Singh, Yash Pal Sharma, Nawang Tashi, Rajender Singh Charak, Geeta Sharma, Om Prakash Vidyarthi, Tasir Iqbal, Bishander Singh & Kewal Kumar, Pp. 14827–14844

A checklist of rust fungi from Himachal Pradesh, India

– Ajay Kumar Gautam & Shubhi Avasthi, Pp. 14845–14861

The distribution of blue-green algae (Cyanobacteria) from the paddy fields of Patan and Karad tehsils of Satara District, Maharashtra, India

– Sharada Jagannath Ghadage & Vaneeta Chandrashekhar Karande, Pp. 14862–14869

Short Communications

***Cordia diffusa* K.C. Jacob, the Kovai Manjack (Boraginaceae): a highly threatened steno-endemic species from Coimbatore City, Tamil Nadu, India**

– S. Arumugam, K. Sampath Kumar, B. Karthik & V. Ravichandran, Pp. 14870–14875

New distribution records in the orchid flora of Tripura, India

– Arjun Adit, Monika Koul & Rajesh Tandon, Pp. 14876–14885

Notes on the extended distribution of *Humboldtia bourdillonii* (Fabales: Fabaceae), an Endangered tree legume in the Western Ghats, India

– Anoop P. Balan, A.J. Robi & S.V. Predeep, Pp. 14886–14890

Notes

Vertebrate prey handling in the Indian Grey Hornbill *Ocyroceros birostris* (Aves: Bucerotiformes: Bucerotidae)

– James A. Fitzsimons, Pp. 14891–14894

Impact of cyclone Fani on the breeding success of sandbar-nesting birds along the Mahanadi River in Odisha, India

– Subrat Debata, Pp. 14895–14898

First record of the micromoth *Ethmia lineatonotella* (Moore, 1867) (Lepidoptera: Depressariidae: Ethmiinae) from Bhutan

– Jatishwor Singh Irungbam & Meenakshi Jatishwor Irungbam, Pp. 14899–14901

Additional distribution records of the rare Nepal Comma *Polygonia c-album agnicula* (Moore, 1872) (Insecta: Lepidoptera: Nymphalidae) from Rara National Park, Nepal

– Sanej Prasad Suwal, Biraj Shrestha, Binita Pandey, Bibek Shrestha, Prithivi Lal Nepali, Kaashi Chandra Rokaya & Bimal Raj Shrestha, Pp. 14902–14905

A new distribution record of the gall midge *Octodiplosis bispina* Sharma (Diptera: Cecidomyiidae) from the Western Ghats of Tamil Nadu, India

– Duraikannu Vasanthakumar, Radheshyam Murlidhar Sharma & Palanisamy Senthilkumar, Pp. 14906–14907

New recruitment of staghorn corals in the Gulf of Mannar - the emergence of a resilient coral reef

– Koushik Sadhukhan, Ramesh Chatragadda, T. Shanmugaraj & M.V. Ramana Murthy, Pp. 14908–14911

New records of coral diseases in the Persian Gulf

– Parviz Tavakoli-Kolour & Sanaz Hazraty-Kari, Pp. 14912–134913

***Crepidium aphyllum* (Orchidaceae), a new record from Bhutan**

– Kinley Rabgay & Pankaj Kumar, Pp. 14914–14916

Rediscovery, after over a century, of the endemic climbing vine *Argyria lawii* (Convolvulaceae) from the Western Ghats of India

– Pramod R. Lawand, Rajaram V. Gurav & Vinod B. Shimpale, Pp. 14917–14920

***Linostoma decandrum* (Roxb.) Wall. ex Endl. (Thymelaeaceae): an addition to the flora of Andaman Islands, India**

– L. Rasingam & K. Karthigeyan, Pp. 14921–14922

On the floral biology and pollination of a rare Twining Liana *Sarcobolus carinatus* Wall. (Asclepiadoideae: Apocynaceae) in Coringa Mangrove Forest, Andhra Pradesh, India

– A.J. Solomon Raju, Pp. 14923–14926

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