A checklist of rust fungi from Himachal Pradesh, India

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26 November 2019 | Vol. 11 | No. 14 | Pages: 14845–14861
DOI: 10.11609/jott.4238.11.14.14845-14861
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, mycological analysis, and 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, Fromnea, 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.
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., spermagonia, 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...
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), Pinaceae & Apiaceae (5 each), Rubiaceae (4), Saxifragaceae, Cyperaceae & Euphorbiaceae (3 each), and Berberidaceae, Geraniaceae, Linaceae & Zinziberaceae.
(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* (Dict.) 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


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* and *Clematis buchnania*

Distribution: Shimla

*Coleosporium malayense* Bagchee, (Sydow & Butler 1901)

On *Pinaceae*—branches of *Pinuslongifolia*

Distribution: Shimla

*Uredor* 03

*Peridermium* 06

**Uredo** 07

**Phragmidiaceae** Dadev

**Uromyces** 01

**Phragmidium** 09

**Raveneliaceae** Dadev

**Urocystidaceae** Dadev

**Skierka** 01

**Urocystis** 01

**Urocystis** 02

**Urocystis** 01

**Urocystis** 01

**Total (10)** 21

**23** 167

#### 2. Family: Cronartiaceae Dietel.

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

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

*Peridermium brevis* (Barclay) Sacc., (Barclay 1890)

On *Pinaceae*—Neeles of *Pinus excelsa*

Distribution: Shimla

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

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

Distribution: Shimla

*Peridermium malayense* Bagchee, (Sydow & Butler 1901)

On *Pinaceae*—branches of *Pinuslongifolia*

Distribution: Shimla

<table>
<thead>
<tr>
<th>Family</th>
<th>Genera</th>
<th>Number of species</th>
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<tr>
<td>Coleosporiaceae</td>
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<td>Coleosporium</td>
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<tr>
<td>Cronartiaceae</td>
<td>Uredo</td>
<td>07</td>
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<td>Phakopsora</td>
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<td>Pucciniastreum</td>
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<td>Puccinia</td>
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<td>Uromyces</td>
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<td>Uredinopsis</td>
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<td>Raveneliaceae</td>
<td>Ravenelia</td>
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<td>Urocystidaceae</td>
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<td></td>
<td>Uredo</td>
<td>07</td>
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<tr>
<td>Grand Total (11)</td>
<td></td>
<td>23 167</td>
</tr>
</tbody>
</table>
Checklist of rust fungi from Himachal Pradesh
Gautam & Avasthi

1. Family: **Peridermium** Cooke., (Sydow & Butler 1901)
   On **Pinaceae**—Needles of Pinus longofolia
   Distribution: Shimla, Kangra, Kasauli (Solan)

2. 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

   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

   On **Hypericaceae**—leaves of Hypericum sp.
   Distribution: Shimla

   *Melampsora caprearrum* Thüm., (syn. *Melampsora laricis-caprearrum* 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 mysoreense and Linum grandiflorum.
   Distribution: Flowerdale, Shimla

   *Melampsora medusae* Thum., (Paul et al. 2004).
   On **Salicaceae**—leaves of Populus deltoids
   Distribution: Kangra

   On **Pinaceae**—leaves of Pinus excelsa
   Distribution: Shimla

   *Melampsora salicis-albae* Kleb., (Sydow & Butler 1901)
   On **Salicaceae**—leaves of Salix alba
   Distribution: Suket, Mandi

   *Melampsora rostrupii* G. H. Wagner, (Syn. *M. accidioides, M. populnea*) (Rehill & Puri 1980)
   On **Salicaceae**—leaves of Populus alba
   Distribution: Shimla.

   **Genus: Ochrospora** Dietel.
   Type species: *Ochrospora sorbi* (G. Winter) Dietel (Ochrospora sorbi) (Oudem) Diet., (Arthur & Cummins 1933)
   On **Ranunculaceae**—Anemone sp.
   Distribution: Alwas (Chamba)

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4. Family: Phakopsoraceae Cummins & Y. Hirats. f.,
Genus: Monosporidium Barclay
Type species: Monosporidium euphorbiae Barclay ex Sacc. (1891)
Monosporidium andrachnes Barclay, (Barclay1890)
On Phyllanthaceae—leaves of Andracne 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

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)
On Poaceae—Arthraxon prionodes
Distribution: Kasauli Solan (H.P.).

Genus: Phragmidium Link (Image 2)
Type species: Phragmidium mucronatum (Pers.) Schltldl. (1824)
Phragmidium kmatschakae (H.W. Anderson) Arthur & Cummins, (syn. Pucciniaroseae Barclay; Trolliomyces rosae (Barclay) Ulbrich, Teloconia rosae (Barclay) Syd.) (Mundkar 1938; Pandotra & Ganguy 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
On Rosaceae—Rosa sp.
Distribution: Kalatop forest, Chamba
Phragmidium incompletum Barclay, (Sydow & Butler 1901)
On Rosaceae—leaves of Rubus paniculatus
Distribution: Shimla
Phragmidium kmatschake (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 argyrophylla
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

Genus: Pileolaria Castagne (Image 3)
Type species: Pileolaria terebinthi (DC.) Castagne (1842)
Pileolaria indica Syd., (Sydow 1938)
On Anacardiaceae—leaves of Pistacia integerrima
Checklist of rust fungi from Himachal Pradesh

Gautam & Avasthi

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: Shimla

Puccinia andropogonis Schwein., (Barclay 1890)
On Poaceae—Andropogon tristis
Distribution: Shimla

Puccinia graminis Pers., (syn. Puccinia anthistiriae Barclay) (Sydow & Butler 1912)
On Poaceae—Anthisuria anothera
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

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

Distribution: Shimla

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-falcata_ (DC.) G. Wint. (Barclay 1890)
On _Apiaceae_—_Bupleurum falcatum_
Distribution: Shimla
_Puccinia calthaef Link, (Arthur & Cummins 1933; Chona et al. 1956)
On _Ranunculaceae_—_Caltha palustris var. alba_
Distribution: Dharamshala (Kangra); Rohtang pass (Kullu)
_Puccinia carici var. himalayensis_ Barclay,(Butler & Bisby 1931; Padwick & Khan 1944)
On _Cyperaceae_—_Carex setigera_
Distribution: Shimla
_Puccinia carici-filicinæ_ Barclay, (Mitter & Tandon 1938)
On _Cyperaceae_—_Carex filicina_
Distribution: Shimla
_Puccinia carici-nubigenæ_ Padwick & A. Khan, (Mitter & Tandon 1938)
On _Cyperaceae_—_Carex nubigena_
Distribution: Kufri, Shimla
_Puccinia carthami_ Corda, (Sydow & Butler 1901)
On _Asteraceae_—_Carthamus oxyantha_
Distribution: Kangra
_Puccinia chrysopogoni_ Barclay, (Barclay 1890; Sydow &
Checklist of rust fungi from Himachal Pradesh

Butler 1907)
Oleaceae—Jasminum humile
Poaceae—Chrysopogon gryllus
Distribution: Shimla
*Puccinia circaeae* Pers., (Barclay 1890)
On *Onagraceae—Circaea alpine*
Distribution: Shimla
*Puccinia collettiana* Barclay, (Barclay 1890; Ganguly & Pandotra 1963)
On *Rubieaeae—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 duthei* Ellis & Tracy, (Sydow & Butler 1911)
On Poaceae—*Andropogon pertusus*
Distribution: Kasauli (Solan)
*Puccinia ellsii* De Toni, (Barclay 1891)
On *Apiaceae—Angelica glauca*
Distribution: Phag, Shimla
*Puccinia eremuri* Kom., (Barclay 1891)
On Xanthorrhoeaceae—*Eremurus himalaicus*
Distribution: Kullu
*Puccinia erianthi* Padwick & A. Khan, (Padwick & Khan 1944)
On Poaceae—*Erianthus fulves*
Distribution: Shimla
*Puccinia eucliae* 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 gerani-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-poaec* 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 himalalensis* 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 amphonyra*
Distribution: Shimla
*Puccinia leptodermidis* Barclay, (Barclay 1890; Sydow & Butler 1912)
On Rubieaeae—*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, (Munjal & Gill 1962)
Checklist of rust fungi from Himachal Pradesh

Gautam & Avasthi


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 ampelexicaule
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

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 pagonatheri Petch, (Sharma & Sachan 1994)
On Poaceae—Pagonatherum 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 priniana 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
Checklist of rust fungi from Himachal Pradesh

Gautam & Avasthi


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

On Asteraceae—Tricholepis elongata
Distribution: Saharan & Bushar
Puccinia trifoli (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 trifoli (R. Hedw.) Lév., (Syn. Uromyces flectens
Laghe., Uromyceservipilus (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 dactyliced 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: Dharamshala
Uromyces macintirianus Barclay, (Sydow & Butler 1938)
On Acanthaceae—leaves of Hemigraphis latebrosa
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)

On Caprifoliaceae—leaves of Valeria nawaallichii, 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 syngrammes Munjal & J.N. Kapoor., (Munjal & Kapoor 1961)
On Pteridaceae—Leaves of Syngramme fraxiana Bedd.
Distribution: Narkanda

Genus: Urocystis Rabenh. ex Fuckel
Type species: Urocystis occulta (Wallr.) Rabenh. (1867)
Urocystis sorosporioides Körn. ex Fuckel, (Mundkar & Thirumalchar 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
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 tiliae-folia* (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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A checklist of rust fungi from Himachal Pradesh, India

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