



REGULAR ARTICLE

# DIVERSITY AND DISTRIBUTION OF RUST FUNGI IN CENTRAL HIMALAYAN REGION

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## SUMMARY

An extensive field survey was made during 2007 to 2008 in Nainital (Uttaranchal) for rust diseases of wild plants. In all 12 genera of rust fungi with 35 species belonging to 7 families were collected and identified. Among these, one genus *Aecidium* Pers. ex. Pers. was an anamorphic and 11 were holomorphic. Most of the rust fungi were collected from herbaceous and shrubby hosts, while few were found to be pathogens of tree species. *Populus nigra* var. *italica*, and an extensive cultivated tree in this area was found to be a new host for the rust fungus *Melampsora ciliata* Barclay. The study suggest further exploration of the area for rust disease in order to assess the diversity of these fungi particularly in ferns, grasses, sedges and trees including cultivated ones.

**Key words:** Diversity, Taxonomic Description, Rust Fungi, Central Himalaya

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## 1. Introduction

The rust fungi belong to the order *Uredinales* of class *Basidiomycetes* and comprise a large group of obligate biotrophic parasites. They cause rusty pustular outgrowths on different plant parts especially leaves and stems of a wide range of host plants including ferns, conifers and wild and cultivated flowering plants. Although the fungal flora of Uttaranchal has been explored by several workers in the past, a very important group of fungi has largely been neglected resulting in the paucity of literature and very fragmentary knowledge of these fungi.

There are few reports of rust fungi from Uttaranchal (Mitter and Tandon, 1932, 1937 and 1938; Bisht and Srivastava 1994; Bisht *et al.* 1994; Palni and Pangtey, 2000, 2002). In Kumaun, only a few selected localities have been explored for these fungi and in most of the studies, only enumerations have been made. References of these fungi have been included in the 'Fungi of India' compiled and published by various workers from time to time (Butler and Bisby, 1931; Vasudeva, 1960; Sarbhoy *et al.*, 1975, 1982, 1986, & 1996; Mukerji and Bhasin, 1986; Bilgrami *et al.*, 1979, 1981, 1991; Jamaluddin *et al.*, 2004).

Nainital is a well known summer hill resort of India and is situated on the outer hill ranges of Kumaun Himalaya. The natural vegetation shows a great variation in its composition and distribution. Since the flora (pteridophytes, gymnosperms and flowering plants) of Nainital is very well explored and studied, it provides for an easy identification of the host plants.

Keeping in view these facts, the present study was undertaken to explore and assess the diversity and distribution of rust fungi along with their respective host plants between the altitudes ranging from 1800-2611 m.

## 2. Materials and Methods

On the basis of topography, vegetation composition, climate and altitude, a few floristically rich sites were selected for the collections of fungi. These sites were Thandi Sarak (1800-1938m), Kilbury (1900-2215m), Snow View (2000-2397m), Bada Pathar (2100-2300m), Lariakanta (2250-2491m), Tiffin Top (2352-2450m) and Government House (2250-2450m). The infected specimens were carefully collected throughout the year from the selected sites and also from entire

Nainital and suburbs from the year 2007 to 2008. Since most of the rust fungi are prevalent from September to December, several collection trips were made during these months. The infected specimens were collected in the polythene bags on the spot and brought to the laboratory for further investigation. The identified host specimens were mounted in the herbarium sheets following standard methods and were deposited in the Herbarium of Botany Department, D.S.B. Campus, Kumaun University, Nainital.

The specimens were also preserved in FAA for further detailed study of the pathogens. Using research microscope, the characters of sori were studied such as size, position, colour etc. Microslides were also prepared with Lacto phenol with Cotton blue. After observation, the Camera Lucida drawing was prepared.

Both hand and microtomic sections of the infected part of the specimen were prepared. The microtomic sections were made following Johansen (1940) and Prasad and Prasad (1975). The sections were stained using safranin or cotton blue and finally camera lucida drawings were prepared.

The collected specimens were critically examined and identified with the help of published literature and further confirmed by consulting several experts working on the rust fungi in India and abroad.

### 3. Results and Discussion

In all, 12 genera with 34 species belonging to 7 families were collected. Among these, one genus was anamorphic and others holomorphic. The anamorphic genus was *Aecidium Pers. ex Pers.* The holomorphic genera belonged to 7 families viz. Pucciniastraceae, Coleosporiaceae, Melampsoraceae, Phakopsoraceae, Raveneliaceae, Phragmidiaceae and Pucciniaceae, following the classification

given by Cummins and Hiratsuka (2003). These genera were *Chrysomyxa* Unger, *Coleosporium* Lev., *Gymnosporangium* Hedw., *Melampsora* Cast, *Phakopsora* Diet., *Phragmidium* Link, *Puccinia* Pers., *Pucciniastrum* Otth, and *Pucciniostele* Tranz. & Kom. *Ravenelia* Berk. and *Uromyces* (Link) Unger. Table 1 shows the list of collected rust fungi, their hosts and taxonomic description.

It was noteworthy to find uredinal and telial stages at peak season (September to November) in many rust fungi. However, in other cases, uredinal stages associated with aecidial stages were predominant in the pre-peak season (May to August), while telial stages were observed in the post-peak season (December to February).

It has been reported earlier that rust diseases are abundant in hilly region where high relative humidity and thick vegetal cover provides ideal and congenial condition for the growth and development of these diseases (Cummins, 1943, 2003; Misra *et al.*, 1975; Bisht, 1990). The present study also confirms the earlier observations. It is also interesting to note that among the host plants of rust fungi, 15 were herbaceous plants, 15 shrubby including climbers, one grass and 4 were trees. Most of the fungal species were host specific, while 7 species showed more than one host. Among the various hosts the members of families *Rosaceae*, *Rubiaceae* and *Polygonaceae* were common. The collected rust fungal species are enumerated in the list below along with their respective families, hosts and other details. The observations in this study seem to be in accordance with the earlier reports (Grove, 1913; Bisht, 1990). It was interesting and important to find a tree species (*Populus nigra var. italica*), which is extensively cultivated in this area, to be a new host for the rust fungus *Melampsora ciliata* (Sah and Palni, 2006).

Table 1. List of collected rust fungi and their Taxonomic description

S. No	Pathogen	Host	Plant Part Infected	Period of Infection	Symptoms	Taxonomic Character
1	<i>Pucciniastrum agrimoniae</i> Diet	<i>Agrimonia pilosa</i> Ledeb. (Herb) Family- Rosaceae	Leaves	Aug- Nov.	Creamish yellow Pustules on the lower Surface of leaves which later become dark yellow.	Uredosori hypophyllous, Subepidermal, Urediniospores borne singly, echinulate, spiral to ovate, 17.1-20.2x15.5-17.1 $\mu$ M.
2	<i>Chrysomyxa himalense</i> (Barcl.)	<i>Rhododendron arboreum</i> Smith (Tree) Family.-Ericaceae	Leaves and petiole		Creamish yellow or Orange patches in the petiole and lower surface of leaves.	Uredinia hypophyllous, Subepidermal erumpent, Urediniospores produced in rows resembling aeciospores, 16.5-18x10-12.5 $\mu$ M teliosori, hypophyllous, waxy .Teliospores in simple chains with thin, colorless walls, 12.5-14.3 $\mu$ M in size.
3.	<i>Coleosporium campanulae</i> (Pers.)Lev.	<i>Campanula pallida</i> Wall, (Herb) Family-Campanulaceae	Leaves & Petiole	April- June	Orange-yellow pustules on the leaves and petiole, premature defoliation of leaves	Uredinia hypophyllous , Subepidermal, Scattered, Urediniospores in long chains, catenulate, globose to ellipsoid thick walled, 17.5-22.5x15.5 $\mu$ M.
4	<i>C. clematidis</i> Barcl.	<i>Clematis accuminata</i> D.C. <i>C. buchananiana</i> D.C. <i>C. montana</i> Buch. Ham. ex D.C. (Climbing Shrubs) Family. Ranunculaceae	Leaves	Sept.- Dec.	Orange-yellow pustules, premature defoliation	Uredinia hypophyllous, Subepidermal, Scattered, erumpent, Urediniospores, globoid to oblong, become gelatinous on germinations 16.5-21.0x16.5-19.8 $\mu$ M.
5	<i>C. leptodermidis</i> (Barcl.)	<i>Leptodermis lanceolata</i> Wall (Shrubs) Family. Rubiaceae	Leaves	Aug.- Nov.	Yellow orange pustules on the lower surface of leaves initially in the lower surface but gradually on the upper leaves, premature defoliation	Uredinia hypophyllous, Subepidermal, Scattered , without peridia, Urediniospores globoid 15.2-21.3x9.1-9.8 $\mu$ M. Telia hypophyllous, Scattered, Teliospores indehiscent ,

6	<i>C. plectranthi</i> Barcl.	<i>Plectranthus japonicus</i> (Burm. f.) Koidz (Shrub) Family. Lamiaceae	Leaves	Sept.- Nov.	Small yellowish pustules on the leaves. The infected leaves become curled and brownish before falling off.	flattened waxy, sessile, unicellular, arranged, in a single layer smooth colorless walled, 19.5-21.0x12.5-14.3 μM. Uredinia hypophyllous, Subepidermal erumpent, yellowish. Uredinospores globose smooth yellowish in color and 13.5-15.0x9.5-11 μM in size.
7	<i>Melampsora ciliata</i> Barcl.	<i>Populus ciliata</i> Wall. & <i>P. nigra</i> var. <i>italica</i> (Munchn) Koechne (Tree) Family.-Salicaceae	Leaves	Aug- Sept.	Yellowish patches on the lower surface of leaves infected leaves turn black resulting premature defoliation.	Uredinia minute hypophyllous Subepidermal, uredinospores 17.5-30.5x15.5-22.5 μM, ovate to ellipsoid telia scattered, Subepidermal, orange brown to dark brown, Teliospores 30.5-34.5x7-9 μM in size,
8	<i>M.euphorbiae</i> (Schubert) Cast	<i>Euphorbia pilosa</i> L. (Herb) Family.-Euphorbiaceae	Leaves and stem	July- Nov.	Orange yellow pustules on the leaves & stems. Yellowing and curling of leaves	Aecia Subepidermal, orange aeciospores globose or ellipsoid, 20-27x18-23 μM in size, Uredinia small, amphigenous, dense, Uredinia globose or ellipsoid, echinulate, 14-21x11-19.5 μM, telia amphigenous, erumpent, round Teliospores golden brown, 22.5-49.5x6.5-14.5 μM in size.
9	<i>M. hypericorum</i> (Dc.) Wint.	<i>Hypericum dyeri</i> Rehder <i>H. oblongifolium</i> Choisy (Shrub) Family.- Hypericaceae	Young Leaves	April- June	Bright orange yellow pustules on young leaves, uninfected older leaves remain healthy.	Acacia minute hypophyllous, peridium rudimentary, aeciopores in short chains 14-40x10-18 μM, telia hypophyllous, minute, non erumpent, reddish brown to dark brown, Teliospores one celled rarely 2 celled 20.5-40.5x7.5-16.5 μM in size,
10	<i>M. yoshinagai</i> <i>P. Henning</i>	<i>Wikstroemia canescens</i> Meiss	Leaves	Aug.- Dec.	Whitish brown pustules on the	Uredinia hypophyllous minute

		(Shrub) Family.- Thymelaceae			lower surface of leaves, the diseased area become pale yellow causing early shedding of leaves,	scattered surrounded by paraphyses, Uredinospores, 15-23.5x12.4-20.5 μM, ovoid to ellipsoid, echinulate, telia hypophyllous, 21.5-36.5x7-12.5mm, oblong or prismatic,
11	<i>Pucciniostele clarkiana</i> (Barclay)	<i>Astilbe rivularis</i> Buch.-Ham.ex Benth. (Shrub) Family- Saxifragaceae	Leaves	Sept.- Dec.	Small orange red pustules scattered on the lower surface of leaves causing partial chlorosis of leaf lamina. Upper surface of leaf shows yellowish spotted appearance.	Telia hypophyllous Teliospores in chain or columnar smooth, 5-6 in chains light brown, 17.5-25x12.5-15 μM in size.
12	<i>Phakopsora cronatiformis</i> Diet.	<i>Parthenocissus semicordata</i> (Wall) Planch. (Shrub) Family. Vitaceae	Leaves	Sept.- Nov.	Brownish red pustules on the lower surface of leaves.	Telia hypophyllous, scattered minute, spores sessile, Teliospores one called compact, irregularly arranged 18.6-26.3x15.5-17.0 μM.
13	<i>Ravenelia mitteri</i> H.Syd.	<i>Indigofera heterantha</i> Wall.ex Brandis (Shrub) Family. Fabaceae	Leaves	Aug.- Oct.		Telia subepidermal scattered, Teliospores strongly adherent on pedicellate disc. 1 celled with one germ pore, spores head subtended by colorless hygroscopic cysts. Single walled, smooth 82.1-93.0 x 68.2-93.0 μM in size.
14	<i>Phragmidium incompletum</i> Barcl.	<i>Rubus niveus</i> Thunb. <i>R. paniculatus</i> smith (Climbing shrubs) Family. Rosaceae	Leaves	Aug.- Dec.	Orange yellow Uredosori on lower surface of leaf lets later leaflets exhibit conspicuous brownish black sports	Uredinia hypophyllous, subepidermal, scattered orange yellow or dark brown 15-22.5 μM in size Teliospores pedicellate, 5-7 celled. Light brown to dark brown in color 36.0-70.0x16.0-23.0 μM in size.
15	<i>P. rosae - moschatae</i> Diet.	<i>Rosa brunnea</i> Lindl. (Climbing shrub) Family. Rosaceae	Leaflets	Aug.- Dec.	Orange yellow Uredosori on lower surface of leaf lets later leaflets exhibit conspicuous brownish black sports	Uredinia hypophyllous, subepidermal, scattered orange yellow or dark brown 13.3-20.5 μM in size Teliospores pedicellate, compound, 5-7

16	<i>Gymnosporangium cunninghamianum</i> Barclay	<i>Pyrus pashia</i> Buch-ham.ex D.Don (Tree) Family.-Rosaceae	Leaves	July-Oct.	Small yellowish pustules on the lower surface of leaves. Leaves turn pale and shed off prematurely in case of severe infection	celled, 36.0-70.0x16.0-23.0 μM in size. Aecial sori cup-shaped, well developed peridium, aeciospores in chains rounded echinulate thick walled and 31.5-39x12.5-18mm in size.
17	<i>Puccinia colletiana</i> Barcl.	<i>Rubia cordifolia</i> L. (Herb) Family-Rubiaceae	Leaves	Sept.-Nov.	Brownish red, irregular pustules on lower surface of leaves Later these become dark brown.	Uredinia scattered, Subepidermal erumpent Uredinospores measuring 21.7-24.6x18.6-21.7 μM, Teliospores 68.2-89.9x18.6-21.7 μM in size.
18	<i>P. fagopyricola</i> Jarstad	<i>Fagopyrum dibotrys</i> (D.Don)Hare (Herb) Family.- Polygonaceae	Leaves	Aug.-Nov.	Brownish red to black pustules on the lower surface of leaves and later these leaves become yellow.	Uredinia Subepidermal brownish red, Uredinospores unicellulaly spherical to ovate arranged in clusters thick walled 18.6-21.7x17.5-18.6 μM. Teliospores 2 celled thick celled dark brown 34.0-36.4x11.3-13.5 μM in size.
19	<i>P. iridis</i> Robenharst	<i>Iris germanica</i> (Herb) Family. -Iridaceae	Leaves	March-June	Yellowish brown to black pustules on the leaf.	Uredinia subepidermal Uredinospores subglobose to ovoid, 24.8-26.4x21.7-23.3 μM, Teliospores ellipsoid apex rounded 32.5-36.3x13.5-17.0 μM.
20	<i>P. menthae</i> Pers.	<i>Origanum vulgare</i> L. (Herb) Family.-Polygonaceae	Leaves. Stem &Petiole	June-Oct.	Brownish red, irregular pustules on lower surface of leaves Later these become dark brown.	Uredinia hypophyllous, subepidermal, scattered brownish-red, Spherical to ovate, Uredinospores 16.5-22.5x14-18.5 μM in size Teliospores pulverulent, 2celled. dark brown to black in color 26.5-35.0x17.5-22.5 μM in size.
21	<i>P. nepalensis</i> Barcl. Diet	<i>Rumex nepalensis</i> Spreng. (Herb) Family.-Polygonaceae	Leaves	June-Dec.	Small light or dark pustules on the leaves in the beginning which increases in size	Uredinia subepidermal scattered dark brown. Uredinospores

22	<i>P. oxalidis</i> Diet & Ellis	<i>Oxalis dehradunensis</i> Raizada (Herb) Family. Oxalidaceae	Leaflets	May- October	and number in later stages. Severely infected leaves become pale yellowish leading to defoliation. Orange yellow pustules on the lower surface or leaf lets later on upper surface also become yellowish Uredosori burst exposing golden yellow powdery mass of spores causing death of the leaflets.	unicellular small 17.5-40.0x12.5-17.5 μM in size Teliospores 2 called smooth with convex apex, 27.0-40.0x19.0-28 μM. Uredinia scattered orange yellow colored Uredinospores, unicellular, echinulate ,10.8-15.5x10.8-12.4 μM.
23	<i>P. padwickii</i> Cumm.	<i>Cyathula tomentosa</i> (Roth) Moq. (Shrub) Family .Amaranthaceae	Leaves & stem	April- Oct.	Light or dark brown pustules scattered on the surfaces of leaves causing drying of leaves.	Uredinia scattered elliptical, Uredinospores spherical mixed with myceloid and hyaline paraphyses 26.3-27.5x24.6-26.4 μM.
24	<i>P pimpinellae</i> (Strauss)Rohling	<i>Pimpinella acuminata</i> (Edgew.) (Herb) Family. Apiaceae	Leaves	Aug.- Oct.	Brown pustules on the lower surface of leaves later dark brown, scattered pustules show telial stage.	Uredinia subepidermal Uredinospores unicellular ,oval ,light brown, 21.7-24.8x18.6-20.2 μM. Teliospores dark brown, elliptical slightly constricted 31.0-37.2x15.5-18.6 μM.
25	<i>P. punctata</i> link	<i>Galium aparine</i> l. g. elegans wall. (Herb) Family .Rubiaceae	Leaves	Oct-Dec.	Yellowish spots on both surfaces of leaves. Later the spots on lower surface become studded with pin head like light brown dusty pustules or Uredosori. Finally diseased area turns pale yellow.	Uredinia scattered subepidermal elliptical Uredinospores, ellipsoid 46.5-58.5x12.4-18.6mm Teliospores brown smooth 20.4-27.5x17.5-25.0 μM.
26	<i>P. roscoae</i> Barclay	<i>Hedychium spicatum</i> J.E.Smith (Herb) Family.-Zingiberaceae	Leaves	Aug- Nov	Reddish yellow pustules on the lower surface of leaves in the beginning turning the whole leave reddish yellow. Severely infected leaves become	Uredinia Scattered, dark brown, Subepidermal, Uredinospores ovoid, light yellow, 24-30x21-24 μM, Telia black, amphigenous, Teliospores ellipsoid,smooth,35.0-50.0x20.0-30.0 μM.

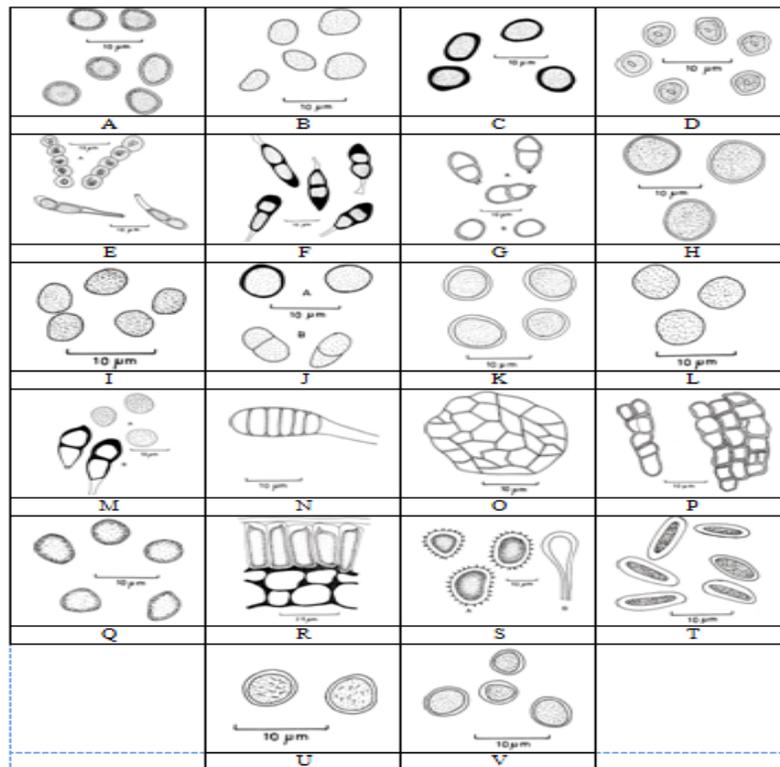
27	<i>P. saxifragae-ciliatae</i> Barcl.	<i>Bergenia ligulata</i> (Wall.)Engler (Herb) Family.-Saxifragaceae	Leaves	April-May	flaccid & finally shed off Reddish brown to violet colored oval or spherical pustules on the lower surface of leaves. The upper surface of leaves turned purple red.	Teliospores 2 celled, grayish brown, thick walled apex generally rounded 54.0-69.0x13.5-19.5 $\mu$ M.
28	<i>P.urticae</i> Barcl.	<i>Urtica ardens</i> Link (Herb) Family-Urticaceae	Leaves	Sep.-Dec.	Aecial sori as yellowish pustules on the lower surface of leaves which disappear after dispersal of spores. Infected leaves become blackish & shed. The upper surface becomes brownish.	Aecia subepidermal hymenium palisade like, aeciospores in basipetal globoid or subglobose, 15.0-16.5x15.5-18.2 $\mu$ M.
29	<i>P. violae</i> DC.	<i>Viola canescens</i> Wall, <i>Viola pilosa</i> Blume (Herb) Family.-Violaceae	Leaves	April-June	Light brown pustules on the lower surface of the leaves which later become dark brown.	Uredinia Subepidermal , light brown, unicellular, oval, thick walled, 16.1x13.3 $\mu$ M. Teliospores compact scattered, 12.4-13.9x 15.5-17.1 $\mu$ M.
30	<i>Uromyces inayati</i> H.Syd.	<i>Apluda mutica</i> L. (Grass) Family-Poaceae	Leaves	Sept-Dec	Dark brown / black spherical pustules of telial sori on the lower surface of leaves. Later pustules occupy considerable area on both the surfaces.	Uredinia subepidermal, scattered, urediniospores, 1 celled, elliptical, ovoid, 24.8-31.0x 18.6-21.7 $\mu$ M.
31	<i>U. valerianae-wallichii</i> Art.& Cumm.	<i>Valeriana jatamansi</i> Jones (Herb) Family- Valeriaceae	Leaves	Oct-Dec	Brownish black pustules on the lower surface of leaves becoming larger occupying considerable area of the leaves	Uredinia Subepidermal without paraphyses, Urediniospores 1 celled ellipsoid 22.5-23.3x 18.6-21.7 m telia chocolate brown, Teliospores globoid 21-25x24-29 $\mu$ M rounded at both the ends.
32	<i>Aecidium deutziae</i> Diet	<i>Deutzia staminea</i> R.Br. (Shrub) Family- Hydrangeaceae	Leaves & Twigs	Aug-Sep	Yellowish small circular pustules on the upper surface of leaves, patches become irregular and scattered throughout the	Aecia cylindrical, aeciospores in chains,24.0-29.5x16.4-14.5 $\mu$ M.

33	<i>A. montanum</i> Butler	<i>Berberis asiatica</i> Roxb. ex DC., <i>Berberis chitria</i> Edwards (Shrub) Family- Berberidaceae	Leaves	March- June	upper surface of leaves Yellowish brown patches on the lower surface. later orange yellow colored aecidia cover the entire surface of leaves	Aecidium cup shaped, 211.3 - 282.4 x 258.9 - 353.10 µM. aeciospores in chains each aeciospores polygonal to subglobose. 46.5 - 58.5 x 19.5 - 21.8 µM.
34.	<i>A. strobilanthes</i> Mitter	<i>Pteracanthus alatus</i> (Wal. ex Nees) Brenck (Shrub) Family- Acanthaceae	Leaves	July- Aug.	Yellow-brown patches on the lower surface of leaves. Later, Orange-Yellow aecidia cover entire area of leaf lamina. Infection causes necrotic portions & premature shedding.	Aecidium cup shaped, aeciospores in chains, Polygonous in shape, catenulate, 28.5 - 32.5 x 16.0 - 19.5 µM.

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Figure 1. Camera Lucida drawings of different spores of Rust Pathogens



- A: *Uromyces valerianae-wallichii*: Urediniospores  
 B: *Aecidium deutziae*: Aeciospores  
 C: *Uromyces inayati*: Urediniospores  
 D: *Puccinia violae*: Urediniospores  
 E: *Puccinia urticae* : ( a) Aeciospores, (b) Teliospores  
 F: *Puccinia punctata*: Teliospores  
 G: *Puccinia pimpinellae* : (a) Aeciospores, (b) Teliospores  
 H: *Puccinia padwickii*: Urediniospores  
 I: *Puccinia oxalidis*: Urediniospores  
 J: *Puccinia nitidula*: (a) Urediniospores, (b) Teliospores  
 K: *Puccinia iridis*: Urediniospores  
 L: *Puccinia fagopyricola*: Urediniospores  
 M: *Puccinia colletiana*: (a) Urediniospores, (b) Teliospores  
 N: *Phragmidium rosae-moschatae*: Teliospores  
 O: *Ravenelia mitteri*: Teliospores  
 P: *Pucciniostele clarkiana*: Teliospores  
 Q: *Phakopsora cronatiformis*: Urediniospores  
 R: *Melampsora hypericorum*: Teliospores  
 S: *Melampsora euphorbiae*: (a) Urediniospores, (b) Paraphyses  
 T: *Melampsora ciliata*: Urediniospores  
 U: *Coleosporium clematidis*: Urediniospores  
 V: *Pucciniastrum agrimoniae*: Urediniospores

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