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New records of *Phragmidium* species from Pakistan

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Abstract — Five *Phragmidium* species on different rosaceous hosts are described and illustrated. *Phragmidium violaceum* is a new record for Pakistan. Aecidial stages of *P. mucronatum, P. rubi-idaei*, and *P. tuberculatum* are re-described following study of their wall characters with SEM. *Potentilla gerardiana* represents a new host record for *Phragmidium papillatum*.

Key words — *Caeoma,* Khanspur, Mansehra, *Phragmidiaceae*

Introduction

The *Phragmidiaceae* are a family of rust fungi in the order *Pucciniales*. Cummins & Hiratsuka (2003) reported that this family contains 14 genera and 164 species. Its genera are distinguished by their aecial, uredinial, and telial stages. Species of *Phragmidium* Link typically infect plant species in the *Rosaceae*. Their telia contain teliospores borne singly on often hygroscopic pedicels and with smooth or (more often) verrucose walls and 1- to several transversely septate cells with 2–3 pores in each cell. The aecia are usually *Caeoma*-type (with catenulate spores) or less often *Uredo*-type (with spores borne singly). About 15 *Phragmidium* species have been described or reported from Pakistan (Ahmad et al. 1997; Afshan et al. 2011, 2012). In this paper, we describe and illustrate five *Phragmidium* species and provide SEM photographs to illustrate important aeciospore wall characters.

Materials & methods

Freehand sections of infected tissue and spores were mounted in lactophenol and gently heated to boiling point. The preparations were observed under a Nikon YS 100 microscope and photographed with a Digipro-Labomed and a JSM5910 scanning electron microscope. Spores and paraphyses were drawn using a Camera Lucida (Ernst Leitz Wetzlar, Germany). Spores were measured using an ocular micrometer, with at

least 25 spores measured for each spore stage. The rusted specimens have been deposited in the herbarium of the Botany Department, University of the Punjab, Lahore (LAH).

Taxonomy

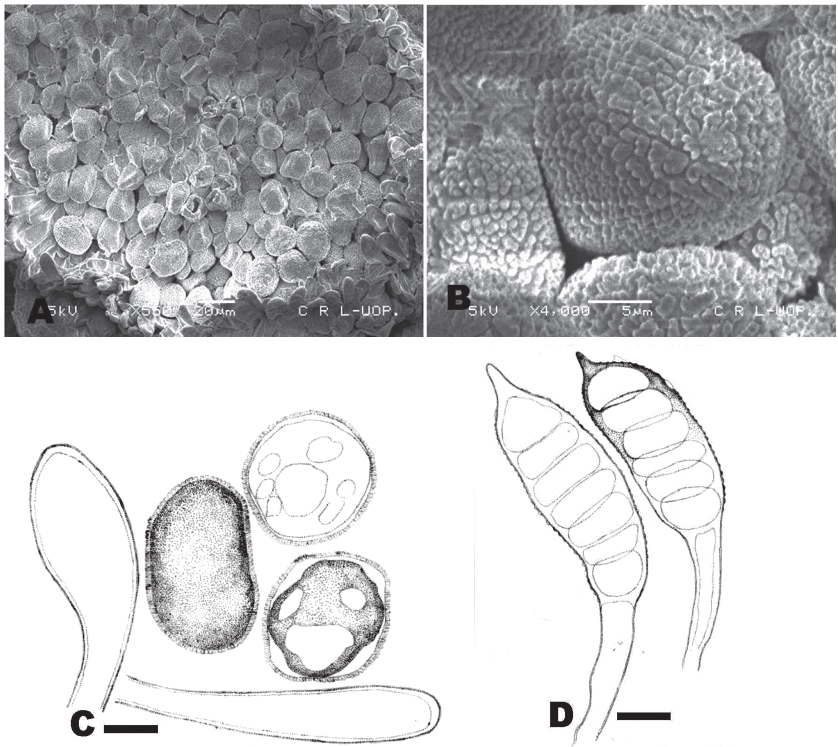

Plate 1: *Phragmidium mucronatum*. (A) SEM photograph of an aecium showing aeciospores surrounded by slightly incurved to erect paraphyses. (B) SEM photograph of aeciospores showing verrucose wall ornamentation. (C) Aeciospores with paraphyses. (D) Teliospores. Scale bars: C, D = 10 µm.

Phragmidium mucronatum (Pers.) Schltdl., Fl. berol. 2: 156 (1824) Plate 1

Spermogonia not found. Aecia hypophyllous, on leaves, bright yellow to orange yellow, rounded or oblong, scattered, sori 0.1–0.4 × 0.09–0.3 mm; surrounded by paraphyses; paraphyses numerous, slightly incurved to erect, clavate, hyaline to nearly colorless, 50–70 µm long and 12–15 µm wide. Aeciospores globose–subglobose or ellipsoid, 16–28 × 23–32 µm (mean 19 × 27.7 µm); wall 1.5–2 µm thick, with obscure, scattered pores, hyaline with yellowish orange to dark orange contents, densely and distinctly verrucose. Uredinia hypophyllous, scattered, yellow; urediniospores rare and not very

clear; paraphyses curved, clavate. Telia hypophyllous, scattered, minute, black. Teliospores cylindrical to ellipsoid or oblong, 3–8 celled, 27–32 × 57–110 µm; wall 4–7 µm thick, verrucose, dark brown to chestnut brown; apex conical, 5–10 µm thick; pedicel long, hyaline to pale yellow.

Material examined: **PAKISTAN**, **Khyber-Pakhtunkhawah**, Khaira Gali, 2347 m a.s.l., on *Rosa macrophylla* Lindl., stages I + II + III, 19 June 2008, NSA #150 (LAH NSA1022).

Comments: *Phragmidium mucronatum,* cosmopolitan on different *Rosa* species (Wilson & Henderson 1966; Hiratsuka et al. 1992), was previously reported from Pakistan on *Rosa* sp. from Rawalpindi (Ahmad 1956a,b).

Phragmidium papillatum Dietel, Hedwigia 29: 25 (1890) Plate 2

Spermogonia and aecia not found. Uredinia mostly hypophyllous on leaves, or on the veins and petioles, bright yellow to orange, scattered, rounded

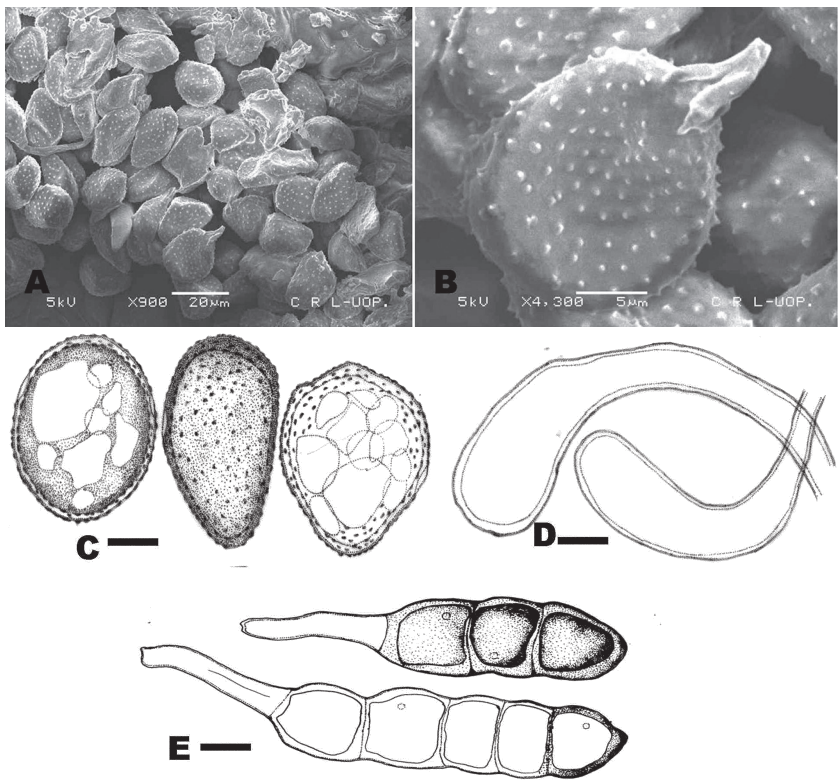

Plate 2: *Phragmidium papillatum.* (A) SEM photograph of urediniu containing urediniospores. (B) A urediniospore showing echinulate to verrucose wall ornamentation. (C) Urediniospores. (D) Paraphyses (E) Teliospores. Scale bars: C–E = 10 µm.

or oblong, sori 0.09–0.2 × 0.2–0.5 mm; PARAPHYSES numerous, incurved to suberect, clavate, hyaline to nearly or quite colorless, 50–80 µm long and 11–15 µm wide. UREDINIOSPORES globose-subglobose or ellipsoid to ovoid, 16–22 × (19–) 21–32 µm (mean 19.0 × 24.5 µm); wall 1–1.5 µm thick, with 2–5 scattered pores, yellow to yellowish orange, echinulate to verrucose, with a hyaline pedicel. TELIA hypophyllous, scattered or gregarious, minute, rounded or irregular, black. TELIOSPORES cylindrical or ellipsoid to oblong, 3–5 celled, rarely 2-celled, 28–34 × 57–95 µm, slightly or not constricted at the septum; wall 2–5 µm thick, smooth, brown to yellowish brown; pedicel long, 6–8 × 30–95 µm, hyaline to pale yellow.

MATERIAL EXAMINED: **PAKISTAN**, **AZAD JAMMU & KASHMIR**, Neelum valley, Muchal, 3000 m a.s.l., on *Potentilla gerardiana* Lindl., stage II, 3 Nov. 2006, NSA #30906 (LAH NSA1024a); **KHYBER-PAKHTUNKHAWAH**, Mansehra, Oghi, 1122 m a.s.l., on *Potentilla gerardiana*, stages II + III, 16 May 2008, NSA #160408 (LAH NSA1024b).

COMMENTS: *Phragmidium papillatum* has been reported on *Potentilla cryptotaeniae* Maxim. and *P. matsumurae* Th. Wolf from Japan and is also common in USSR, China, and Korea (Hiratsuka et al. 1992). From Pakistan, it has previously been reported on *Potentilla nepalensis* Hook. from Kalam (Ahmad 1956a,b), Swat valley (Ono & Kakishima 1992), Kaghan valley (Ono 1992), and Murree (Kakishima et al. 1993a,b). *Potentilla gerardiana* is a new host for this rust fungus.

Phragmidium rubi-idaei (DC.) P. Karst., Bidr. Känn. Finl. Nat. Folk 31: 52 (1879)

PLATE 3

SPERMOGONIA and UREDINIA not found. AECIA hypophyllous, on leaves, solitary or in groups, bright yellow, scattered, sori 0.2–0.3 × 0.1–0.4 mm; surrounded by paraphyses, numerous, incurved to suberect, clavate, hyaline to nearly colorless, 50–70 µm long and 10–16 µm wide. AECIOSPORES globose–subglobose or ovoid to obovoid, 14–17 × 15–23 µm (mean 15.9 × 17.5 µm); wall 1–1.5 µm thick, hyaline to light yellow with yellowish orange contents, sparsely echinulate, echines produced on a distinct base. TELIA hypophyllous, scattered, naked, black. TELIOSPORES cylindrical, 4–10 celled, 28–35 × 70–122 µm, slightly or not constricted at the septum; wall 2–5 µm thick, verrucose, yellowish brown to chestnut brown; apex rounded or attenuated, 10–15 µm long, hyaline; pedicel long, 10–15 × 80–150 µm, hyaline to pale yellow.

MATERIAL EXAMINED: **PAKISTAN**, **KHYBER-PAKHTUNKHAWAH**, Khaira Gali, 2347 m a.s.l., on *Rubus niveus* Thunb., stages I + III, 19 Jun. 2008, NSA #153 (LAH NSA1026).

COMMENTS: *Phragmidium rubi-idaei* is cosmopolitan in temperate regions on various *Rubus* species (Wilson & Henderson 1966; Hiratsuka et al. 1992). It has previously been reported from Pakistan on *Rubus idaeus* L. from Khanspur

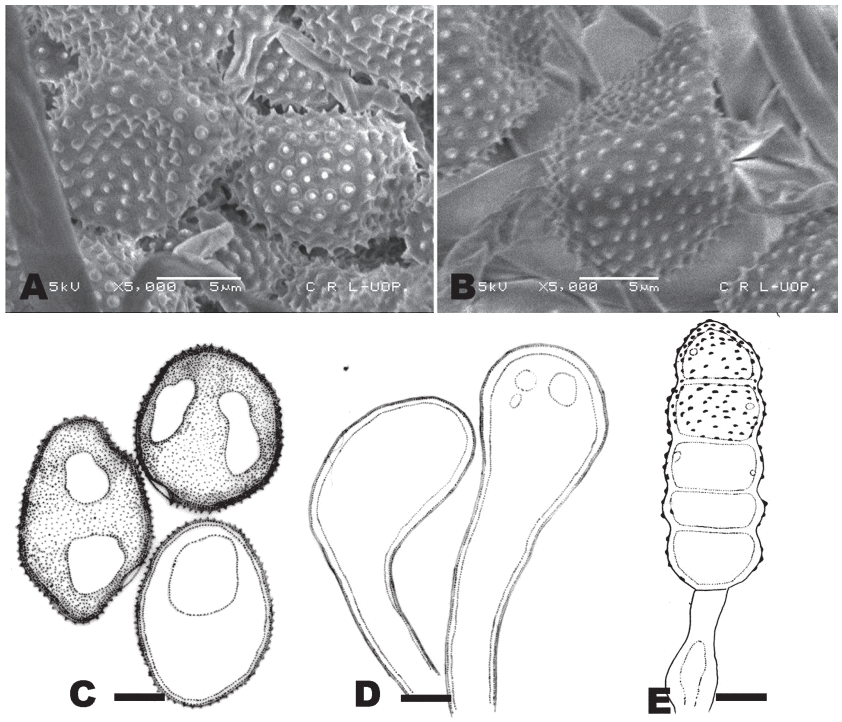

Plate 3: *Phragmidium rubi-idaei*. (A) SEM photograph of aeciospores showing echinulate wall ornamentation. (B) A closer view of an aeciospore. (C) Aeciospores. (D) Paraphysis (E) Teliospores. Scale bars: C–E = 10 μm.

(Khalid et al. 1993). The aecidial stage of *P. rubi-idaei* represents a new record for Pakistan.

Phragmidium tuberculatum Jul. Müll., Ber. dt. bot. Ges. 3: 391 (1885) Plate 4

Spermogonia and Uredinia not found. Aecia hypophyllous, on branches, petioles and leaves, bright yellow to orangish yellow, rounded or oblong, scattered, sori 0.1–0.3 × 0.09–0.1 mm; paraphyses numerous, incurved to suberect, clavate or clavate to capitate, hyaline to nearly or quite colorless, 55–70 μm long and 8–10 μm wide, with apex 15–20 μm in diameter. Aeciospores globose to subglobose or ellipsoid, 18–22 × 21–27 μm; wall 1–1.5 μm thick, with 5–8 scattered pores, hyaline with orange–yellow contents, densely verrucose, one or shorter, cylindrical verrucae produced on a distinct base. Telia hypophyllous, scattered, minute, black. Teliospores ellipsoid to cylindrical, 3–7-celled; 25–30 × 57–85 μm; wall 3–5 μm thick, verrucose, dark brown to chestnut brown; pedicel long, hyaline to pale yellow.

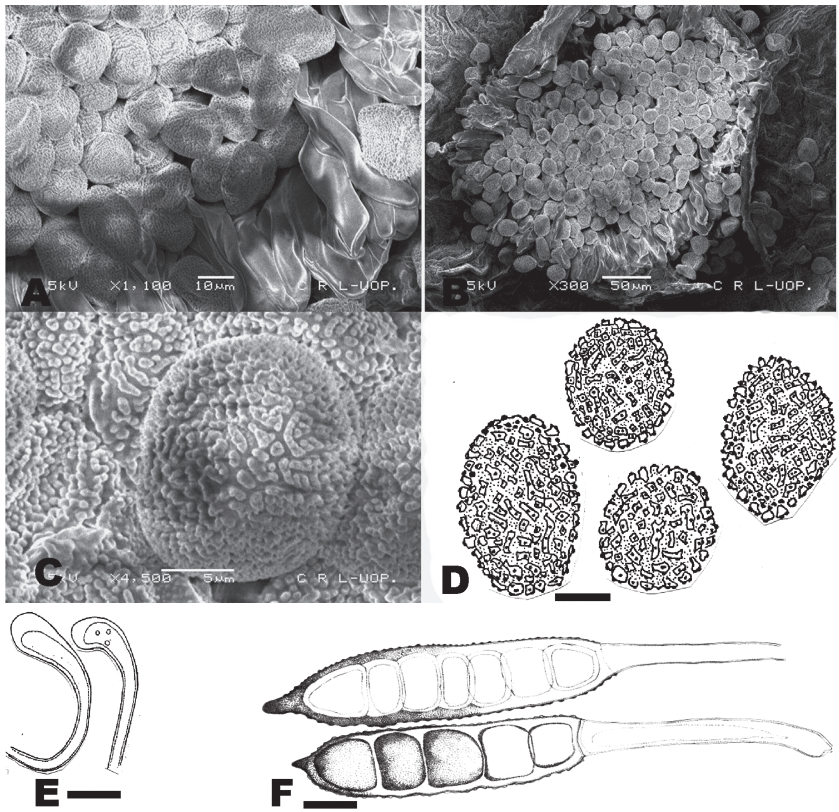

Plate 4: *Phragmidium tuberculatum*. (A) SEM photograph of an aecium. (B) Aeciospores with incurved paraphyses. (C) A close view of surface ornamentation of aeciospores showing cylindrical verrucae produced on a distinct base. (D) Aeciospores. (E) Paraphyses. (F) Multicelled teliospores. Scale bars: D–F= 10 µm.

Material examined: **PAKISTAN**, **Khyber-Pakhtunkhawah**, Ayubia National Park, 2135 m a.s.l., on *Rosa moschata* Herrm., stages I + III, 24 May 2006. NSA #04 (LAH NSA1028).

Comments: *Phragmidium tuberculatum* is cosmopolitan and reported on different *Rosa* species (Wilson & Henderson 1966; Farr & Rossman 2014); it has previously been reported from Pakistan on *Rosa webbiana* Wall. ex Royle and *Rosa* sp. from Kaghan valley, Barum valley, Dungagali, and Swat valley (Ahmad 1956a,b; Kakishima et al. 1993a,b: Okane et al. 1992; Ono & Kakishima 1992).

Phragmidium violaceum (Schultz) G. Winter, Hedwigia 19: 54 (1880) Plate 5

Spermogonia, uredinia and telia not found. Aecia amphigenous, yellowish orange, scattered, on veins and petioles, sori 0.5 × 0.09–0.1 mm.

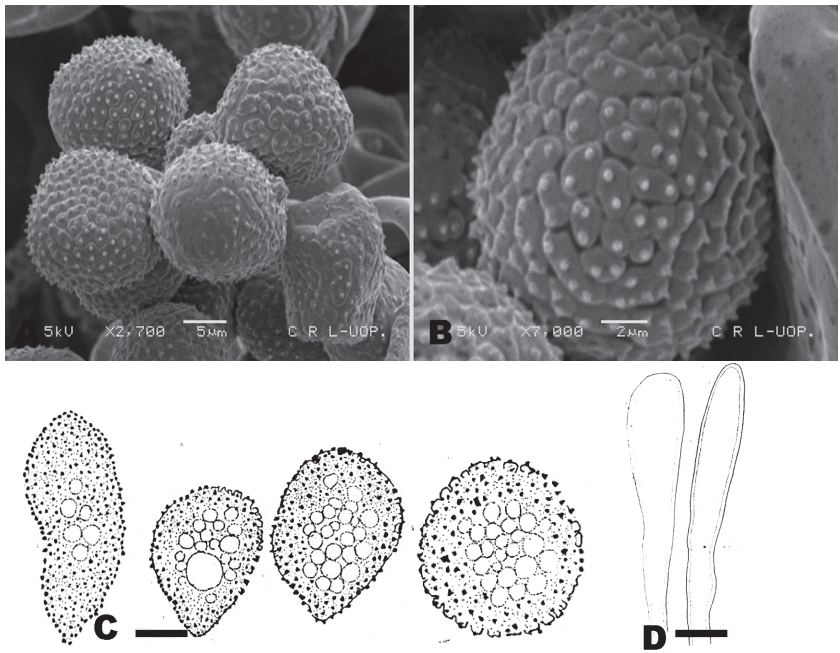

Plate 5: *Phragmidium violaceum*. (A) SEM photograph of aeciospores. (B) A closer view of an aeciospore showing verrucose wall ornamentation. (C) Aeciospores. (D) Paraphyses. Scale bars: C = 10 µm; D = 22 µm.

Aeciospores globose to ovoid or ellipsoid; wall aculeate–verrucose to echinulate, verrucae produced on a distinct base, yellow to orange yellow, sometimes with orangish yellow granules; 16–24 × 20–33 µm; surrounded by peripheral, straight or incurved, clavate and hyaline paraphyses, 94–118 µm long, 8–19µm thick, with uniformly thin walls.

Material examined: **PAKISTAN**, **Azad Jammu & Kashmir**, Neelum valley, Muchal, 3000 m a.s.l., on *Rubus ulmifolius* Schott, stage I, 3 Nov. 2006, NSA #0101 (LAH NSA1029a); **Khyber-Pakhtunkhawah**, Khanspur, 2135 m a.s l., on *Rubus ulmifolius*, stage I, 24 May 2006, NSA #01 (LAH NSA1029b).

Comments: *Phragmidium violaceum* is widespread in Britain, Ireland, North America, Europe, and Africa on different *Rubus* species (Wilson & Henderson 1966; Laundon 1969) and has been introduced as a biological control agent in Australia, New Zealand, and Chile. This report represents a new record for Pakistan.

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