

GENUS *PHORMIDIUM* KUTZING EX GOMONT (CYANOPROKARYOTE) FROM DIVERSE HABITATS OF PUNJAB

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Studies were undertaken to find out the distribution of cyanoprokaryotes in most of the habitats of Punjab. Results show that the genus *Phormidium* is widely distributed throughout the state and was the most frequently occurring genus in various habitats of Punjab like road-sides or highways exposed to vehicular pollution, polluted areas, clean environment, wetlands, sewage disposal sites, dry areas, paddy and other fields with high doses of various agrochemicals or soil receiving industrial effluents. Species of *Phormidium* were found everywhere. Family Phormidiaceae forms 51% of the total Oscillatorian species recorded from the area. *Phormidium* was represented by 32 species, and *P. tereberiforme* and *P. breve* were cosmopolitan in distribution.

Key words: *Phormidium*, Cyanophyta, Punjab, India.

In earlier classifications, Oscillatoriaceae has been placed under order Nostocales (Fritsch, 1945; Desikachary, 1959) but in their revised classification, Anagnostidis and Komarek (1985, 1988); Komarek and Anagnostidis (2005) on the basis of some non-traditional features (type of cell division, occurrence of aerotopes, motility, type of trichome disintegration, etc.) introduced a separate order Oscillatoriales. *Phormidium* is an important genus of order Oscillatoriales with more than 200 species found all over the world (Peinador, 1999). *Phormidium* along with 6 other non-heterocystous genera is marked as magnificent source of biofertilizer, in terms of dry weight, shorter generation period, and tolerance to the biocides at doses much higher than those recommended for rice crops (Tiwari *et al.*, 2001). *Phormidium* has ability to decolourize dyes as reported by Parikh and Madamwar (2005). Certain toxin producing *Phormidium* species have also been reported (Teneva *et al.*, 2005). *P. corallyticum* is also reported to cause "black band disease" that destroyed coral reefs (Frias-Lopez *et al.*, 2003).

Punjab is located between 29°30' and 32° 32' N latitude and 73°54' and 76°50' E longitude. Physiographically it is situated in the north-western part of India. The climate of Punjab is typically subtropical with hot summers and cold winters.

MATERIAL AND METHODS

Two hundred and seventy five samples of algae were collected from various habitats (wetlands, ponds, roadside ditches, paddy fields, tree barks, rocks, cryptogamic crusts etc) of Punjab between the periods of March 2003 to June 2006. *Phormidium* species were usually found forming membranous, leathery thallus, slimy mats, attached to substratum or floating free. Samples were preserved in a preservative consisting of 4% formalin and 1% glycerine after their microscopic examination. Taxonomic identification of the taxa was done according to Desikachary (1959); Anagnostidis and Komarek (1985, 1988); Komárek and Hauer (2004); Komarek and Anagnostidis (2005).

SYSTEMATIC ACCOUNT

Phormidium Kutzing ex Gomont

Phormidium aerugineo-caeruleum (Gomont)
Anagnostidis & Komarek

Filaments flexuous, up to 8 mm wide, sheath firm, colourless in young and yellow-brown in old filaments, trichomes 4-6 mm wide, cylindrical, no attenuation, cells up to 1/3 times longer than wide, apical cell obtusely rounded (Fig. 1).

Locality: HOSHIARPUR: Dholbaha wetland, reservoir; FEROZEPUR: Periphytic on tank wall; SANGRUR: Dhanaula – Sangrur road, wet soil.

PAN No & Date: 189(14.12.2004), 236 (13.03.2005) & 407 (28.05.2005).

***Phormidium ambiguum* Gomont**

Filaments long, flexuous to straight, 5-6.5 mm wide, sheath thin, firm, colourless, trichomes bright blue-green, 4-5 mm wide, cells 1.5-2 mm long, ends straight without attenuation, apical cell flatly rounded (Fig. 2).

Locality : SANGRUR: Tapa Mandi, wet soil receiving effluents from Sukhraj paper mill.

PAN No & Date: 403 (4.12.2004).

***Phormidium amoenum* Kutz ex Anagnostidis & Komarek**

Sheath lacking, trichomes feebly curved, blue-green, 3 mm wide, attenuated at the ends, apical cell broadly conical (Fig. 3).

Locality : KAPURTHALA. Kanjli wetland, moist soil surrounding the reservoir; GURDASPUR, Miani wetland.

PAN No & Date: 275 (7.09.2004) & 301 (14.06.2005)

***Phormidium animale* (Agardh ex Gomont) Anagnostidis & Komarek.**

Thallus membranous, trichomes straight, blue-green, attenuated and slightly bent at the ends, sheath absent, cells 3.5-4 mm wide, 2-3 mm long, cell content homogeneous, apical cell acute conical (Fig. 4).

Locality: CHANDIGARH: Rock garden, moist rocks; SANGRUR: Bhawanigarh, paddy fields; GURDASPUR: Kahnuwan wetland, damp soil;

NAWANSHEHR: paddy fields

PAN No & Date: 134 (17. 01.2004), 292 (14.12.2004), 416 (27.05.2005) & 417 (16.09.2005).

***Phormidium articulatum* (Gardner) Anagnostidis & Komarek**

Sheath lacking, trichomes blackish grey, long, almost straight, constricted at the thick cross-walls, 4-4.5 mm wide, 2-2.5 mm long, not attenuated, apical cell rounded (Fig. 5).

Locality: PATIALA: Rajpura- Patiala road, stagnant water.

PAN No & Date: 466 (15.12.2004).

***Phormidium autumnale* (Agardh) Trevisan ex Gomont**

Filaments almost straight, sheath lacking, trichomes bright blue-green, 5-6 mm wide, cells 4-6 mm long, slightly constricted, attenuated at the ends, straight or hooked, sheath thin, facultative, cell content keritomised, apical cell elongated, capitate with rounded calyptra (Fig. 6).

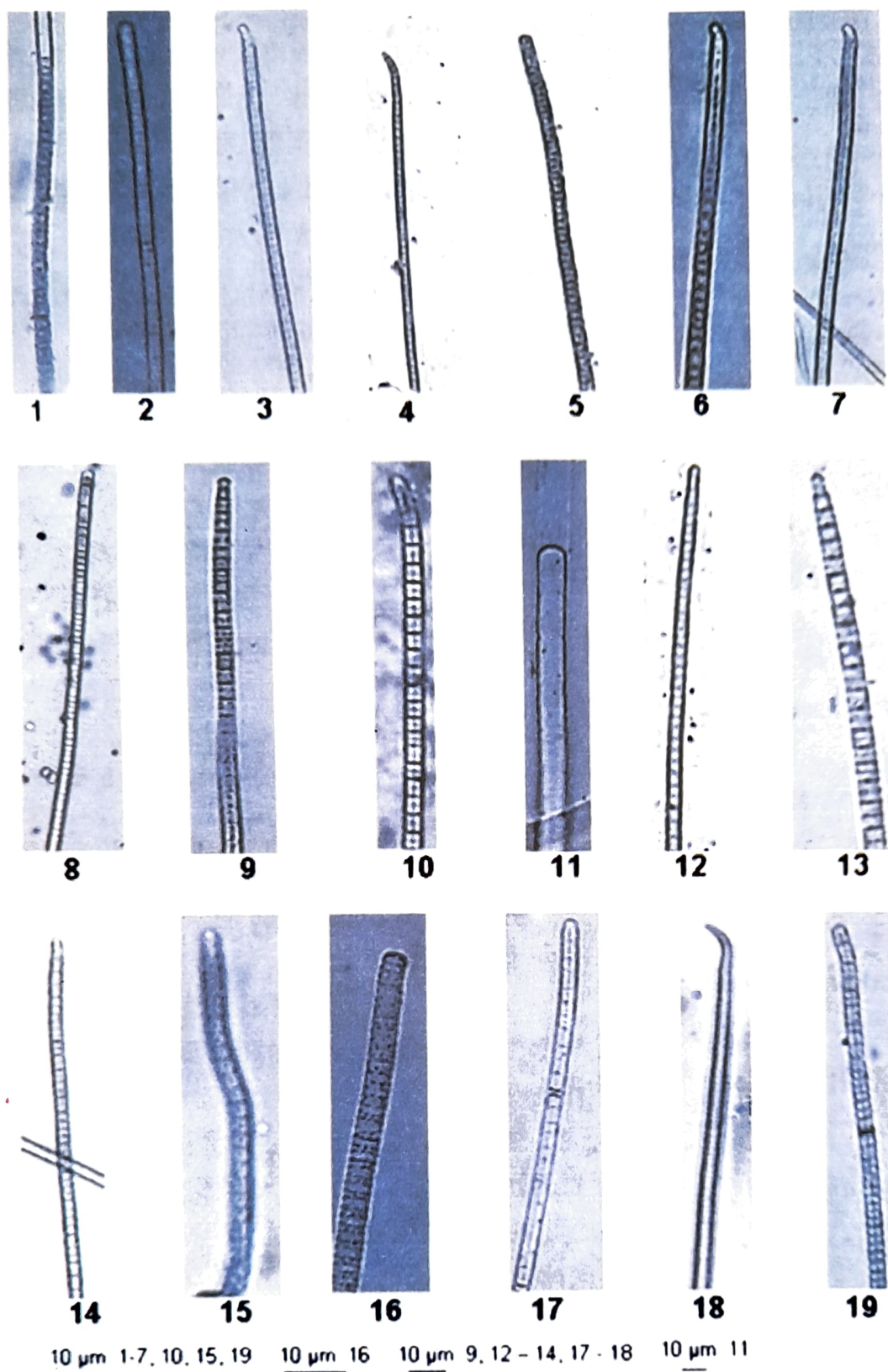
Locality: HOSHIARPUR: Tanda, paddy fields; Dholbaha wetland, AMRITSAR: Jastarwal wetland, moist rock; LUDHIANA: Pakhowal, paddy fields.

PAN No & Date: 196 (27.7.2003), 265 (13.03.2005), 331(15.09.2005) & 379 (16. 09.2005).

***Phormidium breve* (Kutzing ex Gomont) Anagnostidis & Komarek**

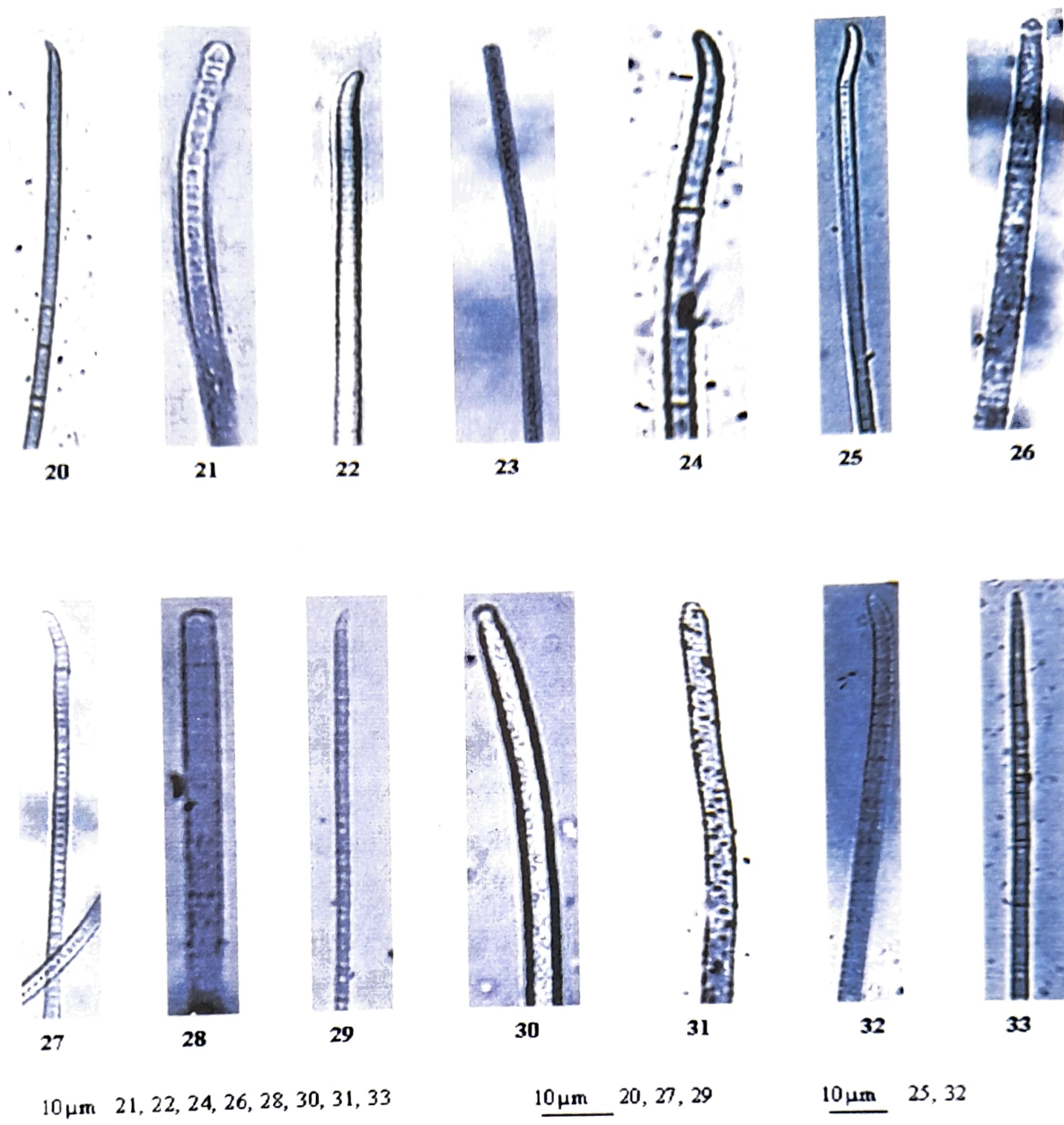
Trichomes slightly flexuous, up to 5mm wide, cells 2-2.5 mm long, briefly attenuated at the ends, mostly bent, apical cell rounded, conical, without calyptra (Fig. 7).

Locality: BATHINDA: Aali Ke, moist soil near a pond; MANSA: Joga, soil; GURDASPUR: Miani wetland, damp soil; AMRITSAR: Raja Sansi, moist



Figures 1-33 *Phormidium* species from state of Punjab.

Fig. 1. *Phormidium aerugineo-caeruleum*, Fig. 2. *Phormidium ambiguum*, Fig. 3. *Phormidium amoenum*, Fig. 4. *Phormidium animale*, Fig. 5. *Phormidium articulatum*, Fig. 6. *Phormidium autumnale*, Fig. 7. *Phormidium breve*, Fig. 8. *Phormidium bulgaricum*, Fig. 9. *Phormidium calcareum*, Fig. 10. *Phormidium chlorinum*, Fig. 11. *Phormidium corbierei*, Fig. 12. *Phormidium cortianum*, Fig. 13. *Phormidium favosum*, Fig. 14. *Phormidium formosum*, Fig. 15. *Phormidium gebhardtianum*, Fig. 16. *Phormidium granulatum*, Fig. 17. *Phormidium interruptum*, Fig. 18. *Phormidium janthiphorum*, Fig. 19. *Phormidium jenkelianum*



Figures 20-33 *Phormidium karakalpakense*, Fig. 21. *Phormidium kuetzingianum*, Fig. 22. *Phormidium laete-virens*, Fig. 23. *Phormidium nigrum*, Fig. 24. *Phormidium okenii*, Fig. 25. *Phormidium paulsenianum* f. *takyricum*, Fig. 26. *Phormidium subfuscum*, Fig. 27. *Phormidium terebriforme*, Fig. 28. *Phormidium tergestinum*, Fig. 29. *Phormidium tortuosum*, Fig. 30 & 31. *Phormidium uncinatum*, Fig. 32. *Phormidium* sp., Fig. 33. *Phormidium* sp.

soil; SANGRUR: moist soil outside & Komarek
gurudwara gate.

PAN No & Date: 201, 220 (4.06.2004), 328
(14.06.2005) & 442 (15.09.2005).

Phormidium bulgaricum (Komarek) Anagnostidis

Trichomes pale to deep blue-green, almost straight, slightly constricted at the cross walls, 3-4.5 mm wide, cells 1-2 mm long homogeneous content with granules, not attenuated at the ends,

apical cell widely-rounded, with or without thickened outer cell wall (Fig. 8).

Locality: MANSA: Bhaini-Bagha, eutrophic pond; Garaddi, stagnant water, CHANDIGARH: Shanti Kunj, benthic in drain; AMRITSAR: roadside puddle; HOSHIARPUR, Sidwan wala, eutrophic water.

PAN No & Date: 226 (14.12.2004), 227 (7. 06.2005), 258(15.09.2005), 341 & 349 (16.09.2005).

***Phormidium calcareum* Kutzin**g ex Starmach

Trichomes, blue-green, almost straight, sheath absent, 4-5 mm wide, in the middle part slightly longer than as wide, 3-5.8 mm long, granules present, gradually attenuated towards ends, apical cell conical, some trichomes with spherical calyptra (Fig. 9).

Locality: HOSHIARPUR: Dholbaha wetland, epilithic on the wet rock.

PAN No & Date: 193 (14.03.2005).

***Phormidium chlorinum* (Kutzing ex Gomont)** Anagnostidis

Trichomes yellow-green, straight to slightly flexuous, sheath lacking, up to 4.5 mm wide, cells up to 5 mm long, slightly constricted at the cross-walls, light perpendicular striations on the cell surface, apical cell widely-rounded (Fig. 10).

Locality: CHANDIGARH: Terrace garden, moist soil; GURDASPUR; Dakoha, field soil.

PAN No & Date: 266 (7.06. 2005) & 323 (14.06.2005)

***Phormidium corbierei* (Freymy)** Anagnostidis

Filaments straight to flexuous, up to 14 mm wide, sheath firm, colourless, trichomes cylindrical,

yellow green, up to 8 mm wide, cells 3.5-5 mm long, apical cell widely rounded (Fig. 11).

Locality: HOSHIARPUR: Hazipur, epilithic on a submerged stone.

PAN No. & Date: 264 (14.03.2005).

***Phormidium cortianum* (Meneghini ex Gomont)** Anagnostidis & Komarek

Trichomes straight, pale blue-green, up to 6 mm wide, 2.5-4.5 mm long, attenuated but extent of attenuation less, cell content homogeneous, apical cell flat-conical, not capitate (Fig. 12).

Locality: BATHINDA: Bhucho Mandi, paddy field.

PAN No & Date: 206 (26.05. 2005).

***Phormidium favosum* Gomont ex Gomont**

Trichomes almost straight, long, sheath lacking, deep blue-green to blackish blue-green, up to 7 mm wide, cells 2.5-6 mm long, granulated cross-walls, slightly attenuated at the ends, apical cell mostly capitate with obtuse conical calyptra (Fig. 13).

Locality : FARIDKOT: Kotkapura, pond; KAPURTHALA: Kanjli wetland, on submerged stones.

PAN No & Date: 429 & 433 (22.03.2006) and 468 (7.09.2004).

***Phormidium formosum* (Bory ex Gomont)** Anagnostidis & Komarek

Trichomes straight to slightly flexuous, bright blue-green, sheath lacking, 5-6.5 mm wide, cells shorter or isodiametric, briefly attenuated at the ends, apical part slightly bent, apical cell rounded or conical (Fig. 14).

Locality : MOHALI: roadside wet soil;

TARAN–TARAN: periphytic in a pool;
AMRITSAR: Jastarwal wetland, benthic in stagnant
water, Harike wetland, moist soil.

PAN No & Date: 182 (15.08.2004), 334 & 335
(15.09.2005), 505 (21.03.2006).

Phormidium gebhardtianum (Claus) Anagnostidis
& Komarek

Trichomes blue-green, flexuous, 2.5-3 mm wide,
cells 2.5-3 mm long, constricted at crosswalls, slight
attenuation at the ends, end cell rounded (Fig. 15)

Locality: KAPURTHALA: Phagwara, moist
flower beds.

PAN No & Date: 478 (9.03.2006).

Phormidium granulatum (Gardner) Anagnostidis

Trichomes straight, 4-4.5 mm wide, cells 3-3.3
mm long, no attenuation, distinct 4-6 granules at
the crosswalls, apical cell rounded with slightly
thickened cell wall (Fig. 16).

Locality: SANGRUR: Tapa Mandi, moist soil
receiving effluents from Sukhraj Paper Mill.

PAN No & Date: 403 (14.12.2004).

Phormidium interruptum Kutzing *ex* Gomont

Filaments straight to irregularly coiled, sheath
thin, colourless, trichomes blue-green, 5 mm wide,
cells shorter than wide, few granules present at cross
walls, no attenuation toward end, apical cell flatly
rounded (Fig. 17).

Locality: HOSHIARPUR: tank wall;
GURDASPUR: Miani, epilithic.

PAN No & Date: 191 (13.03.2005) & 315
(14.06.2005)

Phormidium janthiphorum (Fiorini-Mazzetti *ex*

Gomont) Elenkin

Trichomes bright blue-green, 4.5-5 mm wide,
cells 2-2.5 mm long almost straight, sharply
attenuated, slightly bent at ends, apical cell hooked,
acute-conical with pointed end (Fig. 18).

Locality: SANGRUR: Tapa Mandi, moist soil
of Baba Math.

PAN No & Date: 415 (27.05.2005).

Phormidium jenkelianum Schmidt

Trichomes flexuous to straight, blue-green, 2.5-
3.5 mm wide, cells 1-1.5 mm long, distinctly
constricted at cross walls cylindrical, no attenuation
at the ends, terminal part straight to little bent, apical
cell broadly rounded (Fig. 19).

Locality: PATIALA: Nabha road, roadside
puddle.

PAN No & Date: 249 (15.12. 2004).

Phormidium karakalpakense (Muzafarov)
Anagnostidis & Komarek

Trichomes solitary, olivaceous blue-green, 3.5-
4.5 mm wide, cells 2-2.5 mm long, sheath thin,
colourless, facultative, gradually attenuated towards
ends, slightly bent, cell content homogeneous, apical
cell conical and pointed rounded (Fig. 20).

Locality: ROPAR: Anandpur Sahib, waterlogged
soil along highway; BATHINDA: Giddharbaha,
from newly transplanted paddy fields.

PAN No & Date: 151 (7.05.2004 & 203
(26.05.2005).

Phormidium kuetzingianum (Kirchner)
Anagnostidis & Komarek

Filaments bright blue-green, long, sheath thin,
colourless, trichomes 3.5-4 mm wide, cells up to 3

mm long., constricted only at the apical end, apical cell widely rounded (Fig. 21).

Locality: LUDHIANA: Pakhowal, paddy fields.

PAN No & Date: 378 (27.7.2003).

Phormidium laete-virens (Crouan ex Gomont) Anagnostidis & Komarek Fig. 22

Trichomes straight, olive-yellow green, 4-5 mm wide, cells 2.5-3 mm long, constricted at translucent cross-walls, attenuated for a short stretch and slightly bent, apical cell narrow, triangular with round margins.

Locality: BATHINDA: Bhuchon, paddy field; MOGA: Bhagapurana, moist soil.

PAN No & Date: 205 (26 .05. 2005) and 219 (27 .05. 2005).

Phormidium nigrum (Vaucher ex Gomont) Anagnostidis & Komarek

Trichome dark blue-green, straight, 5.5-6.5 mm wide, cells 2.5-3 mm long, minor constrictions at cross-walls, cell content granular, no attenuation at ends, end cell flatly rounded (Fig. 23).

Locality: AMRITSAR: Harike wetland, shallow water.

PAN No & Date: 490 (21.03.2006).

Phormidium okenii (Agardh ex Gomont) Anagnostidis & Komarek

Trichomes long, straight to flexuous, 4.5-6 mm wide, cells 2.5-3 mm long, slightly constricted at septa, slightly hooked, attenuation near the ends, cell content differentiated into chromatoplasm and centropasm, apical cell conical rounded (Fig. 24).

Locality: BATHINDA: Bhuchon Mandi, paddy fields.

PAN No & Date: 205 (26.05. 2005).

Phormidium paulsenianum f.takyricum Novickova

Trichomes blue green, 4 mm wide, up to 2 mm long, shortly attenuated towards end, apical cell pointed, rounded (Fig. 25).

Locality: FEROZEPUR: Bazidpur, moist soil.

PAN No & Date: 221 (28.05.2004).

Phormidium subfuscum Kutzing ex Gomont

Filaments straight, sheath facultative, trichomes olive-green, straight, 5.5-6 mm wide, cells up to 5 mm long, briefly attenuated towards the ends, capitate, apical cell straight with conical calyptra or obtusely rounded calyptra (Fig. 26).

Locality: AMRITSAR: Tangra, roadside paddy fields.

PAN No & Date: 339 (15.09.2005).

Phormidium terebriforme (Agardh ex Gomont) Anagnostidis & Komarek

Trichomes bright blue-green, 5-6 mm wide, cells 2.5-4 mm long, slightly attenuated and hooked towards end, cell content homogeneous, apical cells rounded to hemispherical (Fig. 27).

Locality: HOSHIARPUR: Dholbaha wetland, wet soil; PATIALA: Tripari, near water tank; BATHINDA: Lehra Muhabbat., wet soil; MOGA: Bhagapurana; HOSHIARPUR: Tanda, soil near water tank; SANGRUR: Sunam , waterlogged soil of Sitasar pond.

PAN No & Date: 190 (14.12. 2004), 202 (14.03.2005), 223 & 250 (26.05.2005), 282 (27.05.2005), 400 (28.08.2005).

Phormidium tergestinum (Kutzing) Anagnostidis

& Komarek

Trichomes parallel in arrangement, almost straight, blue-green, 5-6 mm wide, cells shorter than wide, 2.5-3.5 mm long, minor constrictions, granulated, straight end, apical cell hemispherical without thickened cell wall (Fig. 28).

Locality: KAPURTHALA, Kanjli wetland, waterlogged soil.

PAN No & Date: 174 (7.09.2004).

Phormidium tortuosum (Gardner) Anagnostidis & Komarek

Trichomes flexuous, light blue-green, sheath lacking, 2.5-3 mm wide, cells 2-3 mm long, gradually attenuated at ends, end cell conical acuminate (Fig. 29).

Locality: KAPURTHALA, Kanjli wetland, waterlogged soil along with other *Phormidium* species.

PAN No & Date: 174 (7.09.2004).

Phormidium uncinatum Gomont ex Gomont

Trichomes parallel in arrangement, sheath facultative, straight to slightly flexuous, 6-7 mm wide, shortly attenuated towards the ends, 2.5-3.5 mm long, cell content distinctly granulated, apical cell spherically capitate (Figs. 30 & 31).

Locality: AMRITSAR: periphytic on tank wall.

PAN No & Date: 347 (15.09.2005).

***Phormidium* sp₁**

Trichomes without sheath, almost straight, green, 6-8 mm wide, 3.2-4 mm long, constricted at crosswalls, cell content concentrated on periphery, gradually attenuated and bent, apical cell conical with rounded margins (Fig. 32).

Locality: ROPAR: Tanjori, polluted sewage water.

PAN No & Date: 142 (12.03.2003)

***Phormidium* sp₂**

Trichome thin, pale blue-green, sheath lacking, up to 2.5 mm wide, cells 1-1.5 mm long, gradually attenuated over a long stretch, terminal cells hooked, slightly bent or straight, apical cell conical, narrowed, sharply pointed (Fig. 33).

Locality: BATHINDA: Bhuchon Mandi, paddy field.

PAN No & Date: 206 (26.05.2005).

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