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Distribution of diatom flora of the family Achnantheaceae in two different mountain ecoregions: The Himalaya and the Central Highland

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Abstract

This paper describes the diatom flora of the family Achnantheaceae from two different ecoregions of India. In the present study, thirty nine diatom taxa belonging to the genus Achnanthes, Achnanthidium and Planothidium were identified. The morphological and ecological characteristics of this taxon are little known in spite of the fact that it is generally considered to be widely distributed. The species of this family comprises a large number of monoraphid diatoms common in freshwater. Many representatives of these genera are good indicators of water quality and its physicochemical characteristics. In the flora twenty nine species were recorded from the Himalaya while twenty species from Vindhya. All of them were first records for the Vindhyan rivers.

Key-words: *Central Highlands, diatoms, ecoregions, flora, India.*

Introduction

Floristic aspects of the algae of the Indian subcontinent have been the subject of investigations for many years (Sarode and Kamat, 1984; Gandhi 1999; Karthick *et al*., 2011; 2015; Nautiyal *et al*., 1999 a&b, Nautiyal *et al.*, 2004 a&b, Verma and Nautiyal 2010; 2016) making it one of the better-known diatom floras of India. This paper presents the results of a floristic study focused on small taxa of the family **Achnanthaceae** Kutzing 1844.

The taxonomy of the genus *Achnanthes* has undergone many changes, particularly in the last 14 years. The most striking changes concern the genus *Achnanthidium*, redefined by Round et al. in 1990, based on *Achnanthes minutissima* Kützing. The genus *Achnanthidium* as defined by Round and Bukhtiyarova (1996) contains two groups of species: those with straight terminal raphe ends ("*A. minutissimum*" group) and those with

terminal raphe fissures curved to the same side of the valve ("*A. pyrenaicum*" group). This genus comprises a large number of monoraphid diatoms common in freshwater. They are very abundant in periphytic communities. Many representatives of these genera are good indicators of water quality and its physicochemical characteristics (Lange Bertalot and Krammer, 1989; Krammer and Lange-Bertalot, 1991; Van Dam *et al.*, 1994).

Diatoms in mountain springs have been investigated since the 1990s in the Pyrenees (Sabater and Roca, 1992) and in the Alps (Cantonati, 1998). These and other investigations, which compared diatom assemblages of mountain ranges in different continents (i.e. Alps vs. Himalayas) clearly confirmed the importance of lithology-related variables (conductivity, pH) in shaping near-natural spring diatom assemblages (Cantonati *et al.*, 2001; Nautiyal *et al.*, 2004a&b; Wojtal *et al.*, 2010).

Materials and methods

Sampling: Diatom collections were obtained from 20 stations; 11 stations on 3 rivers in the Vindhya region and 9 stations on 3 rivers and 2 streams in the Himalaya seasonally in 2008. The diatom samples were collected, processed and identified according to the Wojtal *et al.*, 2010. The dimensions and distribution of the species were separately indicated for each species. Species and intraspecific taxa are arranged in the text and plates.

Observations

1. ***Achnanthes*** spec. cf. *coarctata* (Brebisson) Grunow in Cleve and Grunow 1880, p. 20 (Figs. 13: 9-16). L 23-27, W 7-8, S 13-14, Elliptical-lanceolate, outline with more or less drawn out ends and flatly rounded to trimmed, rapheless valve with narrow pseudoraphe, shifted transapicaly to margin, without central area. (Plate 1, Fig. 1).

2. *A. crenulata* Grunow in Cleve and Grunow 1880, p. 20 (Figs. 13: 17-19, REM-Figs. 14: 3-6). L 30-45, W 9-12, S 15-16, Linear-lanceolate, valve ends narrow, broadly rounded, without central area. Raphe valve with straight robust raphe, axial area distinct, central area broad and rectangular, transapical striae slightly radial, punctate 9-10 puncta (Plate 1, Figs. 2-11).

3. ***Achnanthidium*** *biasolettiana* Grunow 1880 (Figs. 61: 1-17). L 8-12, W 2-5-3.5, Valves linear, rounded apices, slightly narrowed on the ends, rapheless valve with very narrow pseudoraphe, without central area, raphe valve with narrow axial area, central area small roundish, because striae

are continuous, striae delicate more than 30 and radial (Plate 1, Figs. 12-13).

4. *A. biasolettiana* Grunow var. *biasolettiana,* Grunow in Cleve and Grunow 1880, p. 22 (Figs. 57: 1-7, siehe auchTafel 58-60). L 14-19, W 3-3.5, S 21-23. Differs from the species because central area is formed due to lack of some striae (Plate 1, Figs. 14-15).

5. *A. biasolettiana* Grunow var. 1. L 18, W 4, S 23-25. More elliptic in outline, striae less dense (Plate 1, Fig. 16).

6. *A. biasolettiana* Grunow var. 2. L 13, W 4, S 20-22. Smaller but wider than var. *biasolettiana* (Plate 1, Fig. 17).

7. *A. biasolettiana* Grunow var. 3. L 15-22, W 3.5-4, S 23-25. Larger than above described var., rapheless valve with central area (Plate 1, Figs. 18-20).

8. *A. biasolettiana* var. *subatomus* Lange-Bertalot (Figs. 59: 1-11', REM-Figs. 57: 8). L 12-20, W 3-4, S 17-19. Elliptic, broadly rounded ends, raphe valve with narrow axial area, central area absent (Plate 1, Figs. 19, 21-24).

9. *A. biasolettiana* var. *subatomus* Lange-Bertalot *inflata* (Figs. 59: 1-11', REM-Figs. 57: 8) or Intial cell. L 20, W 4, S 18. Valve margins inflated in middle, central area distinct, small, rhombic (Plate 1, Fig. 25).

10. *A. conspicua* Mayer 1919, p. 198, Figs.6: 9, 10 (Figs. 32: 1-19, REM-Figs. 32: 28-31, 31: 8). L 7-10, W 4-5, S 20-22, Elliptical, rapheless valve with narrow central area between the middle striae, usually reaching out to the edge (Plate 1, Figs. 26-29).

11. *A. exigua* Grunow var. *exigua,* K. Sv. Vet. Akad. Handl. Vol. 17, 2, p. 21 (1880). L 12-16, W 5-6.5, S 28-30, Elliptical, valve with rounded protracted ends, raphe valve with narrow axial area, fascia cross-shaped, striae radiate, asymmetrical central area (Plate 1, Figs. 30-31).

12. *A. exigua* var. *constricta* Torka Hust. 1921, p. 145, Figs. 7, 8. L 12-14, W 4.5-5.5, S 20-22, Valves transapically constricted in middle (Plate 1, Figs. 32-33).

13. *A.* cf. *exilis* (girdle view) Kützing 1833 (Figs. 33: 23-33, Figs. 35: 4). L 23-25, W 4-4.5, S >24, Central area of the raphe valve romboid-elliptical, proximal raphe ends widely spaced (Plate 1, Fig. 34).

14. *A. helvetica* (Hustedt) Lange-Bertalot (Figs. 19: 1-20, 26, REM-Figs. 20: 1-6, vgl. Auch Figs. 96: 6-11; vgl. Simonsen 1987, Figs. 220: 1-9). L 5-8, W 2.5-3, Elliptical, small, raphes bent to opposite sides at poles (Plate 1, Figs. 35-36).

15. *A. holsatica* Hustedt in A. Schmidt et al. 1936, Figs. 407: 67-72. L 6.5, W 3, S 20, Elliptical, rapheless valve with much larger elliptical central area, as a result the striae are arround the edge, also distally there is no

narrower separate axial area, striae coarse (Plate 1, Fig. 37).

16. *A. lineare* (W. Smith) Grunow (Figs. 37: 19-23) or *petersenii* Hustedt 1937 (Figs. 37: 24-40). L 22-28, W 4-5, S >24, Linear-lanceolate, rounded apices, raphe valve with narrow axial area and small central area formed by the shortening of one or more striae at midvalve, RL valve with narrow linear pseudoraphe, rhombic central area due to shortening of striae (Plate 1, Figs. 38-39).

17. *A. marginulata* Grunow in Cleve and Grunow 1880, p. 21 (Figs. 26: 1-18, 95: 15-21, REM-Figs. 24: 4-7). L 8-11, W 3-4, Elliptical, valve slightly bent in girdle view, rounded apices, raphe valve with narrow axial area, rectangular central area, RL valve with broad lanceolate pseudoraphe (Plate 1, Figs. 40-44).

18. *A. minutissima* var. *affinis* (Grunow) Lange-Bertalot (Figs. 53: 22-37 u.a., REM-Figs. 56: 5-7). L 21, W 4,. Linear-lanceolate, margins suddenly narrowing towards the end, apices protracted, bluntly rounded, axial area very narrow, striae very delicate, parallel, wide at center (Plate 1, Fig. 45).

19. *A. minutissima* var. *gracillima* (Meister) Lange-Bertalot (Figs. 54: 21-32, 55: 1-3). L 28-40, W 4-4.5, S 20-23, Linear-lanceolate, valve gradually narrowed from the middle towards the ends, ends rounded, rapheless valve with linear pseudoraphe, central area not distinct, middle striae on both sides sometimes shorter than adjacent striae, raphe valve with filamentous raphe, central area very narrow, striae somewhat parallel, very close (Plate 1, Figs. 46-48).

20. *A. minutissima* var. *minutissima* Kützing 1833, p. 578, Fig. 54 (Figs. 51: 1-20 u.a., vgl. REM-Figs.auf Tafel 52 u. 56). L 11-16, S 2-2.5, Linear-lanceolate, valve gradually narrowed towards the middle, broadly rounded near slightly capitate apices, raphe valve with narrow axial area and small round central area both, transapical striae very delicate, middle striae shortened (Plate 1, Figs. 49-52).

21. *A. minutissima* var. *minutissima* Kützing 1833, p. 578, Fig. 54 (Figs. 51: 1-20 u.a., vgl. REM-Figs.auf Tafel 52 u. 56) or var.? L 14, W 2.5, Linear-lanceolate, valve with rounded apices, raphe valve with narrow axial area and small central area, transapical striae very delicate, both middle striae shortened (Plate 1, Fig. 53).

22. *A. minutissima* var. *robusta* Hustedt 1937, p. 192, Figs. 13: 41-46 (Figs. 51: 40, 41? 42-45; vgl. Simonsen 1987, Figs. 325: 1-12) or *A. crassa* (see Appendix 1) Hustedt 1937, p. 194, Figs. 13: 37-40 (Figs. 59: 20-23; vgl. Simonsen 1987, Figs. 325: 23-31). L 12, W 3, Linear-elliptical, bluntly rounded

ends, rapheless valve with narrow axial area, middle striae on both sides sometimes shorter than adjacent longer but radial striae (Plate 1, Fig. 54).

23. *A. minutissima* var. *jackii* (Rabenhorst) Lange-Bertalot 1980, p. 18 (Figs. 51: 22-29, 31-39). L 12-16, W 2.5-3, Broader in middle, valve margins parallel towards apices, bluntly rounded ends (Plate 1, Figs. 55-57).

24. *A. minutissima* var. *scotica* (Carter) Lange-Bertalot in Lange-Bertalot and Krammer 1989 (Figs. 34: 1-6). L 18-25, W 2.5-3.5, Linear-lanceolate, gradually narrowed from the middle towards the ends, ends more or less distinctly constricted and capitately rounded, linear pseudoraphe, (Plate 1, Figs. 58-60).

25. *A. modestiformis* Lange-Bertalot (Figs. 55: 33-42'). L 14-18, W 4-5, Elliptical lanceolate, valve inflated in middle, ends constricted, broadly rounded, central area indistinct or small, striae delicate and radial (Plate 1, Figs. 61).

26. *A. petersenii* Hustedt 1937 (Figs. 37: 24-40). L 19-28, W 4-5, S >26, Linear, valve ends blunt, rounded apices, linear pseudoraphe, central area indistinct, transapical striae delicate (Plate 1, Fig. 62).

27. *A. pusilla (*Grunow) De Toni, l.c. p. 485. L 14-16, W 3-4, S >20, Linear, valve with parallel margins and broad rounded apices, striae parallel, widely spaced, both middle striae shortened (Plate 1, Figs. 63-64).

28. A. cf. *pseudoswazi* J. R. Carter 1963 (Figs. 24: 1-7). L 14-18, W 3-4, Linear-elliptic forms, valves constricted near ends, bluntly rounded, rapheless valve very narrow, 1-2 middle striae shorter than adjacent longer but radial striae (Plate 1, Figs. 65-67).

29. *A. sphacelata* J. R. Carter 1970, p. 611, Figs. 1: 41-44 (Figs. 67: 10-13). L 5-7, W 3-3.5, Elliptical, rounded apices, axial area narrow, raphe very distinct, middle two striae shortened, striae radial, central area rectangular (Plate 1, Figs. 68-71).

30. *A. subhudsonis* Hustedt 1921, p. 144, Figs. 9-12. L 12-14, W 3.5-4, S 18-20, Elliptical-lanceolate, valves bluntly rounded, narrowed towards apices, axial area small, central area very distinct, elliptical in shape due to shortening of striae, striae radial (Plate 1, Figs. 72-73).

31. *A. taeniata* Grunow in Cleve and Grunow 1880, p. 22, Figs. 1: 5. L 16, W 3, Elliptical-lanceolate, ends bluntly rounded apices, axial area very narrow, raphe narrow, linear, central area not distinct, striae delicate (Plate 1, Fig. 74).

32. ***Planothidium*** *lanceolata* var. *elliptica* Cleve Lange-Bertalot 1991 (Figs. 86: 33-34'). L 7-12, W 4-6, S 12-15, Elliptical,

valves with broad elliptical middle part, striae radiate (Plate 1, Figs. 75-76).

33. *P. lanceolata* (Brebisson) Grunow var. *lanceolata,* Lange-Bertalot 1991 (Figs. 84: 1-16). L 16-18, W 6-7, S 13-16, Elliptical-lanceolate, valve more or less inflated in middle, with broadly rounded apices, raphe valve with narrow axial area, with robust filamentous raphe and widened rectangular central area, horseshoe-shaped clear area present on one side of the central area, transapical striae radial, robust (Plate 1, Figs. 77-78).

34. *P. lanceolata* fo. *rostrata* (Ństrup) Lange-Bertalot 1991 (Figs. 43: 1-14). L 14-16, W 5-6, S 12-13, Elliptical, valve with broad elliptical middle part, quite suddenly and strongly narrowed near the apices and therefore with drawnout, narrow, protracted ends, raphe valve with asymmetrical central area extending to one margin only, striae radial and robust (Plate 1, Fig. 79).

35. *P. lanceolata* ssp. *frequentissima* Lange-Bertalot 1991 (Figs. 44: 1-38). L 9-20, W 3.5-5, S 14-16, Elliptical-lanceolate, valve with narrow rounded apices, raphe valve with narrow axial area, robust raphe, rapheless valve with horseshoe-shaped clear area, on one side of the central area, transapical striae radial, robust (Plate 1, Figs. 80-82).

36. *P. lanceolata* ssp. *dubia* (Grun.) Lange-Bertalot 1991 (Figs. 42: 7-26). L 12-18, W 5-6, Elliptical-lanceolate, valve with protracted rounded apices (Plate 1, Fig. 83).

37. *P. lanceolata* var. *robusta* (Hustedt) Lange-Bertalot 1991 (Figs. 46: 1-3). L 18-25, W 7-8, S 10-11, Elliptical, valve with rounded apices, axial area narrow, with robust filamentous raphe, central area broad and rectangular, transapical striae robust (Plate 1, Fig. 84).

38. *P. lanceolata* var.? L 11, W 5, S 15, Elliptical, broadly rounded apices, raphe valve delicately striated than the rapheless valve (Plate 1, Figs. 87-88).

39. *P.* spec. cf. *biporomum* (Hohn and Hellerman) Lange-Bertalot 1991 (Figs. 43: 30-40). L 13-15, W 4, S 15-16, Elliptical-lanceolate, ends slightly constricted, capitetly rounded, inflated middle, central area horse-shoe shaped (Plate 1, Figs. 90-91).

Discussion

Family Achnanthaceae Kützing 1844 was represented by genera *Achnanthes* (2 species), *Achnanthidium* (29 species) *and Planathodium* (8 species) and Achnanthaceae comprised three genera and thirty nine taxa in the Gangetic flora, 3 genera in both region with 20 taxa in the Vindhya and 29 taxa in the Himalaya (Table 1). However, *Achnanthes* was represented

by *A. cf. coarctata* in the Vindhya and *A. crenulata* in the Himalaya. Most of the taxa in this family belonged to *Achnanthidium* relatively more in the Himalaya than the Vindhya. Thus Himalaya was richer in *achnanthoid* elements.

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Table 1. Distribution of the in the epilithic diatom flora of family Achnantheaceae in the Vindhyan and Himalayan region

Diatom flora	Vindhya	Himalaya
1. Achnanthes spec. cf. *coarctata* (Brebisson) Grunow	+	
2. A. crenulata Grunow		+
3. Achnanthidium biasolettiana Grunow		+
4. A. b. Grunow v. *biasolettiana*		+
5. A. b. Grunow v. 1		+
6. A. b. Grunow v. 2		+
7. A. b. Grunow v. 3		+
8. A. b. v. *subatomus* Lange-Bertalot	+	+
9. A. b. v. *subatomus* Lange-Bertalot (Intial cell) or (inflata)		+
10. A. cf. *exilis* Kützing (girdle view)	+	
11. A. cf. *pseudoswazi* J. R. Carter		+
12. A. conspicua Mayer		+
13. A. exigua Grunow v. *exigua*	+	+
14. A. e. v. *constricta* Torka Hustedt	+	+
15. A. helvetica (Hustedt) Lange-Bertalot		+
16. A. holistica Hustedt		+
17. A. lineare (W. Smith) Grunow or *petersenii* Hustedt	+	
18. A. marginulata Grunow		+
19. A. minutissima v. *affinis* (Grunow) Lange-Bertalot		+
20. A. m. v. *jackii* (Rabenhorst) Lange-Bertalot	+	
21. A. m. v. *gracillima* (Meister) Lange-Bertalot	+	
22. A. m. v. *minutissima* Kützing	+	+
23. A. m. v. *minutissima* Kützing or var.?	+	+
24. A. m. v. *robusta* Hustedt or *A. crassa* Hustedt	+	+
25. A. m. v. *scotica* (Carter) Lange-Bertalot	+	
26. A. modestiformis Lange-Bertalot	+	
27. A. petersenii Hustedt	+	+
28. A. pusilla Grunow		+
29. A. sphacelata J. R. Carter		+
30. A. subhudsonis Hustedt		+
31. A. taeniata Lange-Bertalot	+	
32. Planothidium lanceolata v. *elliptica* Cleve	+	+
33. P. l. (Brebisson) Grunow v. *lanceolata*	+	
34. P. l. fo. *rostrata* (Østrup) Hustedt	+	+
35. P. l. ssp. *frequentissima* Lange-Bertalot	+	+
36. P. l. a v. *dubia* Grunow	+	
37. P. l. v. *robusta* Lange-Bertalot		+
38. P. lanceolata var.?		+
39. P. spec. cf. *biporomum* (Hohn & Hellerman) Lange-Bertalot		+