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DISTRIBUTION OF FAMILY *FRAGILARACEAE* (BACILLAROPHYCOTA) IN THE REGION OF MULTAN, PAKISTAN

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Abstract

Eleven species of Bacillariophycota were collected from various freshwater habitat of Multan Pakistan. The present paper describes the taxonomy and distribution of 11 freshwater pennate diatoms belonging to freshwater bodies such as ponds, lakes and fish farms of Multan from April to November 2009. All these 11 species belonging to family *Fragilaraceae* have been described for the first time from these areas.

Introduction

Plankton community is a heterogenous group of phytoplankton and zooplankton which are suspended in the sea and freshwater (Battish, 1992). Phytoplankton play important role in food chain as they are primary producers in aquatic ecosystem of our biotope (Shameel, 2002). The production of fish is also influenced by primary and secondary productivity of aquatic ecosystem (Panday, 1981). The first investigation on diatoms was made by West & West (1902) from the region now included in Pakistan. Later on Carter (1926) reported 49 species followed by Abdul-Majeed (1935). Salim & Khan (1960) described 102 species of Peshawar velley (N.W.F.P.) of Pakistan. Investigations on diatoms from coastal waters of Pakistan were also made (Salim, 1954, 1963; Salim & Iqbal, 1964; Saifullah & Moazzum, 1978; Ghazala, 2006, 2007). Freshwater diatoms of Sindh (Daudpota & Leghari, 1993, Jahangir *et al*., 2000, 2001; Leghari *et al*., 2001, 2002, 2004, 2005a, b; Leghari & Leghari, 2002), Punjab, N. W. F. P. and Azad-Kashmir (Masud-ul-Hasan & Zeb-un-Nisa, 1986, Masud-ul-Hasan & Batool, 1987; Masud-ul-Hasan & Yunus, 1989; Leghari MK *et al*., 1991, 1995, 2002, 2003, 2004; Sultana *et al*., 1991, Leghari & Sultana, 1993; Tariq-Ali *et al*., 2005, 2006a, b, c, d, 2007, 2008). But no survey was conducted in the southern regions of Punjab. So, a research programme has been started in April 2009 to investigate distribution pattern of diatoms from different habitats in Multan region (Ghazala & Arifa, 2009). In this collection 11 species of 6 genera belonging to family *Fragilaraceae* have been found, their taxonomic description and distribution in various habitats of Multan have been discussed in this paper.

Materials and Methods

Genera *Anomoeoneis, Fragilaria, Fragilariforma, Asterionella, Delphinies, Cymatosira* and *Synedra* belonging to family *Fragilaraceae* (Bacillariophycota) have been collected mainly from Multan, the southern region of Punjab, Pakistan, during April-November 2009. Collections have been made from ponds, lakes, fish farms and treated water of various factories of Multan.

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Phytoplankton samples were collected through 53µm mesh plankton net. The physico-chemical data was also observed during surveys (Table 1). The locations of sampling sites; water transparency, water temperature and pH were recorded. All samples were preserved in Lugol's solution and brought to the laboratory and examined under LABORLUX K. WILD MPS12 and MICROS MCX AUSTRIA microscope, which kept in General Botany Lab, IPAB, Bahauddin Zakariya University of Multan, where the further studies were carried out. After 24 hours, 1 mL of sample was poured onto the slide "Counting Cell" (Sedgewick-Rafter Cell S 50 Microlitre). The collected material of phytoplankton was taxonomically determined with the help of authentic literature (Jörgensen 1911, Hendey 1964, Schoeman 1970) and species have been arranged systematically, according to classification system of new millennium (Shameel, 2001) and new terminologies (Shameel, 2008).

Results

One species of *Anomoeoneis, Fragilariforma, Asterionella, Delphinies, Cymatosira,* 2 species of *Synedra* and 4 species of *Fragilaria* have been reported. Their distribution in different localities and description is described as follows:

Family *Fragilaraceae*

Valve transversely striae or punctuate, without a raphe, polar and central nodules are absent. Frustules solitary or in colonies, sometimes epiphytic; truncate apices with elongated girdle; valve straight, linear or lanceolate; ends attenuated or capitate. Girdles may overlap each other or separated by one to several intercalary bands; chromatophores one or two, plate-like along the sides of the valves.

Most of the species are sessile, littoral, bottom-living forms, but some e.g., *Fragilaria spp*., *Synedra spp*., *Thalassiothrix* and *Thalassionema spp*. are planktonic. All members of the *Fragilaraceae* are non-motile. Following genera of this family have been collected, which are distinguished as follows:

Anomoeoneis Pfitzer

Cells solitary, free. Valves elliptical, lanceolate to lanceolate-rhombic; frustules rectangular. Raphe clearly defined, straight, axial area narrow. Central area dilated, usually unilaterally. Valve surface striate, punctuate, striae irregular or in undulating rows; chromatophore single, laminate with pyrenoids. Following species was identified in the present collection.

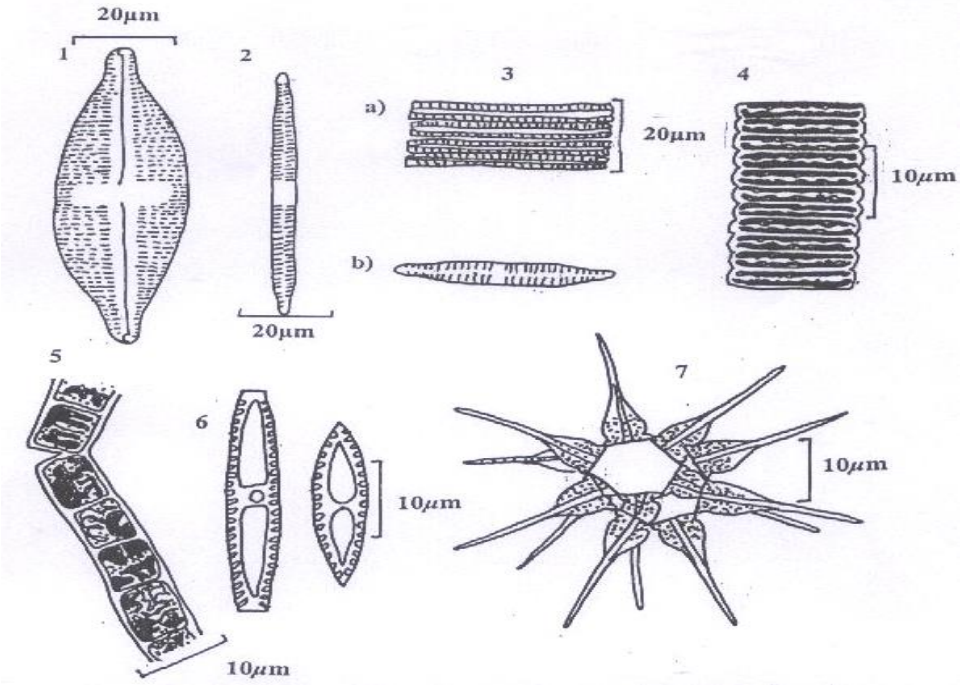
A. sphaerophora (Kützing) Pfitzer
(Fig. 1)

General characters: Valve elliptic-lanceolate, ends capitate; raphe clearly visible; cells 40-80 µm □long, 13-20 µm □wide; striae indistinct, 6-8 within 10 µm.
Cytological features: Chromatophore single, laminate with pyrenoids.
Geographical distribution: Pakistan: Peshawar; Afghanistan; Libya; Poland.
Locality: Matti Tal Road: fish farm.

Table 1. Physico-chemical parameters of sampling sites of Multan.

#	Sampling Sites	Timings						
		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
1.	BZU Fish Pond	02:00 *p.m.*	12:00 *p.m.*	11:15 *a.m.*	12:30 *p.m.*	12:00 *p.m.*	12:30 *p.m.*	01:35 *p.m.*
2.	Fish Farm	11:50 *a.m.*	02:00 *p.m.*	12:40 *p.m.*	12:05 *p.m.*	12:25 *p.m.*	12:10 *p.m.*	12:00 *p.m.*
3.	Pak-Arab Fertilizers	11:40 *a.m.*	01:00 *p.m.*	12:10 *p.m.*	11:30 *a.m.*	12:35 *p.m.*	12:20 *p.m.*	12:40 *p.m.*
4.	Tennaries	11:10 *a.m.*	11:00 *a.m.*	12:25 *p.m.*	12:05 *p.m.*	12:40 *p.m.*	12:00 *p.m.*	12:10 *p.m.*
5.	Shah Shams Park	12:25 *p.m.*	11:50 *a.m.*	12:40 *p.m.*	01:30 *p.m.*	12:45 *p.m.*	12:25 *p.m.*	11:35 *a.m.*
6.	Askari Lake	01:40 *p.m.*	12:45 *p.m.*	11:30 *a.m.*	12:20 *p.m.*	12:35 *p.m.*	12:40 *p.m.*	12:00 *p.m.*
7.	Cantonment Park	01:05 *p.m.*	12:10 *p.m.*	12:10 *p.m.*	11:30 *a.m.*	12:50 *p.m.*	12:45 *p.m.*	01:05 *p.m.*
8.	Islampur	10:00 *a.m.*	12:40 *p.m.*	12:00 *p.m.*	11:30 *a.m.*	12:00 *p.m.*	12:35 *p.m.*	12:45 *p.m.*
9.	Military Farm	11:10 *a.m.*	01:30 *p.m.*	12:35 *p.m.*	11:45 *a.m.*	12:00 *p.m.*	12:40 *p.m.*	12:55 *p.m.*
10.	Muzaffarabad	01:00 *p.m.*	12:10 *p.m.*	12:30 *p.m.*	11:50 *a.m.*	01:05 *p.m.*	12:15 *p.m.*	12:05 *p.m.*
		Temperature (°C)						
1.	BZU Fish Pond	30	45	45	44	44.5	43.5	42
2.	Fish Farm	35	43	44.5	45	44	42	43
3.	Pak-Arab Fertilizers	39	44	44.5	45.5	44	43	42
4.	Tennaries	38	44.5	45	44.5	45.5	41.5	42
5.	Shah Shams Park	40	45.5	45.5	45.5	44.5	43	43
6.	Askari Lake	40	45.5	46	44	45.5	43	42
7.	Cantonment Park	44	45	45	44.5	44	43.5	42
8.	Islampur	45	44.5	45	45	44.5	43.5	43
9.	Military Farm	45	44.5	46	43.5	45	42.5	42
10.	Muzaffarabad	44	45	45	44	44.5	42.5	43
		pH						
1.	BZU Fish Pond	8	8.5	9	7.5	8.5	9	9
2.	Fish Farm	9	9.5	9	9.5	8.5	8.5	8
3.	Pak-Arab Fertilizers	10	9.5	9.5	9	9	8.5	8
4.	Tennaries	7	8	9	9	9.5	9	9
5.	Shah Shams Park	8	7.5	8	7	8	7.5	8
6.	Askari Lake	7	7	6	6.5	6.5	8.5	7
7.	Cantonment Park	8	7.5	7.5	8	7.5	7.5	9
8.	Islampur	9	7.5	8.5	9	7	7	6
9.	Military Farm	7	9	8.5	8	8	8	8
10.	Muzaffarabad	8	8.5	8.5	7.5	8.5	8.5	8

Apr. = April, Jun. = June, Jul. = July, Aug. = August, Sep. = September, Oct. = October



Figs. 1-7. Species belonging to family *Fragilaraceae*, 1. *Anomoconeis shaerophora*, 2. *Fragilaria capucina*, 3. *Fragilaria intermedia* a) girdle view, b) valve view, 4. *Fragilaria islandica*, 5. *Fragilaria oblonga*, 6. *Fragilariforma virescens*, 7. *Asterionella japonica*.

Fragilaria **Lyngbye**

Cells conical. Valves linear-lanceolate or elliptical. Apical axis sometimes occupied by an elongated hyaline axial area. Valve surface with faint striae, either marginal or continuous across the face of the valve. Frustules rectangular in girdle view. Internal septa absent. Chromatophores, usually two plate-like bodies and according to species. Following species were distinguished as follows:

1. Cells 30-80 µm long with 2-5 µm breadth ..……..…. *F. capucina*
   Cells less than 30 µm long with 6-10 µm breadth ……..……..… 2
2. Striae 9-11 µm ……...……..… *F. intermedia*
   Striae less than 9 µm ..……...……. 3
3. Apical axis 8-40 µm ...……..……..… *F. islandica*
   Apical axis less than 8 µm ……..… *F. oblonga*

F. capucina **Desazieres**
(Fig. 2)

General characters: Cells united in flat ribbon-like colonies, rectangular in girdle view. Valves linear, with apices slightly produced. Valve surface finely striate, striae transverse. Axial area indistinct or suppressed. 30-80 µm long, 2-5 µm wide.

Cytological features: Central area rectangular or elliptic, hyaline.
Geographical distribution: A freshwater species, but frequently found in neritic plankton.
Locality: Cantonment: Askari lake.

***F. intermedia* Grunow**
(Fig. 3)

General characters: Valves 50-77 µm long and 6-7 µm broad, linear with constricted produced or slightly capitate ends. Central area unilateral. Striae; 9-11 µm.
Locality: Military Farm: pond.

***F. islandica* Grunow *ex* Van Heurck**
(Fig. 4)

General characters: Cells united to form flat ribbon-like colonies. Frustules in girdle view rectangular. Valves lanceolate with sub-acute apices. Valve surface with a finely striate margin and a wide hyaline axial area. Apical axis 8-40 µm.
Cytological features: Chromatophores, sub-rectangular plate-like bodies lying along the girdle.
Geographical distribution: A neritic species.
Locality: Hasanabad: Pak-Arab Fertilizers pond, Shamsabad: Shah Shams park, Cantonment: Askari lake and Cantonment park.

***F. oblonga* Drebes *et* Schulz**
(Fig. 5)

General characters: Frustules oblong elliptical, rectangular cells, 5-8 µm in apical axis, with a long girdle (8-20 µm). The species forms zig zag or short ribbon-like colonies, usually attached to floating detritus.
Cytological features: Chromatophores two or four.
Locality: Matti Tal Road: fish farm.

***Fragilariforma* (J. Ralfs) D.M. Williams *et* r. E. Round**

Frustules a raphid, rectangular in linear or zig zag colonies. Valves elliptical, lanceolate or linear with tapering rostrate to capitate apices. Narrow sternum, labiate processes and spines present. Apical pore fields simple, extending on the valve face. Only following species was collected:

***F. virescens* (Ralfs 1843) D. M. Williams *et* R. E. Round**
(Fig. 6)

References: West, 1904; Østrup, 1908; Starmach, 1964; Förster & Schlichting Jr., 1965; Hohn & Hellerman, 1966; Sultana *et al*., 1991; Leghari MK *et al*., 2002, 2004.
Basionym: *Fragilaria virescens* Ralfs, 1843.
General characters: Frustules rectangular, valve lanceolate, length 65-67µm and width 10-13 µm; has costae.

Cytological features: Chromatophores, vary in shape.
Geographical distribution: Myanmar Japan, Afghanistan, Ontario (Canada), Baltimore, Poland, Faeroes (Danmark).
Locality: Bosan Road: BZ University fish pond, Matti Tal Road: fish farm, Hasanabad: Pak-Arab Fertilizers pond, Cantonment: Askari lake and Cantonment park, Islampur: pond, Military Farm: pond, Muzaffarabad: stagnant water.

***Asterionella* Hassall**

Cells linear with dissimilar ends and united into stellate or spiral colonies, or free. Valve linear, with inflated apices, one more so than the other. Cells united by adhesion at the larger ends. Valve surface finely striate, striae interrupted by a median pseudoraphe in the apical axis. Chromatophores, one or two small bodies, often folded, located at the broader end of the cell. Following species was identified:

***A. japonica* Cleve & Müller *ex* Gran 1905: 118**
(Fig. 7)

References: Gran, 1905: 118; Hendey, 1937: 333.
General characters: Cells united to form spiral star-shaped colonies, eight to twenty cells to form a colony. Cells having one end inflated into a triangular head, while the other end is produced into a narrow rod-like outer portion. Valve possessing a narrow pseudoraphe. Length of apical axis of cell 50-90 □m; inflated portion about one-quarter of the total length.
Cytological features: Chromatophores, usually two, confined to the broad end of the cell.
Geographical distribution: A neritic species common and widespread in European waters.
Locality: Bosan Road: BZ University fish pond, Shamsabad: Shah Shams park, Muzaffarabad: stagnant water.

***Delphinies* Andrews**

Species of the genus occur single-celled or in ribbons (chains), often attached to sand grains or frustules of other diatoms. Species can only be identified in valve view. Cells are broad, elliptical to lanceolate or linear in this view. Valves with small spines or granules and without apical pore fields (in contrast to *Raphoneis*). Following species was collected:

***D. surirella* (Ehrenberg) Andrews**
(Fig. 8)

References: Van Heurck, 1880-85: 147; Paragallo, 1897-1908; Hendey, 1959: 53.
Synonym: *Raphoneis surirella* (Ehrenberg) Grunow, *Zygoceros surirella* Ehrenberg, 1840a: 160.
General characters: Cells solitary; valves broadly elliptical to elliptic-lanceolate. Valve surface punctuate, puncta large, sub-rectangular, being arranged in curved, weakly radiating lines upon either side of a clearly marked pseudoraphe. The ends of the pseudoraphe widen slightly as they approach the valve apices. Length of valve 20-46 µm; width 12-25 µm.

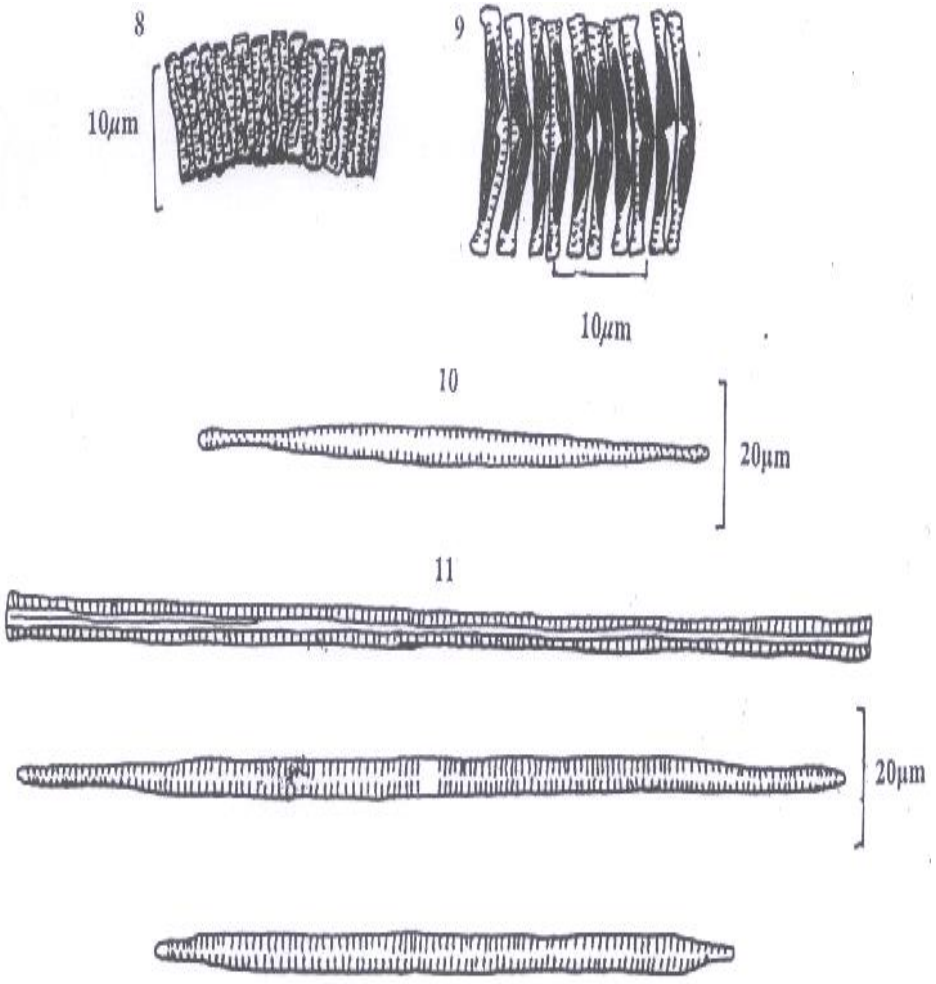


Fig. 8-11. Species belonging to family Fragilaraceae, 8. *Delphinies surirella*, 9. *Cymatosira lorenziana*, 10. *Synedra tabulate*, 11. *Synedra ulna*.

Geographical distribution: Common on mud and sand flats; fresh brackish and marine water.
Locality: Shamsabad: Shah Shams park.

Cymatosira Grunow

Cells small, usually united in small packets valve to valve, by means of a system of spines. Frustules linear in girdle view, inflated in the middle and at the ends. Valves linear, inflated in the middle. Valve surface punctate. Raphe absent, pseudoraphe absent or much obscured. Its following species have been collected, which may be distinguished as follows:

C. lorenziana Grunow
(Fig. 9)

General characters: The apical axis is 10-40 µm. Curved cells in girdle view, coarsely silicified. It is longer colonies in which the cells are held together by more prominent marginal spines and by having a labiate process only on one of the two valves.
Geographical distribution: Cosmopolitan species preferring sandy sediments. Sporadically found in the plankton.
Locality: Bosan Road: BZ University fishpond.

Synedra Ehrenberg

Cells free or united in fan-like or ribbon-like colonies. Cells linear, valves linear or linear-lanceolate; apical axis usually occupied by a pseudoraphe. Valve surface marginally striate, or striate more or less completely over the entire surface. Chromatophores, usually small plates. Following two species have been identified, which may be distinguished as follows:

1. Cells colonial, valve marginally same, striae short ……. *S. tabulata*
   Cells 50-350 µm long ……. *S. ulna*

S. tabulata (C. A. Agardh 1832: 50) Kützing 1844: 68
(Fig. 10)

References: Kützing, 1844: 68; Wm. Smith, 1853: 72; Boyer, 1927: 206; Giffen, 1963: 254, 1966: 287, 1970: 96, Starmach, 1964: 175; Gerloff & Lüdemann, 1966: 107; Nizamuddin, 1984: 103; Daudpota & Leghari, 1993: 122; Jahangir *et al.* 2000: 1967; Leghari & Leghari, 2002: 183; Leghari MK *et al*., 2004: 42; Husna *et al*., 2006: 161.
Synonym: *Diatoma tabulatum* Agardh, 1830-32: 50 (1832).
General characters: Cells colonial. Valve solitary, narrow, lanceolate, with obtuse apices. Valve surface occupied mainly by a broad pseudoraphe or hyaline apical area. Marginal striae very short, 10 in 10 µm. Length 95-96 µm and width 3-6 µm; striae marginal and short, 10-12 within 10 µm.
Cytological features: Chromatophores two, plate-like.
Geographical distribution: Widely distributed in the littoral zone.
Locality: Bosan Road: BZ University fish pond, Matti Tal Road: fish farms, Hasanabad: Pak-Arab Fertilizers pond, Cantonment: Cantonment park, Muzaffarabad: stagnant water.

S. ulna (Nitzsch) Ehrenberg
(Fig. 11)

General characters: Cells solitary; valves linear to linear-lanceolate, middle area absent, striae robust, pseudoraphe narrow, shorter than the type, ends attenuated, poles blunt, broadly rounded, diameter of poles 3 µm. Cells 50-350 µm long, 5-9 µm wide; striae delicate, distinctly punctuate, 8-12 (usually about 10) in 10 µm; highly variable. X 600.
Geographical distribution: Widely distributed, scraped from submerged stone surface in a spring at Gorakh Diggi, Nagoman, Pabbi.
Locality: Bosan Road: BZ University fish pond, Cantonment: Askari lake.

Discussion

In the present study, 11 species belonging to 7 genera were recorded from a variety of freshwater habitats of Multan (Table 2). In stations S1, S6, S8, S9, S10 two peaks of *Fragilariforma* were found frequently (Fig. 3a), while Synedra has high peak in S2. Number of *Fragilaria* species was high in S3 and S5. *Asterionella* occurred in S1, S5, S10. *Anomoeoeneis*, *Cymatosira* and *Delphinies* rarely occurred. *Anomoeoneis* was found in S2. *Cymatosira* was only found in S1 and *Delphinies* in S5. No species belonging to family *Fragilaraceae* has been collected from S4. S1 was found to be most polluted than other sites (Table 3).

The seasonal variations in phytoplankton distribution are directly related to physico-chemical parameters (Table 1). Primary production is regulated by nutrients concentration, light intensity and temperature (Rath, 1993). The maximum water temperature was observed in August (48˚C) and minimum in April (33˚C). Water pH is also important because many biochemical reactions take place within narrow range of pH (Shepherd & Bromage, 1992). The pH 6-11 was noted during surveys. During study, seasonal fluctuations of phytoplankton were also observed (Fig. 3b). *Anomoeoneis* and *Cymatosira* occurred in May, *Delphinies* in June and *Fragilaria capucina* in June. Higher population of *Fragilariforma* was recorded in May and August, while lower population was recorded in September and October. Population of genus *Asterionella* was absent in all months except April and May. Highest peak of *Fragilaria* was observed in May and then, there was gradual decrease but in September, no species was collected (Graph B). Species of genus *Synedra* showed gradual increase and maximum population was observed in July, which was, then, gradually decreased, but in October, population was increased. Ecologically,

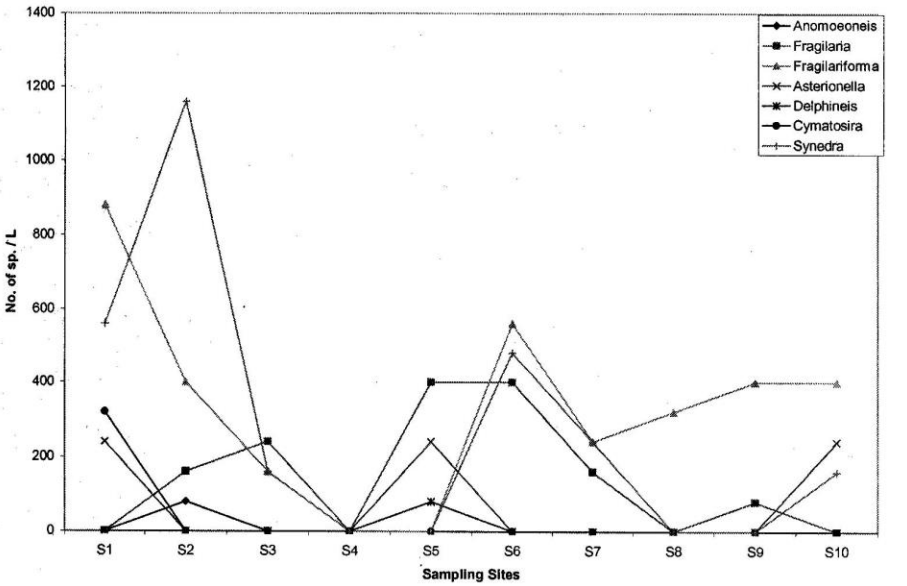


Fig. 3a. Quantitative distribution of genera belonging to family *Fragilararceae* in different localities of Multan.

Table 2. Species collected from freshwater habitats in the region of Multan.

No.	Algal taxa	1	2	3	4	5	6	7	8	9	10
1.	*Anomoeoneis sphaerophora* (Kützing) Pfitzer	-	+	-	-	-	-	-	-	-	-
2.	*Fragilaria capucina* Desazieres	-	-	-	-	-	+	-	-	-	-
3.	*F. intermedia* Grunow	-	-	-	-	-	-	-	-	+	-
4.	*F. islandica* Grunow *ex* Van Heurck	-	-	+	-	+	+	+	-	-	-
5.	*F. oblonga* Drebes *et* Schulz	-	+	-	-	-	-	-	-	-	-
6.	*Fragilariforma virescens* (Ralfs) D.M. Williams *et* R.E. Round	+	+	+	-	-	+	+	+	+	+
7.	*Asterionella japonica* Cleve & Müller *ex* Gran	+	-	-	-	+	-	-	-	-	+
8.	*Delphinies surirella* (Ehrenberg) Andrews	-	-	-	-	+	-	-	-	-	-
9.	*Cymatosira lorenziana* Grunow	+	-	-	-	-	-	-	-	-	-
10.	*Synedra tabulata* (Agardh) Kützing	+	+	+	-	-	-	+	-	-	+
11.	*S. ulna* (Nitzsch) Ehrenberg	+	-	-	-	-	+	-	-	-	-

1. Bosan Road: BZ University fish pond, **2.** Matti Tal Road: fish farm, **3.** Hasanabad: Pak-Arab Fertilizers pond, **4.** Gulgasht: tennaries water, **5.** Shamsabad: Shah Shams park, **6.** Cantonment: Askari lake, **7.** Cantonment: Cantonment park, **8.** Islampur: pond, **9.** Military Farm: pond, **10.** Muzaffarabad: stagnant water.

Table 3. Monthly distribution of phytoplankton communities in different study areas of Multan.

No.	Algal taxa	Apr	May	Jun	Jul	Aug	Sep	Oct
1.	*Anomoeoneis sphaerophora* (Kützing) Pfitzer	-	+	-	-	-	-	-
2.	*Fragilaria capucina* Desazieres	-	-	+	-	-	-	-
3.	*F. intermedia* Grunow	-	+	-	-	-	-	-
4.	*F. islandica* Grunow *ex* Van Heurck	-	+	+	+	-	-	+
5.	*F. oblonga* Drebes *et* Schulz	-	-	-	+	+	-	-
6.	*Fragilariforma virescens* (Ralfs) D. M. Williams *et* R. E. Round	+	+	+	+	+	+	+
7.	*Asterionella japonica* Cleve & Müller *ex* Gran	+	+	+	-	-	-	-
8.	*Delphinies surirella* (Ehrenberg) Andrews	-	-	+	-	-	-	-
9.	*Cymatosira lorenziana* Grunow	-	+	-	-	-	-	-
10.	*Synedra tabulata* (C. A. Agardh) Kützing	-	+	+	+	+	-	+
11.	*S. ulna* (Nitzsch) Ehrenberg	-	+	+	+	+	+	-

Apr = April, **Jun** = June, **Jul** = July, **Aug** = August, **Sep** = September, **Oct** = October.
+ = Present, **-** = Absent

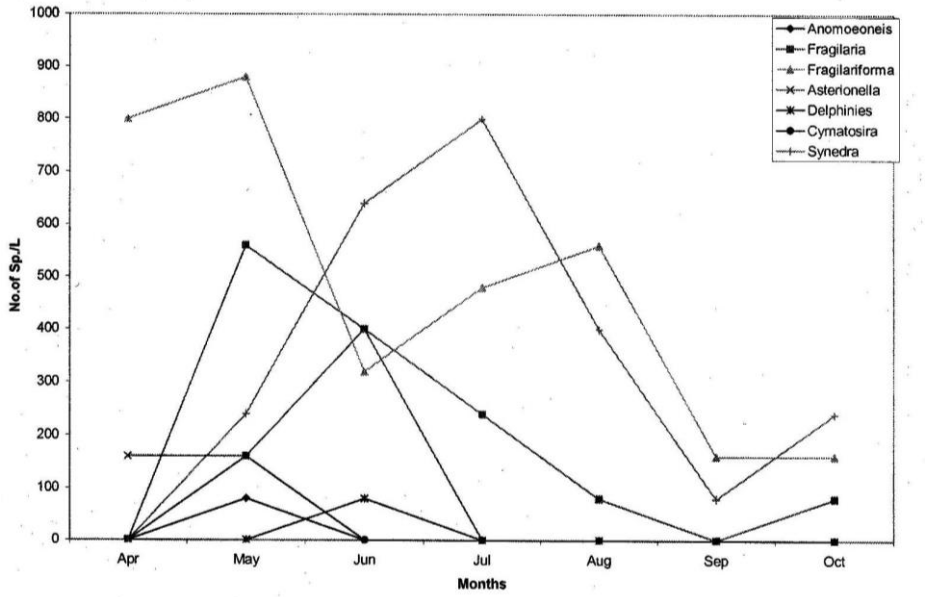


Fig. 3b. Quantitative monthly distribution of genera belonging to family *Fragilaraceae*.

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