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Chlorococcalean algae *(s. l.)* from the Ecological Park of Xochimilco, Mexico

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With 78 figures and 2 tables in the text

Abstract: The chlorococcalean algae from the Ecological Park of Xochimilco were studied in some different water bodies filled with second level treated water. They are eutrophic and some of their physical and chemical water properties (temperature, pH) are similar. In the contrary, the distribution of species is very heterogeneous. Fifty per cent of species were found only in one or two localities. Moreover, the Park is located in a high altitude area (2238 m.a.s.l.) and the composition of species is similar to that found in temperate zones. In our view, if some ecological limitation exists for distribution of the "temperate" species found in this Park, it could be related to environmental factors like climatic light (photoperiod) as the Park is located in the parallel 19°.

Key words: Chlorococcales, eutrophic lakes, Mexico.

Introduction

The Ecological Park of Xochimilco opened in June 1993, it is part of an ecological rescue project of the zone included in the lacustrine system of Mexico Valley (Fig. 1). Part of this system is the ancient Lake Xochimilco, which is considered Human Patrimony by UNESCO. By now, in contrast to the Park, the Lake Xochimilco is only a complex system of shallow channels and chinampas *.

This Ecological Park is situated over an area of ancient marshes with lacustrine and palustrine soils with volcanic, alluvial and organic elements. In this area the phreatic layer change seasonally which favours evaporation and accumulation of sodic salts during the low water. As a part of the rescue plan for

* Accumulation of sediments anchored to the bottom among sticks, which support a high agricultural productivity.

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recovering the flooded zones and to avoid accumulation of salts, organic material, (manure and rest of plants as "green fertilizer") is continuously added to the soils. Today, besides the pluvial, 1500 l/sec of water appropriate for irrigation are incorporated to the water bodies in the Park. This secondary level of treated water is supplied from the treatment plant "Cerro de la Estrella".

As a consequence, all the water bodies in the Park are eutrophic, some with massive water blooms of *Microcystis* spp., besides *Planktothrix agardhii, Anabaenopsis circinalis, Arthrospira* cf. *jenneri, Euglena acus, Phacus tortus, Pteromonas alata*, and many species of diatoms, mainly of *Nitzschia* and *Navicula*. The diversity of Chlorococcales, however, is a peculiar feature of these waters and following LAMPERT & SOMMER (1997) the Park could have a β-mesosaprobic level. The high number of species found up to now needs a special issue for their registration and documentation.

There are no studies of algae from the Park but, in the ancient Lake Xochimilco exist few, some rather old, studies and college theses with little species recorded (SÁMANO 1933, 1934, PÉREZ-REYES & SALAS-GÓMEZ 1961, FLORES 1980, ORTEGA 1984, REYNOSO 1986).

Study Area

The Ecological Park of Xochimilco is situated to the Southeast of Mexico City at 2238 m.a.s.l. The Park area is approximately 190 ha, which almost 50 ha are covered by water as different water bodies: lakes, ditches, channels and wetlands (CONTRERAS 1995). As a *sui generis* environment we distinguished the inflow that feeds the Park and gives origin to Huetzalín lake.

The climate is template sub-humid with summer rainy season. Mean annual precipitation is 700–900 mm, and mean annual temperature of 15 °C (SALAS 1995).

Soils in the Park are deep, humic and very fertile with a high content of organic matter but also with a high content of salts (ENSÁSTIGUE et al. 1995).

Methods

This study of Chlorococcales is based in samples collected in 1994, 1997 and 1998. The studied localities were (Fig. 1) 1 = Main Park inflow (phytoplankton); 2 = Small ditch near Huetzalín lake (periphyton); 3 = Huetzalín lake's wharf (phytoplankton); 4 = Shallow pond at the edge of Huetzalín lake (detritus); 5 = "El Bordo" channel (phytoplankton and periphyton). These localities were selected considering differences in type of environment and presence of chlorococcalean algae. Samples were collected directly or with a phytoplankton net 10 µm pore, and preserved with formaline 2.5 to 3%. Temperature, pH and conductivity were measured simultaneously with conventional portable equipment. Samples were examined and photographed with Reichert and Nikon research microscopes using DIC optics. References are deposited in the Sciences School Herbarium (FCME), National Autonomous University of Mexico.

Results

In the five studied localities the chlorococcalean algae are well represented (Tab. 1). In the main inflow are 32 species; in the ditch 16; in the wharf in Huetzalín 11; in the shallow pond 29, and in El Bordo channel 20 species. According to bibliography most of species present in the Ecological Park of Xochimilco have a cosmopolitan distribution and a planktic life form (Tab. 1). In the literature, few are still documented as species from temperate zones because their registration in tropical areas is not widely known or needs confirmation. Only two species *(Fusola viridis, Gregiochloris lacustris)* presented in this work are documented from a different ecology than the Park has; the ecology of *Rhaphidocelis* cf. *arcuata* remains under discussion as this species needs further morphological observation. The rest of species in the Park are coincident with their documented ecology. In this work we are registering 35 species as new records of chlorococcaleans in the whole lacustrine area of Xochimilco (3^{rd} column in Tab. 1), and most of these records (27) are also new records to Mexico (4^{th} column in Tab. 1).

The localities appearing in Table 2 are a good example of the aquatic environments in the Park. In this table were included also data from two localities, the ditch "Acitlalín" and the small lake of "The resting of birds" (where we did not find chlorococcaleans). They were included for comparison of the parameters measured in the Park's water bodies (Fig. 1). Values of pH, temperature and conductivity correspond to the low water (the dry, hot or cold seasons) and maximum water volume (the rainy and hot season in 1994, 1997 and 1998). These seasons are the most relevant climatic features in the area where the Park is situated. According with the data in this Table it seems that the values for the measured parameters have been similar since 1994 in each locality.

Description of species

Actinastrum hantzschii LAGERH. (Figs 8, 59)

Typical 4–8 cells, star-like coenobia. Cells basically cylindrical from the basis up to $^3/_4$ their length, ends slightly convergent, at poles rounded or acute rounded. Dimensions: cells 6.7–14.2×1.2–4.3 µm.

Chlorolobion braunii (NÄG.) KOM. (Fig. 11 a-c)

Characteristic straight fusiform or cylindrical fusiform cells (flanks in the middle slightly concave), tapering toward the ends, bluntly pointed or broadly rounded; chloroplast with a conspicuous pyrenoid. Dimensions: cells 20–32.7×3.1–3.3 µm.

New record to Mexico.

Closteriopsis acicularis (G.M. SMITH) BELCHER et SWALE. (Figs 7, 47)

Genus morphologically similar to *Monoraphidium* but standing out by the presence of 2 or more pyrenoids embedded in longitudinal series. In *C. acicularis* the cells are fusiform,

Table 1. Characterization of Chlorococcalean species in the Ecological Park of Xochimilco. Content in columns 2 to 4 supported by data in this work. Content in columns 5 to 7 supported by data in bibliography. **C** – cosmopolitan, **T** – temperate zone, **Tr** – tropical zone, **1** – observed in Cuba, **2** – rare in temperate zone, **3** – more common in temperate zone, **4** – rare in tropical zone, **5** – common in tropics. In the fiveth column each species is characterized according with its literature registered life form, **Pl** – plankton, **Pe** – periphyton, **Me** – metaphyton, **Ed** – edaphic, **Li** – littoral places.

Species	Locality	NRX	NRM	Distribution	Life form	Environment
Actinastrum hantzschii	4			C	Pl, rare Pe	lakes, reservoires
Chlorolobium braunii		x	x	C, 1	Pl or Pe	all types
Closteriopsis acicularis	5	x	x	C	Pl	stagnant or running mesotrophic water
Coelastrum astroideum	5	x	x	C	Pl	eutrophic, lakes and rivers
C. reticulatum		x	x	Tr, 2	Pl	all types
Crucigenia tetrapedia				C	Pl	eutrophic, all types
Dictyosphaerium tetrachotomum	5			C	Pl	eutrophic lakes
Fusola viridis	5	x	x	C, 3	Pl	clean lakes and less frequent in small swamps
Golenkinia radiata	5	x		C	Pl	ponds, less frequent in lakes
Gregiochloris lacustris	5	x	x	C	Pl	clean waters
Micractinium pusillum	5			C	Pl	lakes, rare in ponds
Monoraphidium arcuatum	5			C	Pl or Me	eutrophic, rivers and ponds
M. contortum		x		C	Pl?	wide range eutrophic ponds and rivers
M. convolutum		x		C	Pl	wide range eutrophic ponds and rivers
M. griffithii	5	x		C	Pl	meso to eutrophic rivers
M. irregulare	5	x	x	C, 3	Pl	oligo to mesotrophic rivers
Nephrochlamys subsolitaria		x	x	C	Pl	eutrophic lakes
N. willeana	5			C	Pl	eutrophic ponds
Oocystidium ovale	5	x	x	C, 3	Pl	eutrophic reservoires and ponds
Oocystis borgei	5			C	Pl	all (shallow) types
O. lacustris	5	x		C, 4	Pl	all (oligo to eutrophic and brackish) types
Pediastrum boryanum		x		C	Pl or Pe	all types
Quadricoccus cf. *ellipticus*		x	x	C	Pl	lakes, reservoires and ponds

Table 1. (continued)

Species	Locality					NRX	NRM	Distribution	Life form	Environment
Rhaphidocelis cf. *arcuata*				4		x	x	T	Pl	clean lakes
R. subcapitata				4		x	x	C	Pl	meso to eutrophic lakes
Scenedesmus acuminatus s.l.				4	5			C	Pl	all types
Sc. armatus		2	3	4	5	x	x	C	Pl	all (eutrophic) types
Sc. cf. *gutwinskii*			3	4		x	x	C	Pl	eutrophic lakes
Sc. helveticus				4		x	x	T	Pl	lakes and ponds
Sc. intermedius			3	4		x	x	C	Pl	eutrophic lakes and rivers
Sc. magnus			3	4		x	x	C, 5	Pl	lakes, reservoires and ponds
Sc. obliquus var. *obliquus*				4		x		C	Pl?	eutrophic ponds
Sc. obliquus var. *dimorphus*			3			x		C	Pl?	eutrophic ponds
Sc. obtusus				4		x	x	C	Pl	reservoires, lakes and rivers
Sc. opoliensis		2	3	4	5			C	Pl	all (eutrophic) types
Sc. cf. *pannonicus*		2	3	4		x	x	C	Pl	all types, tolerant to pollution
Sc. praetervisus				4		x	x	C, 3	Pl	reservoires and lakes
Sc. protuberans	1					x	x	C	Pl	reservoires, lakes and rivers
Sc. cf. *soli*			3	4		x	x	C	Ed	soils
Sc. spinosus						x	x	C, 3	Pl	small ponds
Sc. velitaris				4		x	x	C	Pl	eutrophic lakes
Sc. westii		2	3	4		x	x	C	Pl, Li	all (meso to eutrophic) types
Schroederia setigera		2			5			T	Pl	lakes and reservoires
Tetraedron minimum	1			4		x		C	Pl or Pe	all (eutrophic) types
Treubaria triappendiculata	1					x	x	C	Pl	eutrophic lakes, rivers and fish ponds

straight, many times longer as broad, tapering gradually toward the ends, pointed; not setiform. The specimens correspond better to *C. acicularis* than to *C. longissima:* cell dimensions, pointed cell ends and number of pyrenoids (according KOMÁREK & FOTT 1983 the former presents up to 8 pyrenoids). *C. longissima* have bigger cells with up to 16 pyrenoids. Dimensions: cells 14.2–94.1×2.1–4.1 µm.

New record to Mexico.

Coelastrum astroideum DE NOT. (Figs 3, 61)

Coenobia spherical, 4–8 celled, cells basically ovoid, without connecting processes; cell wall smooth, very often thickened at the apical ends. Dimensions: cells 9.7–10.8 µm in diameter.

New record to Mexico.

Coelastrum reticulatum (DANGEARD) SENN. (Figs 4, 73)

Coenobia spherical, 4–8 celled, sometimes with a layer of mucilage; cells spherical; between two cells, 1-(2) subapical, long and relatively narrow connecting processes crosswise divided in the center. Dimensions: cells 10.6–14.1 µm in diameter.

New record to Mexico.

Crucigenia tetrapedia (KIRCHN.) W. et G. S. WEST (Fig. 9)

Coenobia flat, 4-cells, more or less square-shaped, without median opening; cells triangular, flattened with the outer side straight to slightly concave, with coalesced flanks, cell wall smooth, chloroplast without pyrenoid. The algae examined resembles *Tetrastrum komarekii*, but the reproduction processes correspond exactly with the genus *Crucigenia* (not drawn). The species could be recognized also by the external margins. Dimensions: cells 6–7.2 µm in diameter, coenobia 10.1–12.4 µm in diameter.

Dictyosphaerium tetrachotomum PRINTZ (Figs 2, 72)

Cells widely oval to irregularly oval, slightly asymmetric, attached by the median part or the end (younger cells) to mucous strands, joined in multicelled colonies with a wide structureless, mucilaginous envelope, mucous strands distinct, regularly branched. Dimensions: cells 2.8–9.8×5.8–6.9 µm in diameter, colonies 28.5 µm in diameter.

Fusola viridis SNOW (Fig. 10 a-b)

The species is characterized by broadly fusiform cells (each cell has a distinctly limited mucilage), and the mode of reproduction by serial arranged autospores into the gelatinized mother cell wall; chloroplast (in our specimen) single, parietal with a pyrenoid. Dimensions: cells 28.5×7.6 µm.

In our alga the reproduction occurs by two autospores originated by obliquely division of the protoplast of the mother cell, similar with *F. viridis* registered from Cuba (COMAS 1996), however, differs from it by cell dimensions and structure of chloroplast, which was not evidently single but massive, or in fact, several small ones or only one fragmented in small parts with a pyrenoid. In spite of the different meanings concerning to the number and chloroplast shape (the revised literature reported one to several chloroplasts with a single pyrenoid?) (see KOMÁREK & FOTT 1983), we considered that if only one pyrenoid is present, consequently only one chloroplast is involved.

New record to Mexico

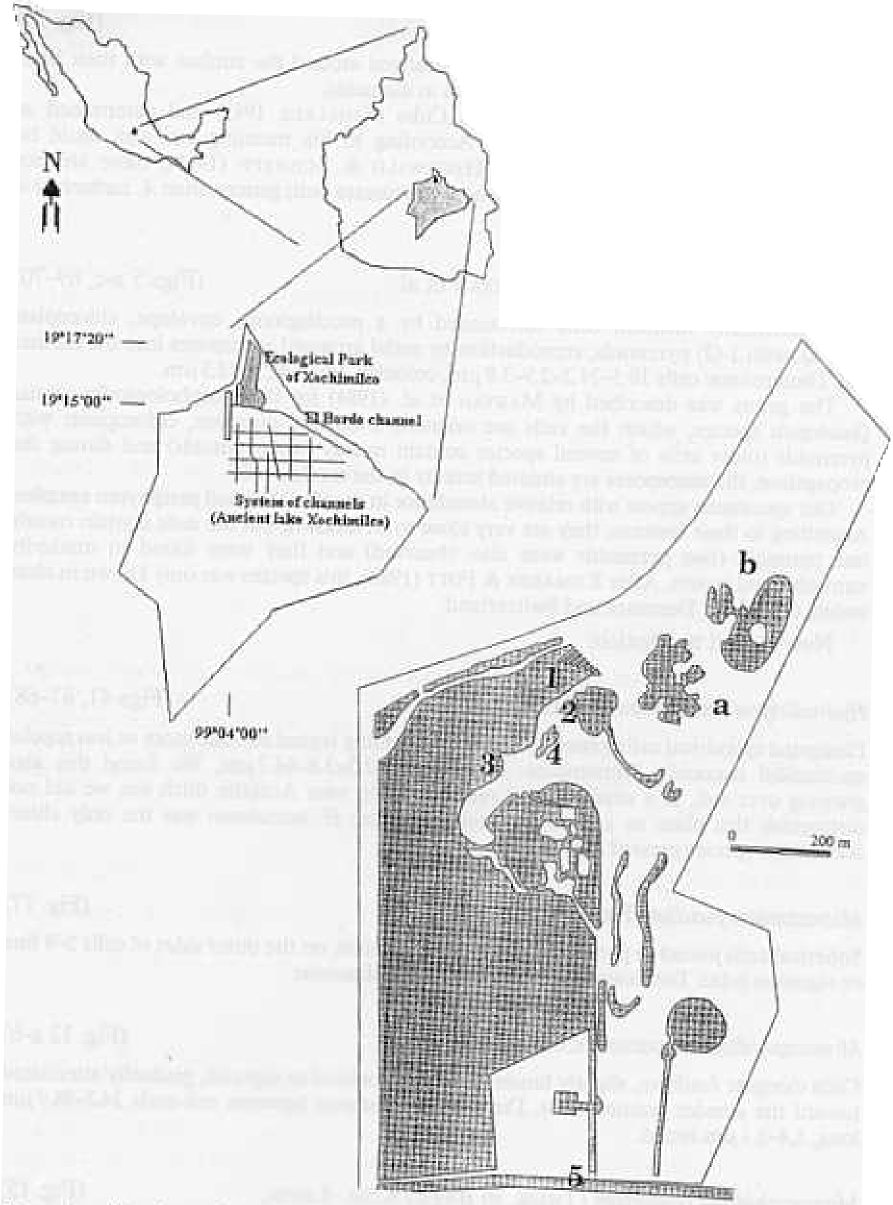


Figure 1. Situation of the Ecological Park of Xochimilco and distribution of collected localities. Those signed by numbers indicate places where Chlorococcalean algae were found.

Golenkinia radiata CHOD. (Fig. 78)

Spherical cells with numerous setae radial arranged around the surface with their basis slightly broader. Dimensions: cells 9.9–14 µm in diameter.

Very similar alga was registered from Cuba (KOMÁREK 1983) and determined as *Acanthosphaera zachariasii* LEMM. 1898. According to his meaning our alga could be identified with this species, but after HEGEWALD & SCHNEPF (1984), there are not morphological and ultrastructural differences to separate both genera, then *A. zachariasii* is synonymous of *G. radiata.*

Gregiochloris lacustris (CHOD.) MARVAN et al. (Figs 5 a-c, 69–70)

Characteristically fusiform cells surrounded by a mucilaginous envelope; chloroplast parietal, with 1-(2) pyrenoids; reproduction by serial arranged autospores into the mother cell. Dimensions: cells 10.5–24.2×2.9–3.8 µm, colonies, up to 42.5×12.3 µm.

The genus was described by MARVAN et al. (1984) for the morphologically similar *Quadrigula* species, which the cells are oriented ± on one direction, chloroplasts with pyrenoids (older cells of several species contain mostly two pyrenoids) and during the propagation, the autospores are situated serially in the mother cell.

Our specimens appear with relative abundance in the plankton and periphyton samples. According to their features, they are very close to *G. lacustris*, but the cells contain mostly one pyrenoid (two pyrenoids were also observed) and they were found in markedly eutrophicated waters. After KOMÁREK & FOTT (1983), this species was only known in clear waters of U. S. A., Denmark and Switzerland.

New record to Mexico.

Hydrodictyon reticulatum (L.) LAGERH. (Figs 41, 67–68)

Elongated cylindrical cells joined by their ends forming typical net-like more or less regular multicelled coenobia. Dimensions: cells, 17.6–242.3×3.6–64.7 µm. We found this alga growing over soil, in a small flow of running water, near Acitlalín ditch but we did not distinguish this place as a separate localtiy because *H. reticulatum* was the only chlorococcalean species present there.

Micractinium pusillum FRES. (Fig. 77)

Spherical cells joined in pyramidal or irregular colonies, on the outer sides of cells 2–8 fine or vigorous setae. Dimensions: cells 5.3–8.7 µm in diameter.

Monoraphidium arcuatum (KORŠ.) HIND. (Fig. 12 a-b)

Cells elongate fusiform, slightly lunate to arcuate, twisted to sigmoid, gradually attenuated toward the slender pointed ends. Dimensions: distance between cell-ends 24.2–38.9 µm long, 1.4–3.1 µm broad.

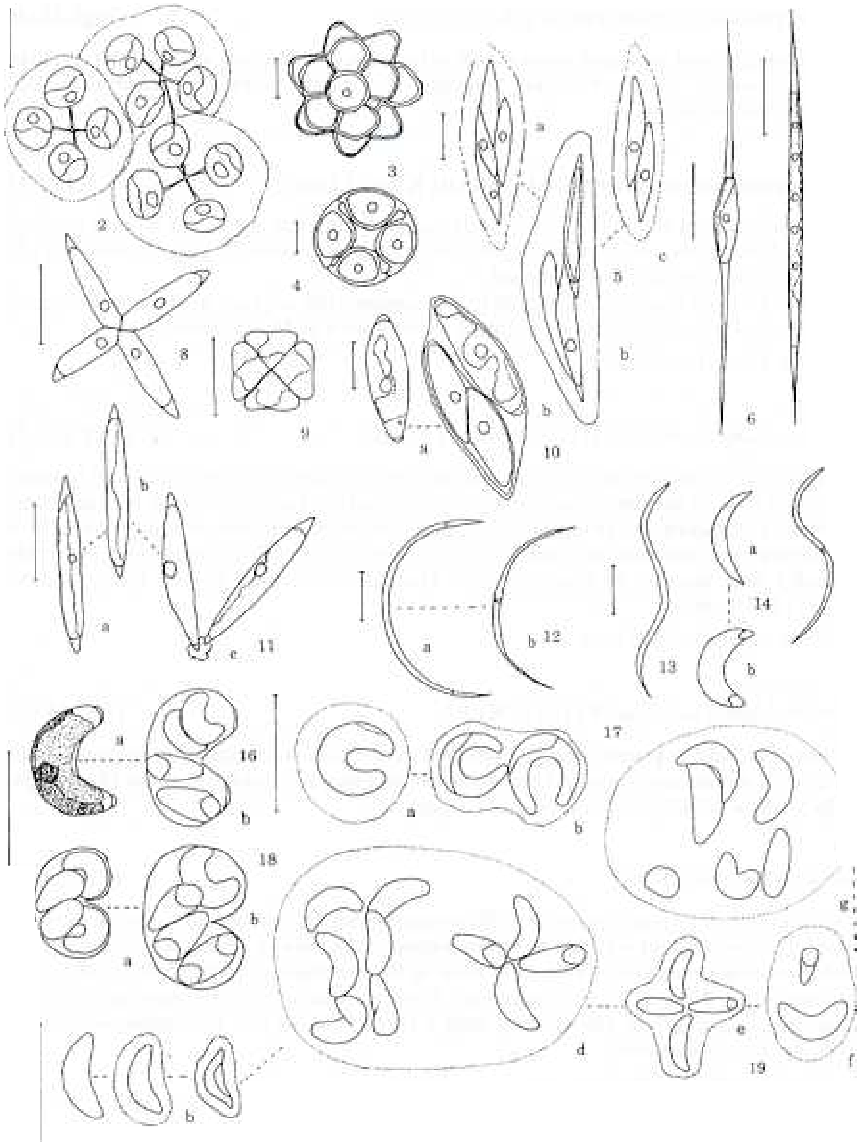
Monoraphidium contortum (THUR. in BRÉB) KOM.-LEGN. (Fig. 15)

Species characterized by their fusiform cells, sigmoid, bent to helicoidal-twisted. Dimensions: cells 10.1–14.7×1.6–1.9 µm.

Monoraphidium convolutum (CORDA) KOM.-LEGN. (Figs 14 a-b)

Cells fusiform, arcuate or slightly lunate, seldom sigmoid, with blunt-pointed to pointed ends, sometimes in different planes. Dimensions: cells 5.8–7.3×2.3–2.6 µm.

New record to Mexico.



Figs 2–19

2 – *Dictyosphaerium tetrachotomum*; **3** – *Coelastrum astroideum*, **4** – *C. reticulatum*, **5a–c** – *Gregiochloris lacustris*, **6** – *Schroederia setigera*, **7** – *Closteriopsis acicularis*, **8** – *Actinastrum hantzschii*, **9** – *Crucigenia tetrapedia*, **10a–b** – *Fusola viridis*, a: single cell, b: colony, **11a–c** – *Chlorolobion braunii*, **12a–b** – *Monoraphidium arcuatum*, **13** – *M. irregulare*, **14a–b** – *M. convolutum*, **15** – *M. contortum*, **16a–b** – *Nephrochlamys willeana*, a: mature cell, b: colony, **17a–b** – *Raphidocelis subcapitata*, **18a–b** – *Nephrochlamys subsolitaria*, **19a–g** – *Raphidocelis* cf. *arcuata*, a–e: solitary cells, d–g: colonies. [Scale bar = 10 µm.]

Monoraphidium griffithii (BERK.) KOM.-LEGN. (Figs 45–46)

Cells elongate fusiform many times longer as broad, straight or only slightly bent, gradually tapered toward the ends and lengthily to thinly pointed. Dimensions: cells 72.6–136.9×2.6–3.6 µm.

Monoraphidium irregulare (G.M. SMITH) KOM.-LEGN. (Fig. 13)

Cells elongate and thinly fusiform, widely sigmoid, undulate with 1-(2) rounds, gradually tapering toward the cell ends and thinly attenuated. Dimensions: distance between cell-ends, 14.7–28.3 µm long, 1.9 µm broad.

The observed alga is more related to *M. irregulare*, the cells are however not markedly undulated as a typical, but widely sigmoid to consider it as *M. contortum*.

New record to Mexico.

Nephrochlamys subsolitaria (G.S. WEST) KORŠ. (Figs 18 a-b, 71)

Typical of the genus are the more or less arcuate to lunate cells whose cell wall broadens prior to release of autospores and more or less remain its shape; cells single or in temporary colonies (composed by produced autospores), without mucilage nor pyrenoids. In *N. subsolitaria* the colonies are widely lunate; cells are distinctly lunate-like bent, with rounded and usually asymmetric ends. Dimensions: cells 7.7–9.6×5.4 µm, colonies, 13.4–15.3×7.9 µm.

New record to Mexico.

Nephrochlamys willeana (PRINTZ) KORŠ. (Fig. 16 a-b)

Colonies arcuate to kidney-shaped, expanded mother cell wall very often thickened at the ends; cells semilunately bent to kidney-shaped with slightly convergent ends. Dimensions: cells 3.7–9.5×1.6–4.7 µm, colonies, 14.4×7.3 µm.

Oocystidium ovale KORŠ. (Fig. 23 a-c)

The genus with a single species is differentiated from *Oocystis* actually only because the mother cell wall would not expand before release of autospores. Young cells with their own dense mucilage envelope, well visible even in the mucilage of mother cell. Cells oval to broadly oval, without polar thickenings. The reproduction occurs identical with that described for the genus. Dimensions: cells 9.1–11.6 ×4.6–9.9 µm, mucilaginous envelope, 16.9–24.2 µm in diameter.

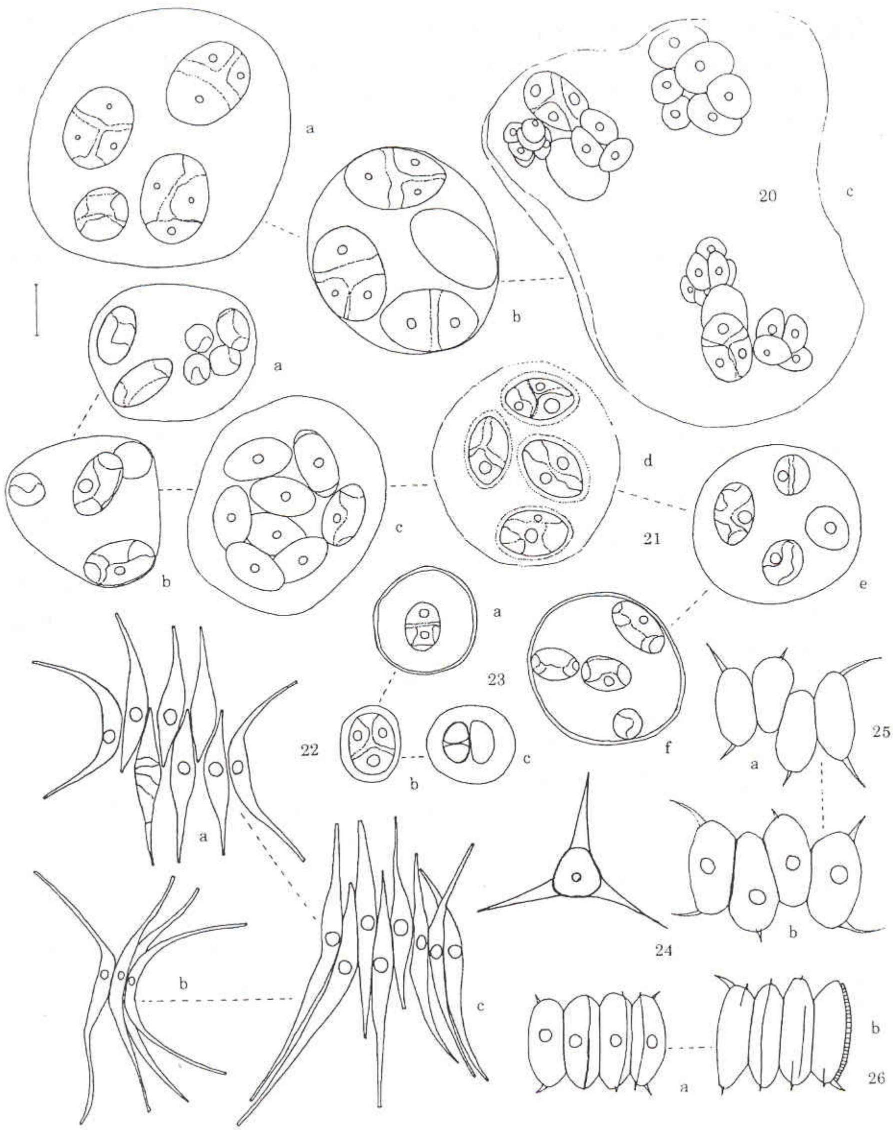
New record to Mexico.

Oocystis borgei SNOW (Figs 20 a-c, 75–76)

Colonies oval to almost spherical, broad with 4–8 cells; cells broadly oval, ends rounded without apical thickenings, young and adult cells with 2–4 parietal chloroplasts, each with a pyrenoid. Dimensions: cells 11.6–14.1×7.9–12 µm.

Oocystis lacustris CHOD. (Fig. 21 a-f)

Colonies with 4–8 cells, oval to almost spherical, surrounded by a broad mucilaginous envelope; cells oval elliptical without polar thickenings; chloroplast single, parietal with a pyrenoid. Dimensions: cells 7.9–13.5×6–9.9 µm



Figs 20–26
20a–c – *Oocystis borgei,* **21a–f** – *O. lacustris,* **22a–c** – *Scenedesmus acuminatus,* **23a–c** – *Oocystidium ovale,* **24** – *Treubaria triappendiculata,* **25a–b** – *Sc.* cf. *pannonicus,* **26a–b** – *Sc. praetervisus.* [Scale bar = 10 µm.]

Pediastrum boryanum (TURP.) MENEGH. (Figs 43, 58)

Coenobia circular, flattened without or with very small spaces between cells; cells polygonal, the marginal ones with two well developed processes; cell wall distinctly ornamented by conspicuous granules. According to the length of the processes, our specimens correspond with the typical variety. Dimensions: cells 8–15.2 µm in diameter.

Quadricoccus cf. *ellipticus* HORTOB. (Fig. 74)

Cells elliptical-cylindrical, without granulation, affixed by the median portion to the edge of the mother cell wall; chloroplast with a pyrenoid, not reaching the edge of the cell. Dimensions: cells 5–1.2×4.8–6.5 µm.

We observed only one specimen, therefore its identification is still not definitive.

New record to Mexico.

Rhaphidocelis cf. *arcuata* (G.M. SMITH) MARVAN et al. (Fig. 19 a-g)

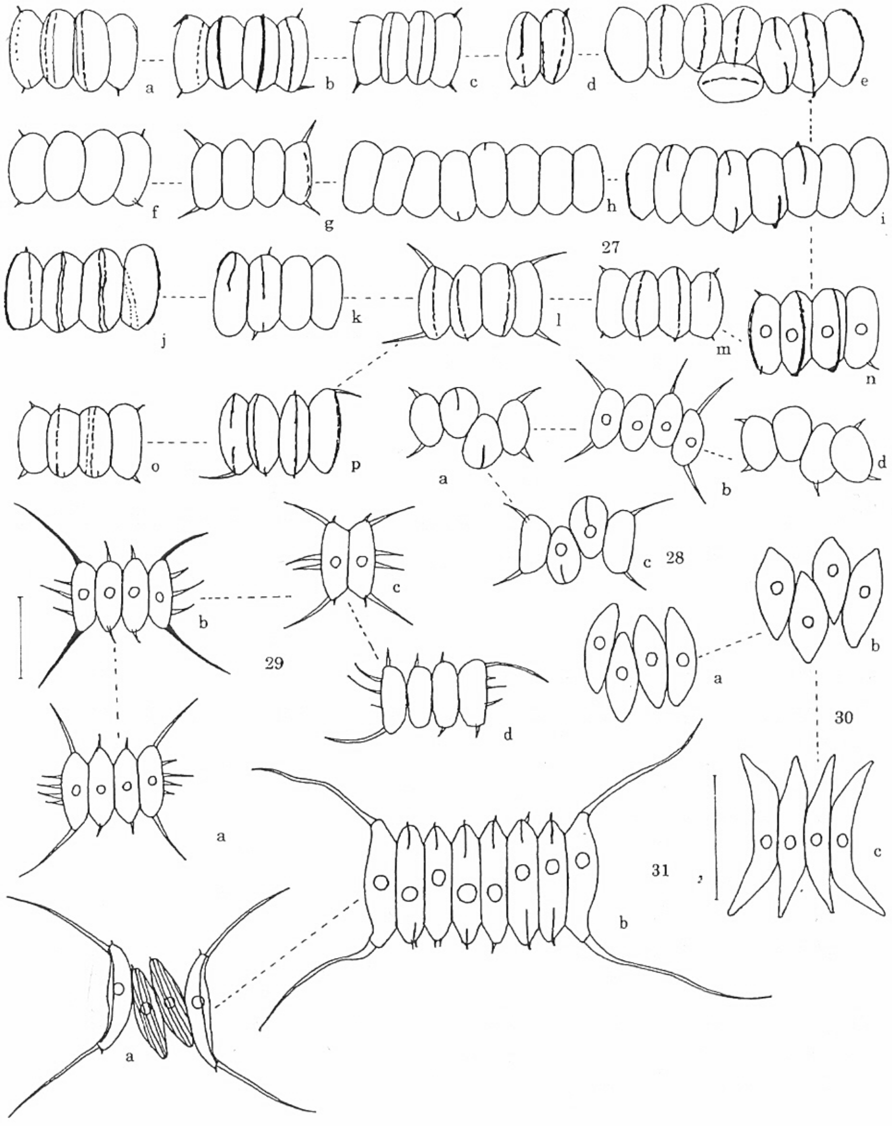
Cells broadly fusiform, oval cylindrical, slightly arcuate or bent, solitary or forming multicelled colonies surrounded by a relatively wide mucilaginous envelope; cell ends slightly convergent, tapering toward the short more or less rounded poles; single cells with its own mucilaginous layer; chloroplast without pyrenoid. Dimensions: cells 3.9–7.5×1.8–2.9 µm.

The genus in the original scope (HINDÁK 1977) considers the granulation on the cell walls as one of the diacritical features of this taxon, including *Kirchneriella*-like species with pointed ends and without pyrenoids. Because the granulation on the cell walls is facultative, that means, it is dependent on environmental conditions, MARVAN et al. (1984), established as the main characters of the genus the presence of spindle-like, mainly sigmoid, *Monoraphidium*-like cells, without pyrenoids (or with "naked" or "multiformed" pyrenoids), forming mucilaginous, *Kirchneriella*-like colonies with irregularly situated cells, and sometimes with rests of mother cell walls inside the colony. According to these criteria, several new combinations were proposed (see MARVAN et al. 1984).

HINDÁK (1984, 1988), pointed out again as significant character of the genus the granulation on cell walls, therefore *Raphidocelis* (he means) should be preserved in its original conception. According to him, only 3 species can be included in the genus: *R. sigmoidea* HIND. (type species), *R. granulata* (HEYNIG) HIND. 1977, and *R. pseudomucosa* KRIENITZ 1986.

According to its morphological features (reproduction was not observed): cell shape, parietal single chloroplast without pyrenoid, forming colonies enveloped by a mucilaginous irregular layer (single cells are also surrounded by mucus), our alga could be identified as a *Raphidocelis* taxon *sensu* MARVAN et al. (1984), by comparing with other described *Raphidocelis* species, *R. arcuata* seems to be the more related taxon, however, differs from it by cell dimensions and less curved cells. *R. arcuata* is also known only for very clear waters in Nothern Europe. A definitive identification of this organism requires indeed, further studies, specially on its reproduction.

New record to Mexico.



Figs 27–31
27a–p – *Scenedesmus* cf. *soli*, a–c, f–g, j–p: 4-celled coenobia, d: 2-celled coenobium, e, h, i: 8-celled coenobia, **28a–d** – *Sc. intermedius,* **29a–d** – *Sc.* cf. *gutwinskii,* **30a–b** – *Sc. obliquus* var. *obliquus,* **30c** – *Sc. obliquus* var. *dimorphus,* **31a–b** – *Sc. opoliensis.* [Scale bar = 10 µm.]

Rhaphidocelis subcapitata (KORŠ.) NYG. et al. (Fig. 17 a-b)

Cells cylindrical, elongated, arcuated and at the ends slightly capitate-widened, forming colonies surrounded by mucilage; chloroplast without pyrenoid. Dimensions: cells 5.8–6.4×1.6–2 µm.

The reproduction was not observed, but according to the another morphological features is very close with the species.

New record to Mexico.

Scenedesmus acuminatus (LAGERH.) CHOD. s.l. (Figs 22 a-c, 57)

Coenobia mostly 8-cells, alternated; cells joined one to another subapically or by their ends, in one or two planes; cells elongate fusiform, many times longer as broad; ends attenuated toward the poles. Dimensions: cells 37.2–65.3×2–7.1 µm.

The species shows a wide morphological variability, organisms identical with several described infraspecific taxa were found: var. *alternans* SVIR. 1924, var. *elongatus* G.M. SMITH 1926, *Sc. falcatus* f. *maximus* UHERK. 1956, *Sc. falcatus* f. *tortuosus* SKUJA 1927, etc. It is not possible the taxonomic evaluation of these different types, because transition specimens in one and the same population were found.

Scenedesmus armatus (CHOD.) CHOD. (Figs 36 a-b, 55–56)

Coenobia strictly linear, the cells are cylindrical, conical rounded at the poles, ribs clearly developed, usually continuously along the whole cell length, rarely only near the poles. At poles of the outer cells, 4 equally long and differently curved spines, at poles of the inner cells rarely occurring short fine spines. Dimensions: cells 15.4–21×5–7.2 µm.

New record to Mexico.

Scenedesmus cf. *gutwinskii* CHOD. (Figs 29 a-d, 54)

According to the cell shape and the number of lateral spines, our specimens correspond with the var. *heterospina* BODROGK. 1950, however the spines of the outer cells are not markedly diagonal symmetric. HINDÁK (1990) and HEGEWALD & SILVA (1988), considered *Sc. gutwinskii* synonymous of *Sc. subspicatus* CHOD. Dimensions of our specimens: cells 3.3–9.4×1.4–5.3 µm.

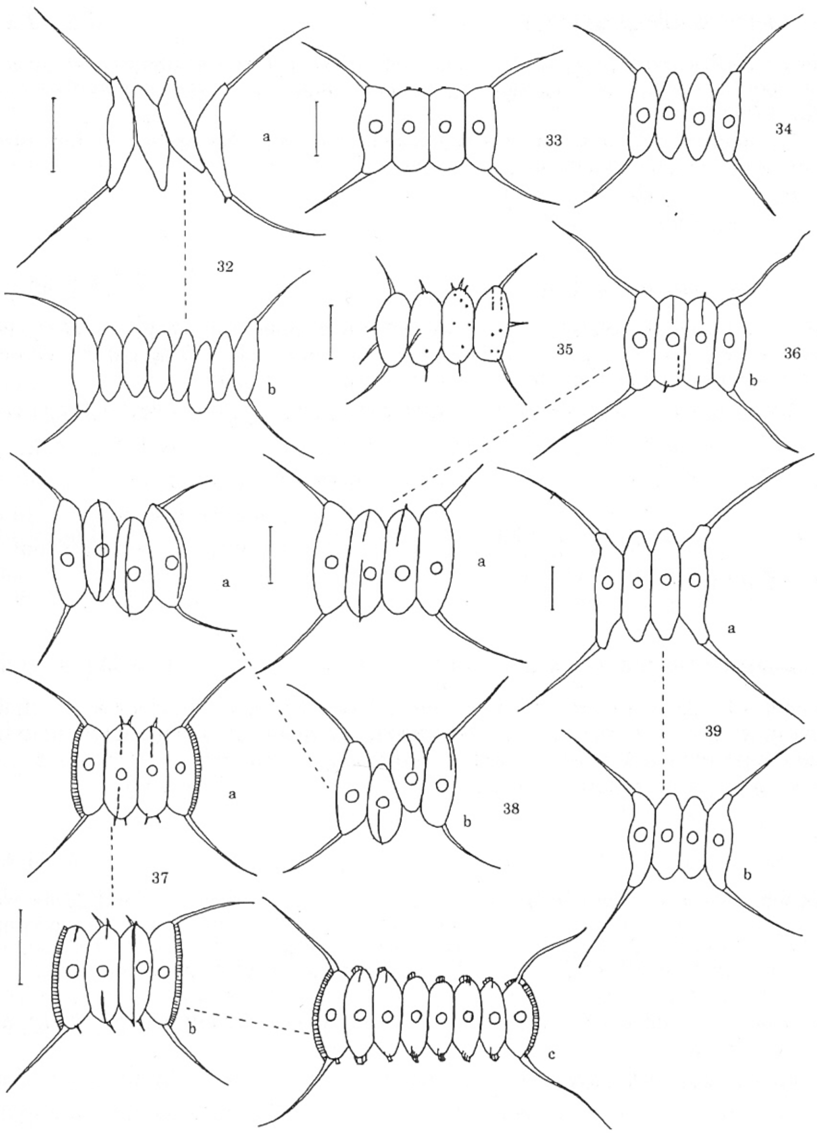
New record to Mexico.

Scenedesmus helveticus CHOD. (Fig. 37 a-c)

The species was considered a synonymous of *Sc. armatus* (HEGEWALD & SILVA 1988) but accepted as a good species by COMAS & KOMÁREK (1984) and HINDÁK (1990).

COMAS & KOMÁREK (1984) supported the separation of *Sc. helveticus* from *Sc. armatus*, because in the former, the cells are oval-cylindrical, with conical-rounded cell poles, the ribs are pregnant, high, mainly forming a clear margin around to outer cells. The four spines at the corner of the coenobium, sometimes 2 of them reduced or lacking in diagonal position, 1–4 teeth or small spines at the cell poles are facultatively present. Dimensions: cells 5.2–21.5×1.8–9.1 µm.

New record to Mexico.



Figs 32–39
32a–b, 34 – *Scenedesmus opoliensis,* **33** – *Sc. westii,* **35** – *Sc. spinosus,* **36a–b** – *Sc. armatus,* **37a–c** – *Sc. helveticus,* **38a–b** – *Sc. velitaris,* **39a–b** – *Sc. protuberans.* [Scale bar = 10 µm.]

Scenedesmus intermedius CHOD. (Figs 28 a-d, 53)

Coenobia 4-cells, strongly alternated; cells ovoid; ends rounded, 4 subapical spines, long or only short tooth-like, apical additional spines short, tooth-like with or without ribs on cell sides. Dimensions: cells 6.7–10.9×3.6–5.5 μm.

A definitive identification of these populations requires investigations on EM, however, according to their morphological features observed on LM, our specimens correspond with the species (comp. HEGEWALD et al. 1998).

New record to Mexico.

Scenedesmus magnus MEYEN (Fig. 40 a-d)

Coenobia 4-(8)-celled, linear; cells elongate cylindrical; outer cells slightly elliptical, ends capitated, rounded or conical, at the corners of outer cells a thickened main spine, additional spines in the median cells are also formed; cell wall very often ornamented. According to cells dimensions, our specimens seem to be in the lower limit of the species. Dimensions: cells 9.9–33.1×4.1–10.6 μm.

New record to Mexico.

Scenedesmus obliquus (TURP.) KÜTZ. var. *obliquus* (Fig. 30 a-b)

Coenobia 4-celled, strong or slightly alternated; cells oval fusiform, more or less straight, poles acute or slightly pointed or acute rounded. Dimensions: cells 10–19.1×5.7–6.7 μm.

Scenedesmus obliquus var. *dimorphus* (TURP.) HANSG. (Figs 30 c, 65)

Coenobia 4-celled linear; cells fusiform; outer cells arcuate, on sides slightly convex in the median parts; median cells more or less straight, ends gradually attenuated toward to the poles, acute pointed. Dimensions: cells 11.1–13.6×2.7–3.9 μm.

New record to Mexico.

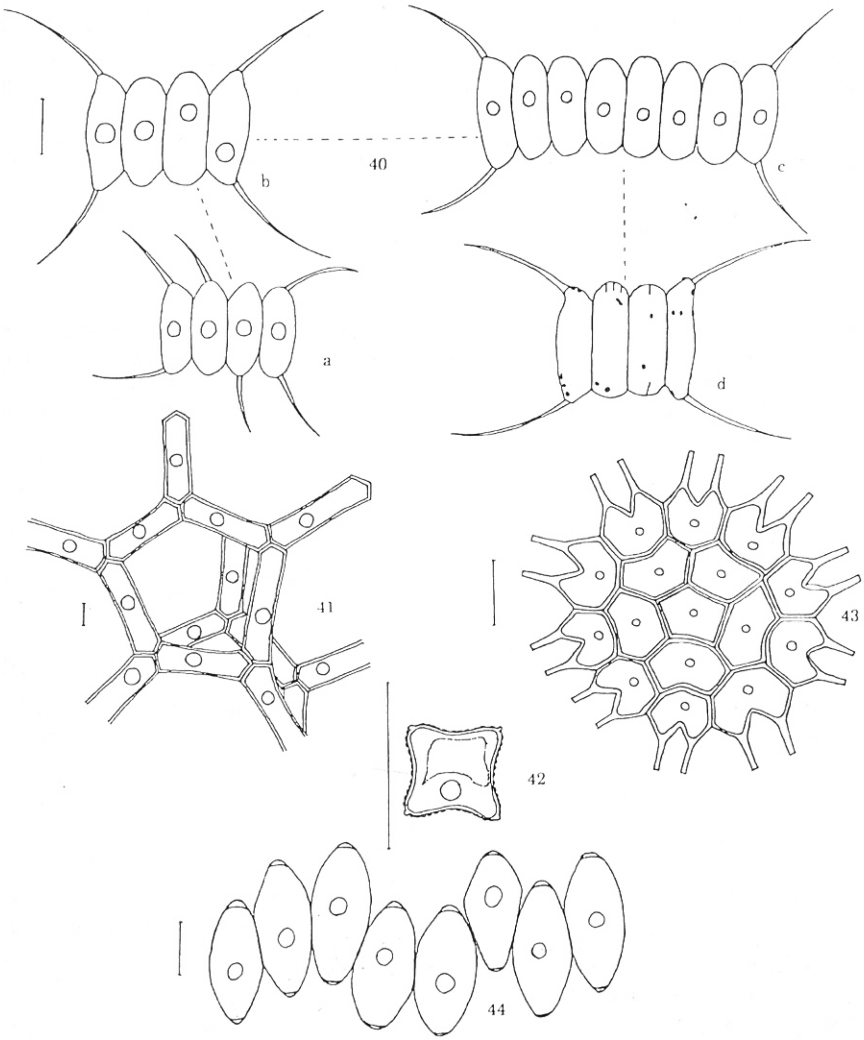
Scenedesmus obtusus MEYEN (Figs 44, 63)

Coenobia 4–8-celled, alternated, 8-celled coenobia in two rows; cells oval to broadly oval, slightly asymmetric; ends rounded, slightly thickened. Dimensions: cells 5–7×4.8–6.5 μm.

New record to Mexico.

Scenedesmus opoliensis RICHTER (Figs 31 a-b, 32 a-b, 34, 49, 62, 64)

Characteristics of *Sc. opoliensis* are: the shape of cells basically fusiform, elongated to truncated poles, at each pole of the outer cells, one relatively long spine, inserted marginally at the free side of cells and cells in the coenobium touch only in a small portion. The species shows however a wide morphological variability, combinations with different ultrastructural elements, spines, teeth, ribs, etc., then, were observed organisms identical with several described infraspecific taxa: from typical var. *opoliensis* to var. *carinatus* LEMM., therefore the taxonomic evaluation of these different types at infraspecific ranks was not easy because of transition types were found in one and the same population and also transition specimens to other species as *Sc. protuberans* and *Sc. armatus* (see HINDÁK 1990). Dimensions: cells 11.3–35.8×3.1–7.8 μm.



Figs 40–44
40a–d – *Scenedesmus magnus,* **41** – *Hydrodictyon reticulatum,* **42** – *Tetraedron minimum,* **43** – *Pediastrum boryanum,* **44** – *Sc. obtusus* (8-celled coenobium). [Scale bar = 10 µm.]

Scenedesmus cf. *pannonicus* HORTOB. (Figs 25 a-b, 48)

Coenobia 4-celled, alternated; cells basically ovoid, at the corners of outer cells, a short spine, more or less diagonal symmetric, in one pole of median cells a shorter spine is formed. Our specimens are not typical because the alternating cells are in the same plane and the spines of outer cells are evidently longer as the typical. Dimensions: cells 4.8–16.2×1.4–13 μm.

New record to Mexico.

Scenedesmus praetervisus CHOD. (Fig. 26 a-b)

Coenobia mostly 4-celled, more or less linear; cells oval-cylindrical, poles slightly convergent or rounded, at poles 1–3 teeth, which in the outer cells, 2 of them longer and diagonal symmetric, on the cell sides characteristic ribs are formed. Dimensions: cells 10–11.5×3.5–4 μm.

New record to Mexico.

Scenedesmus protuberans FRITSCH et RICH. (Figs 39 a-b, 66)

Characteristics of *Sc. protuberans* are: the elongated more or less capitated cell poles and the mostly central insertion of the spines in the poles of the outer cells. It was observed continual transitions from typical *opoliensis* to *protuberans* specimens, therefore it would be necessary to elucidate the taxonomic position between these species. We consider them, however, *ad interim* as two separated species. Dimensions of our specimens: cells 20.8–30.3×6.2–7 μm.

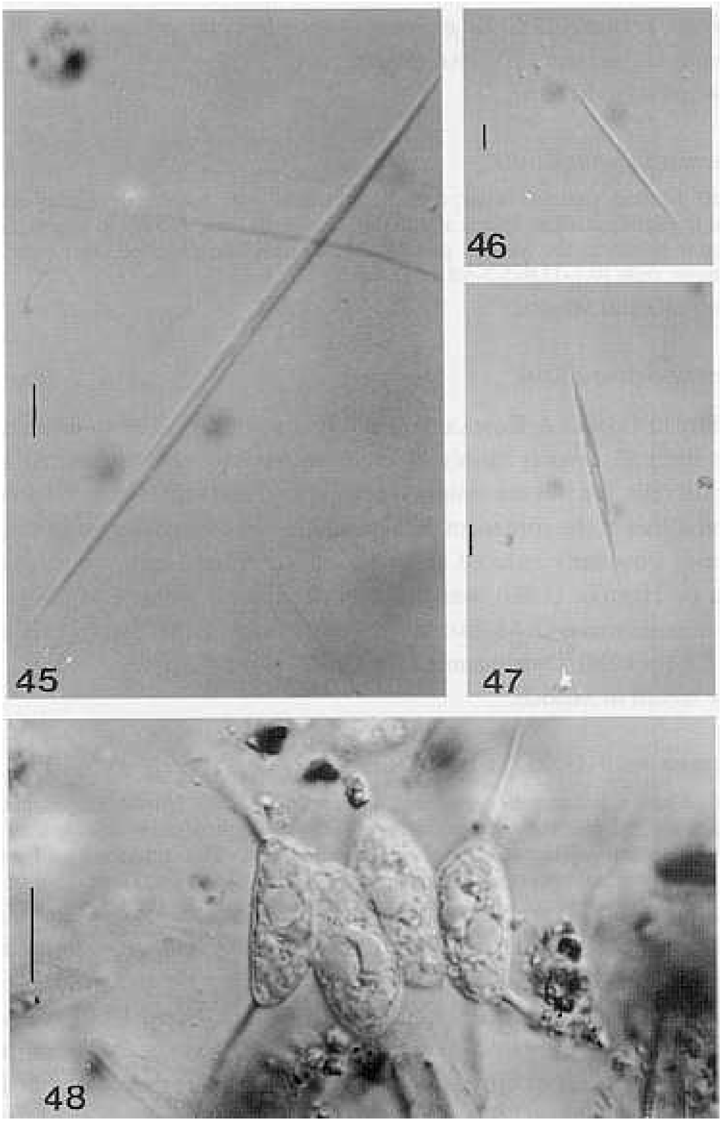
New record to Mexico.

Scenedesmus cf. *soli* HORTOB. (Figs 27 a-p, 50–51)

Our specimens, in spite of their wide morphological variability are more related to *Sc. soli:* mostly 4-celled coenobia were found, less frequently 8-celled coenobia; cells in 4-celled coenobia linear or slightly alternated, in 8-celled coenobia similar or more irregularly arranged. A mucilaginous envelope around the coenobia was observed. Cells were oval to cylindrical oval, ends rounded. The variation in spines, granules and ribs is high. Short or teeth-like spines were usually present at the poles of marginal cells, more or less diagonal symmetric, in some coenobia also the short spines at one pole of inner cells formed or absolutèly lacking. On the cell sides or near to the poles, strongly developed longitudinal ribs, sometimes interrupted, formed by wart rows, additional less developed ribs could be formed. Dimensions: cells 5.4–14×1.6–8.1 μm.

Up to day, a precise identification to the *Scenedesmus* species, specially those with structured cell walls, requires EM investigations, however, studies on LM can provide also valuable data about the morphological variability of the taxa (comp. HINDÁK 1990). According to our observations on LM, a very rich population of *Sc.* cf. *soli* was found. This species was questioned by KOMÁREK & FOTT (1983), later included into *Sc. intermedius* CHOD. (HINDÁK 1990).

Few specimens (into the variability rank of the species) resemble *Sc. armatus* var. *compactus* UHERK. 1978, *Sc. brasiliensis* BOHL. *sensu* HINDÁK 1990 (p.p.), *Sc. brasiliensis* var. *brasiliensis* f. *heterocaudatus* UHERK. 1976, *Sc. praetervisus* CHOD.



Figs 45–48
45–46 - *Monoraphidium griffithii*, 45: autospores formation, 46: mature cell, **47** - *Closteriopsis acicularis*, **48** - *Scenedesmus* cf. *pannonicus*. [Scale bar = 10 µm.]

sensu WOŁOSZYŃSKA 1912, *Sc. praetervisus* var. *semicostatus* UHERK. 1956 and *Sc. intermedius* CHOD. *sensu* HINDÁK 1990 (p.p.).

New record to Mexico.

Scenedesmus spinosus CHOD. (Fig. 35)

Coenobia 4-celled, straight, linear; cells cylindrical to oval, outer cells slightly bent, ends rounded to slightly conical, spines at poles of outer cells long, equally in length, occasionally shorter spines in the median part of all cells or at the poles of inner cells formed. Dimensions: cells 10.7–13.9×5.2–5.8 µm.

New record to Mexico.

Scenedesmus velitaris KOM. (Fig. 38 a-b)

According to COMAS & KOMÁREK (1984) it is possible in LM to distinguish *Sc. velitaris* from *Sc. armatus* mainly by the coenobia with slightly alternating oval-cylindrical cells, the ribs are mainly short, reduced and visible near the poles. The 4 curved spines at the corners of the coenobium are often different in length and sometimes irregularly reduced. The species, considered as synonymous of *Sc. armatus* by HINDÁK (1990), was based in *Sc. armatus sensu* G.M. SMITH 1916 (incl. var. *subalternans* G. M. SMITH 1916, var. *chodatii* G.M. SMITH 1916 and var. *smithii* CHOD. 1926). Dimensions: cells 12.5–17.6×4.8–5.3 µm.

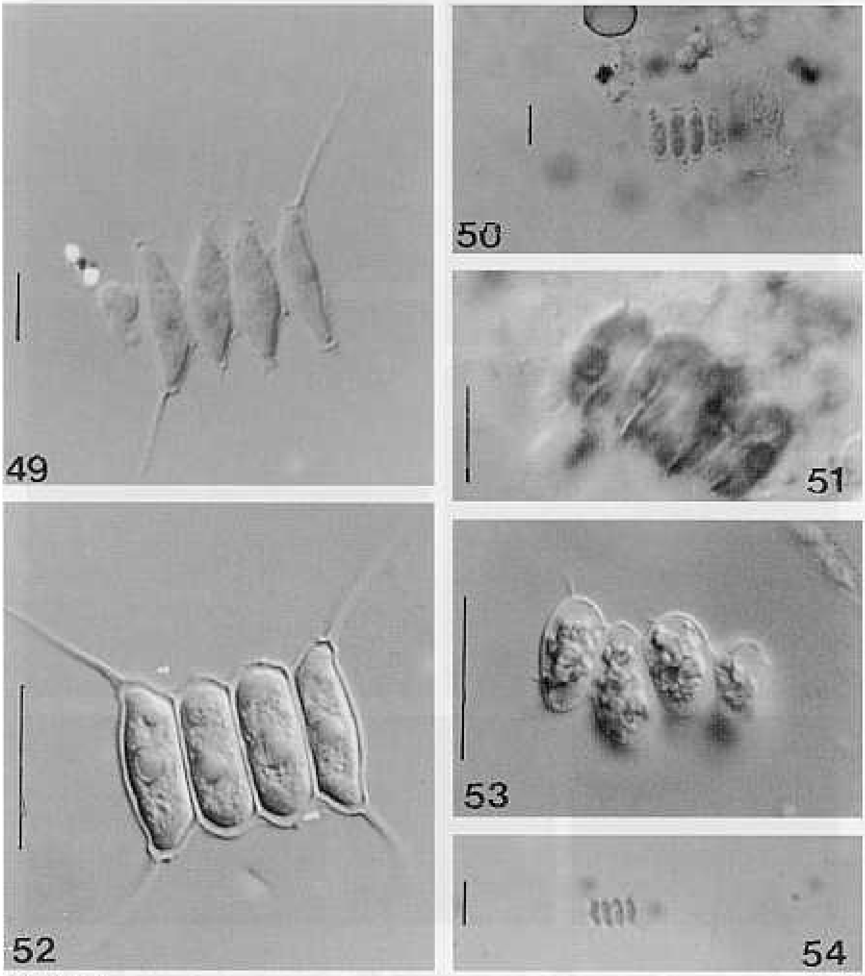
New record to Mexico.

Scenedesmus westii (G. M. SMITH) CHOD. (Figs 33, 52)

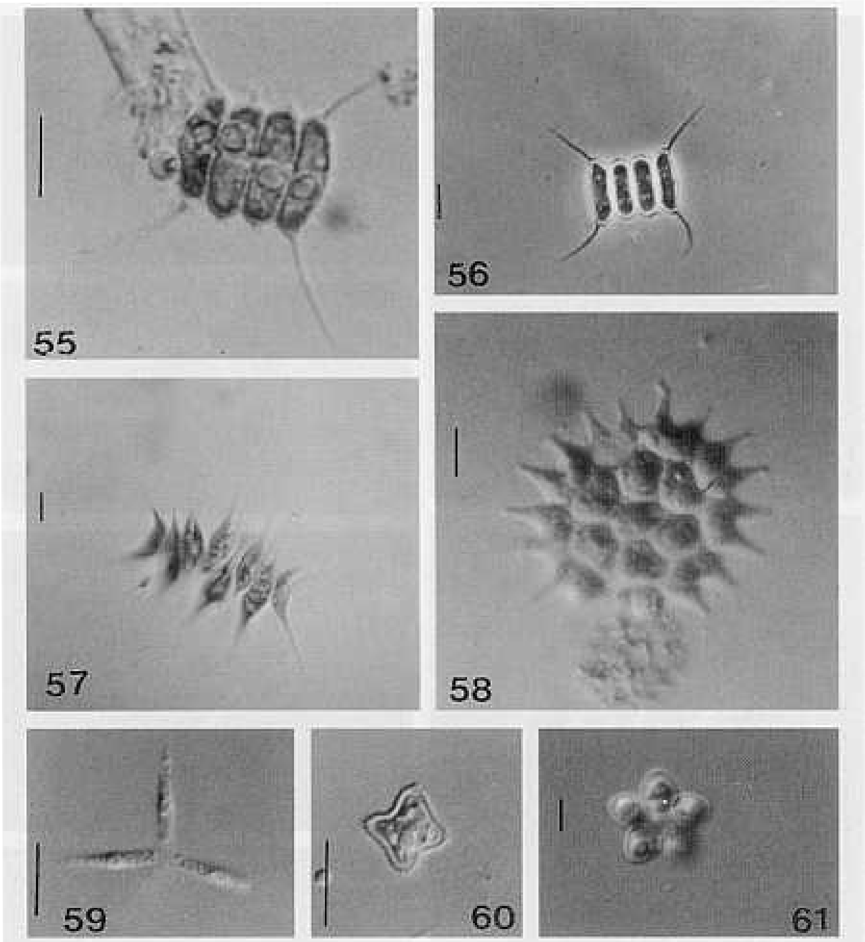
Coenobia 4-celled, linear; cells cylindrical, outer cells to slightly elliptical; ends capitated to rounded or conical, main spines 4, equal length at the corners of outer cells, as long as cells, 1–2 rosettes clearly visible at cell poles of median cells. The outermost cell wall layer between cell poles not observed. Dimensions: cells 9.21–19.8×3.8–7.5 µm.

HEGEWALD (1977) described *Sc. communis* as a new name and a new species for the very common and wide distributed (mainly in temperate zones) *Sc. quadricauda* (TURP.) BRÉB. *sensu* CHODAT 1926, because the species, cited in several publications, sometimes in different meanings (specially by old authors) was interpreted in very broad sense, not clearly defined and therefore, it was a long-persistent source of error. In his well documented paper (based mainly on exsiccatae), HEGEWALD (1977) supported his arguments rejecting one by one the main names traditionally considered as synonym of *Sc. quadricauda* (TURP.) BRÉB. in the sense of CHODAT (1926) (*Sc. longus* MEYEN, *Sc. caudatus* CORDA, *Sc. maximus* (W. et G.S. WEST) CHOD. and *Sc. westii* (G.M. SMITH) CHOD.). His nomenclatural and taxonomic conclusions could be accepted, except, those concerning to *Sc. westii.*

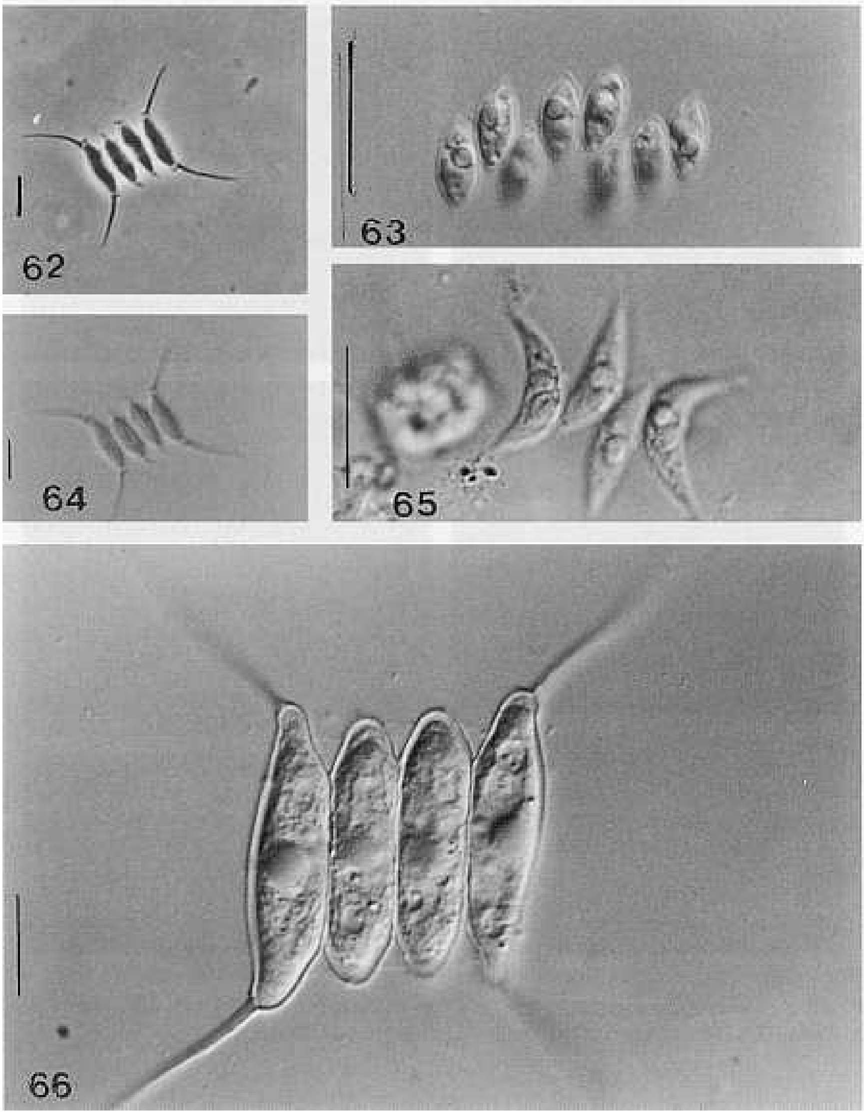
Again the name *Sc. westii*, can be a valid and hence well defined taxon, at least in the rank of variety, as in the HEGEWALD's (1977) argument. "... this species is in according to the original figures (after G.M. SMITH 1916) a *Sc. armatus* or related species", basically taking into account the cell pole configuration and the



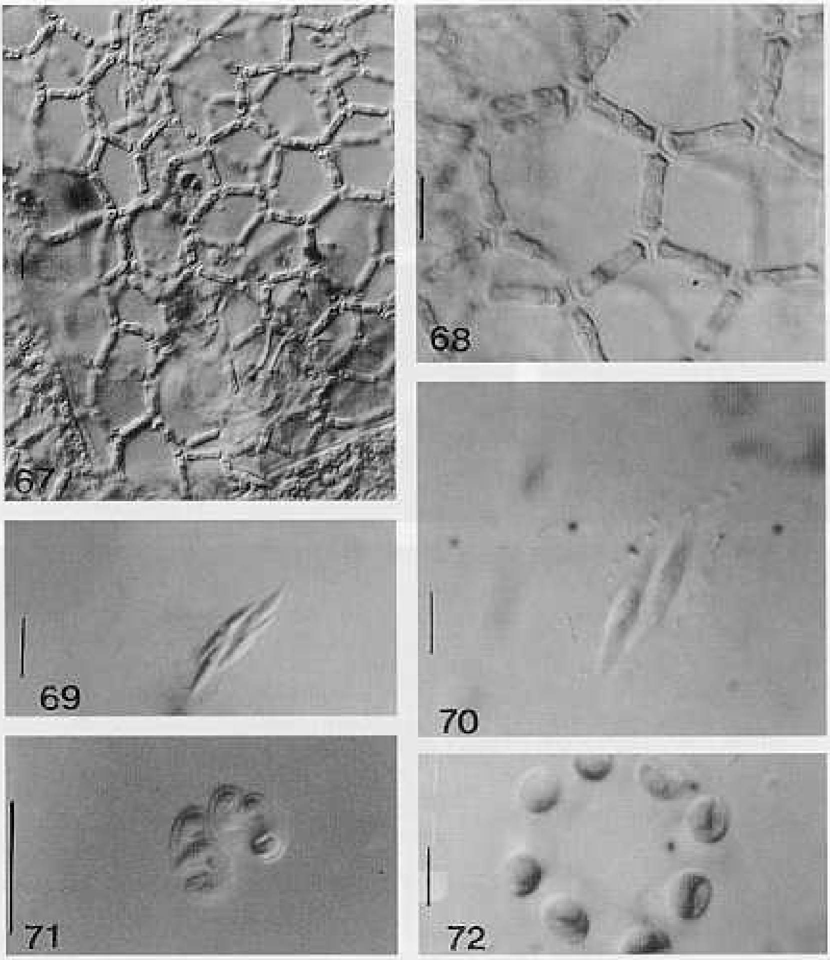
Figs 49–54
49 – *Scenedesmus opoliensis*, **50–51** – *Sc.* cf. *soli*, **52** – *Sc. westii*, **53** – *Sc. intermedius*, **54** – *Sc.* cf. *gutwinskii*. [Scale bar = 10 µm.]



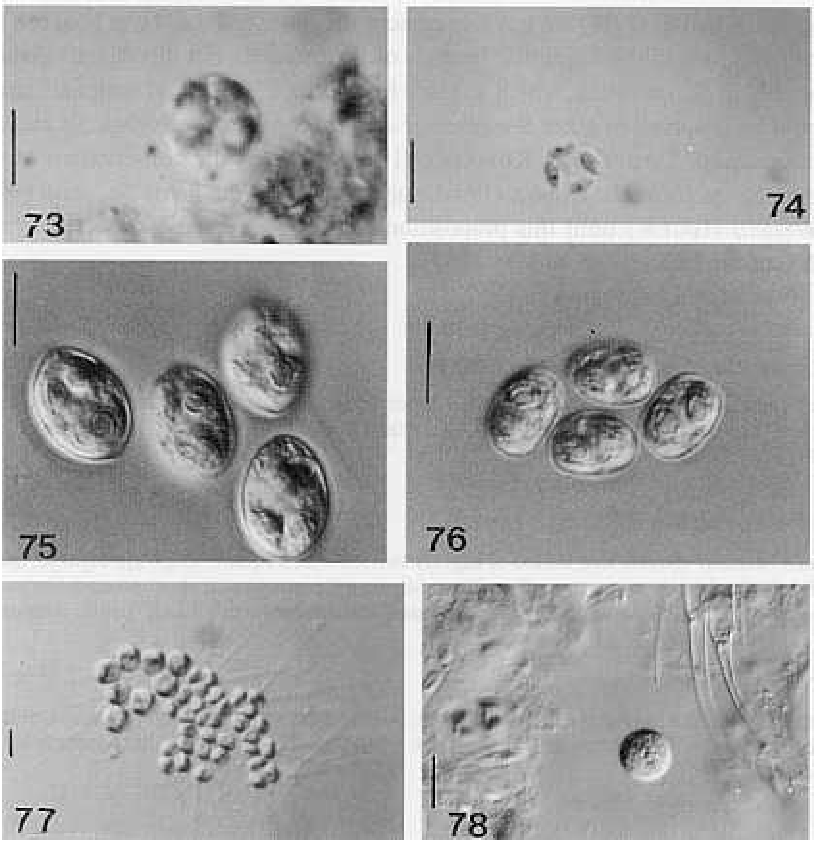
Figs 55–61
55–56 – *Scenedesmus armatus*, **57** – *Sc. acuminatus*, **58** – *Pediastrum boryanum*, **59** – *Actinastrum hantzschii*, **60** – *Tetraedron minimum*, **61** – *Coelastrum astroideum*. [Scale bar = 10 µm.]



Figs 62–66
62, 64 – *Scenedesmus opoliensis,* **63** – *Sc. obtusus* (8-celled coenobium), **65** – *Sc. obliquus* var. *dimorphus,* **66** – *Sc. protuberans.* [Scale bar = 10 μm.]



Figs 67–72
67–68 – *Hydrodictyon reticulatum*, **69–70** – *Gregiochloris lacustris*, **71** – *Nephrochlamys subsolitaria*, **72** – *Dictyosphaerium tetrachotomum*. [Scale bar = 10 µm.]



Figs 73–78
73 – *Coelastrum reticulatum,* **74** – *Quadricoccus* cf. *ellipticus,* **75–76** – *Oocystis borgei;* **77** – *Micractinium pusillum,* **78** – *Golenkinia radiata.* [Scale bar = 10 μm.]

slightly diagonal median cells of the 8-celled coenobia. It is remarkable that the ribs or rib-like structures on the cell sides are not present in any of the original figures of SMITH (1916). According to original description (G.M. SMITH 1916), *Sc. quadricauda* var. *westii* G.M. SMITH (basionym of *Sc. westii*), differs from the typical variety only in cell size and spine length, however, CHODAT (1926), raised the variety to the rank of species based mainly in the curved spines, therefore, he used only the Figs 176, 177, 180 of SMITH (1916), but not the Figs 178 and 179 (cited by HEGEWALD 1977). HEGEWALD (1977) considered the Fig. 176 of G.M. SMITH (1916) as identical with *Sc. quadricauda* var. *quadricauda* and not to the var. *westii.*

In our opinion there are not convincing arguments to consider *Sc. westii* identical to *Sc. armatus* (cell sides without ribs or rib-like structures). In the figures of SMITH (1916) are not also present the outer cell wall layer between the cell poles, one of the diagnostic features of *Sc. communis*, but this characteristic is variable in *Sc. communis*, which appears frequently in preserved materials and it could be observed in other *Scenedesmus* species, too *(Sc. protuberans, Sc. magnus, Sc. maximus)*. COMPÈRE & KOMÁREK (1990) proposed the conservation of the name *Sc. quadricauda*. COMAS (1996), suggested apply the name *Sc. westii* (= *Sc. communis* HEGEW.) until this proposition could be accepted or rejected by the PNC of the IBC.

New record to Mexico.

Schroederia setigera (SCHRÖD.) LEMM. (Fig. 6)

Cells elongate fusiform, straight, many times longer as broad, ends tapered toward the poles, thinly pointed; chloroplast parietal with a pyrenoid. Dimensions: cells 108.9–121.1×4.3–4.7 µm.

Tetraedron minimum (A. BR.) HANSG. (Figs 42, 60)

Cells basically tetraedrical, flatted or slightly twisted with a square-shape appearance, flanks slightly or strongly concave; cell wall smooth or with granules; a short process formed at the corners; chloroplast parietal with pyrenoid. Dimensions: cells 3.3–3.7 µm in diameter.

Treubaria triappendiculata BERN. (Fig. 24)

Cells tetraedrical, margins slightly concave; 3–4 hyaline, slightly broad processes, chloroplast parietal with a pyrenoid. Dimensions: cells 10.5–12 µm in diameter, process lenght 4–5 µm.

New record to Mexico.

Discussion

According to the information presented here, the Ecological Park of Xochimilco seems to have an homogeneous ecology. We found similar values of water temperature in the localities through several seasons and the same can be observed in the pH values (Tab. 2). In our view this suggests that quality and amount of water filling the water bodies, the commercial cultivation of vegetables and horticulture taking place in the Park, allow that certain ecological stability. As for variations in conductivity through the seasons, these could be due to the movement of the phreatic layer towards the water bodies; according to ENSÁSTIGUE et al. (1995) concentrations of Ca^{++} and Mg^{++} are very variable but Na^{+} and K^{+} keep rather constant. This could be influenced also by the rain, although not necessarily has a cyclic behavior.

In spite of these similarities and differences, it is noticeable that the chlorococcaleans show a trend to distribute only in certain localities. For instance, a high number of *Scenedesmus* species are mainly in localities 1 and 4, which share

Table 2. Values of pH, temperature and conductivity of water for the most distinctive climatic seasons in the study area. The localities presented correspond to the different types of aquatic environments. Localities are noted with the position numbers or letters which appear in Figure 1.

Season/Year	Locality		pH	Temperature [°C]	Conductivity [µS cm^{-1}]
Hot, dry, May 1994	Main inflow	1	7.5	21.6	830
	Wharf of Huetzalín Lake	3	10.6	23.6	450
	El Bordo channel	5	9.6	22.3	1240
	Acitlalín ditch	a	9.8	25	1081
	The resting of birds Lake	b	10.8	24.7	730
Hot, rainy, June 1997	Main inflow	1	7.3	19	502
	Wharf of Huetzalín Lake	3	9.4	22	600
	El Bordo channel	5	9.4	28	658
	Acitlalín ditch	a	8.4	26.9	450
	The resting of birds Lake	b	8.6	25	230
Cold, dry, November 1998	Main inflow	1	7.5	21	519
	Wharf of Huetzalín Lake	3	8.2	24	755
	El Bordo channel	5	9.6	21	826
	Acitlalín ditch	a	9.0	22.9	1335
	The resting of birds Lake	b	9.0	22.6	575

11 from the 17 species of this genus, present in the whole Park. The high number of shared species could be related to nutrient concentrations by their continuous supply at the inflow (locality 1) and by the highest evaporation at the pond (locality 4). Something similar occurs within other genus. The two species of *Coelastrum* are also in localities 1 and 4; the two species of *Nephrochlamys* are in 1 and 2; the two species of *Oocystis* are in 1 and 5 and the two species of *Rhaphidocelis* are in locality 4. These groups (associations) could be pointing out ecological affinity between species in some genus of Chlorococcales. Thus, the apparently physical and chemical homogeneity (Tab. 2) between the collected localities may have subtle differences signed out by the species associations.

Moreover, the little dense populations of some species like *Fusola viridis* and *Gregiochloris lacustris*, which up to now have been observed only in clean waters, may be indicating that eventual variations in the water quality may occur; or probably that their own response to saprobic conditions could be different under some environmental different factors than those predominant in temperate zones, like the photoperiod.

In a general form, the high altitude fresh-water chlorococcalean species in Mexico, can be characterized as typical of temperate water bodies, considering their global distribution. This is not extraordinary if we bear in mind that Xochimilco is situated in a high altitude valley. However, in this latitude some ecological limitation for the species in this Park could be related to climatic light, besides particular environmental conditions, like temperature or the eutrophic level of the water bodies. Such ecological limitation could be expressed in variations of populations density. As we observed evident differences in distribution and abundance of species, further observation and some experimentation will be necessary in the future.

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