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Survey and distribution of Batrachospermaceae (Rhodophyta) in tropical, high-altitude streams from central Mexico

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Abstract – Freshwater Rhodophyta populations from high altitude streams (1,725-2,900 m a.s.l.) in the Mexican Volcanic Belt (MVB), between 18-19° N and 96-100° W, were investigated through the sampling of six stream segments from 1982 to 2006. Three species are documented, *Batrachospermum gelatinosum, B. helminthosum* and *Sirodotia suecica*, including their descriptions and physical and chemical water quality data from their environment. *Batachospermum helminthosum* and *S. suecica* are reported for the second time in MVB streams, with a first description in detail for the freshwater red algal flora from Mexico. All species were found in tropical climates (two seasons along a year, dry and rainy), at high altitudes (> 1,700 m a.s.l.), mild water temperatures (9.0-20.4°C), circumneutral (pH 6.0-8.2, bicarbonate as the dominant anion), and with a relative low ionic content (salinity 0.1 to 0.2 g l^{-1}, specific conductance 77-270 µS cm^{-1}). Two ecological groups of species were clearly distinguished on the basis of nutrient content. The first group, which includes *B. helminthosum*, is characterized by clean waters with low nutrient concentration, while the other, with *B. gelatinosum* and *S. suecica,* thrive surprisingly well in nutrient-rich waters. The overall species composition for streams in the MVB revealed strong similarities with freshwater red algal floras from other temperate regions in North America and other continents.

Batrachospermaceae / distribution / high-altitude / Mexico / Rhodophyta / streams / taxonomy

Résumé – Taxonomie et distribution des Batrachospermaceae (Rhodophyta) dans les rivières tropicales de haute altitude du centre du Mexique. Des populations de Rhodophytes d'eau douce de ruisseaux de haute altitude à eaux tempérées ont été étudiées dans la Zone Volcanique du Mexique (ZVM) entre 18°-19° N et 96°-100° W. Six segments de ruisseau de 1725 m à 2900 m d'altitude ont été échantillonnés de 1982 à 2006. Trois espèces, *Batrachospermum gelatinosum*, *B. helminthosum* et *Sirodotia suecica*, sont présentées avec leurs descriptions et des données sur la physico-chimie des eaux. C'est la deuxième observation de *B. helminthosum* et de *S. suecica* dans des ruisseaux mexicains, mais c'est la première description détaillée de la flore des algues rouges d'eau douce au

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Mexique. Tous les espèces ont été trouvées sous un climat tropical tempéré par la haute altitude (> 1700 m), dans l'eau tempérée (9-20.4 °C), plutôt neutre (pH 6.0-8.2 avec dominance de bicarbonates), et avec une teneur ionique modérée (0.1 à 0.2 g l^{-1} de salinité, 77-270 µS cm^{-1} de conductivité spécifique). Deux groupes d'espèces ont été clairement distingués d'après la teneur en éléments nutritifs. Le premier groupe, qui comprend *B. helminthosum*, se trouve dans des eaux claires à concentration nutritive modérée, alors que l'autre, qui inclut *B. gelatinosum* et *S. suecica*, se développe spécialement bien dans des eaux riches en éléments nutritifs. La composition générale en espèces dans les ruisseaux de la ZVM révèle une grande similitude avec la flore d'algues rouges d'eau douce d'autres zones tempérées d'Amérique du Nord et d'autres continents.

Batrachospermaceae / distribution / haute altitude / Mexico / Rhodophyta / rivières / taxonomie

INTRODUCTION

The red algal family Batrachospermaceae is the major group of freshwater Rhodophyta and occurs widely in lotic ecosystems throughout the world (Necchi, 1990; Sheath & Hambrook, 1990). These algae have a main axis composed of a row of axial cells and whorls of short branches, and carpogonium-bearing branches arising from periaxial cells and/or fascicles cells of cortical filaments (Coomans & Hommersand, 1990). Four genera are recognized in the family and can be separated as follows (based on Necchi *et al.*, 1993; Kumano, 1993; Kwandrans & Eloranta, 1994; Sheath *et al.*, 1996). *Batrachospermum* includes algae with spherical carposporophytes and a gonimoblast filament arising directly from the fertilized carpogonium. *Tuomeya* has spherical carposporophytes and a gonimoblast filament arising from a dense mass of fusion cells (placenta). *Sirodotia* has trichogynes with a large protuberance at their base and a gonimoblast filament indeterminately creeping along cortical filaments. *Nothocladus* has contorted carpogonial branches and a gonimoblast filament arising from a fertilized carpogonium, indeterminately creeping among outer cortical filaments.

Two ecological groups of Batrachosopermaceae have been recognized in central Mexico, a region characterized by a tropical climate, that is, with a rainy season during summer, and a dry season composed by a cold period (around January, when daily temperature easily show differences of more than 20°C), a hot one (during April-May) and the transition between both. The first group includes two species previously reported in warm waters: *Batrachospermum globosporum* (Sheath *et al.*, 1992; Carmona *et al.*, 2004) and *Sirodotia huillensis* (Vis & Sheath, 1999; Carmona *et al.*, 2004; Carmona *et al.*, 2006). The second group contain five species from high altitude streams with temperate waters: *B. arcuatum* Kylin from one locality (Vis *et al.*, 1996b), *B. gelatinosum* [=*B. moniliforme* var. *moniliforme* Roth, =*B. moniliforme* Roth var. *pulchirrincum* (Bory) C. Agardh] from six localities (Sámano-Bishop & Sokoloff, 1931; Sánchez-Rodríguez, 1974; Sheath *et al.* 1992; Carmona *et al.*, 2004), *B. helminthosum* from one locality (Sheath *et al.*, 1994a), *B. vagum* from three localities (Sámano-Bishop & Sokoloff, 1931; Sánchez-Rodriguez, 1974), and *S. suecica* from one locality (Carmona *et al.,* 2004). However, there are few morphometric data in the collections from these high altitude streams; as well, very few data on environmental information have been collected. This research was undertaken to evaluate the taxonomic characters, the occurrence environment and the geographic distribution of the Batrachospermaceae populations from tropical, high-altitude streams in the MVB, together with previous reports from central Mexico.

MATERIALS AND METHODS

Central Mexico contains an immense mountainous chain (MVB), stretching over the country from coast to coast (Fig. 1). The geomorphologic and climatic conditions of the area have led to the formation of exuberant coniferous forest and streams with relatively cold to warm waters (Ferrusquía-Villafranca, 1993; García, 2004; Carmona *et al.,* 2004). The populations of Batrachospermaceae analysed in this study were collected in six streams from the MVB (18-19° N, 96-100° W) at altitudes from 1,725 to 2,900 m. The following environmental variables were measured: temperature, pH and specific conductance with a Conductronic PC-18 conductivity meter and oxygen with an YSI-85 Oxygen meter. For water chemistry, 1000 ml (preserved in dark and cold conditions) and 500 ml (preserved with nitric acid at pH 2-3) sub samples were used. Dissolved nutrients (30 ml filtered *in situ* with 0.45 and 0.22 μm pore diameter membranes, preserved with 1-2 drops of chloroform and kept frozen until their analyses) were measured in the laboratory with a multichannel analyzer, following standard titration. Total phosphorus and nitrogen were taken directly and stored in cold conditions until analyses were completed (Table 2, APHA *et al*., 1989). Microhabitat variables were measured *in situ* at the centre of each population: current velocity and irradiance were measured as close to the alga as possible, using a Swoffer 2100 current velocity meter and a Li-Cor LI-1000 quantum meter with a flat subaquatic sensor of photosynthetically active radiation (PAR). The samples were preserved in 3% formaldehyde and included in the herbaria **FCME** (Holmgren *et al*., 1990). We have taken into account all quantitative and qualitative morphological characters previously considered to be of taxonomic importance at generic and specific levels in previous relevant studies

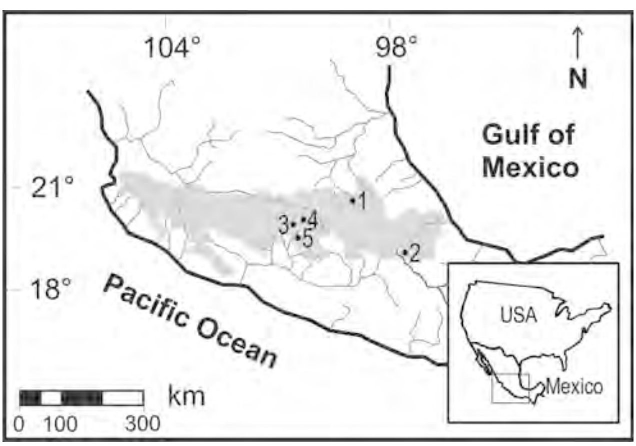


Fig. 1. Location of the study region in central Mexico with indications of the sites with populations of Batrachospermaceae (●) and the Mexican Volcanic Belt (grey part). Number of localities according with Table 1.

(Necchi, 1990; Necchi *et al.*, 1993; Sheath *et al.*, 1992; Sheath *et al.*, 1994a, 1994b; Vis *et al.*, 1995; Vis *et al.*, 1996a, 1996b; Kumano, 2002). For microscopic analyses and photographic documentation of cytological characters, we used an Olympus BX51 microscope, with an SC35 microphotography system. Morphometric characters were measured in 20 replicates; the number of replicates was determined using the equation: $n = (s/E\ \bar{x})^2$; where s= standard deviation, E = standard error (0.05), $\bar{x}$ = mean (Southwood, 1978).

RESULTS AND DISCUSSION

Taxonomic survey

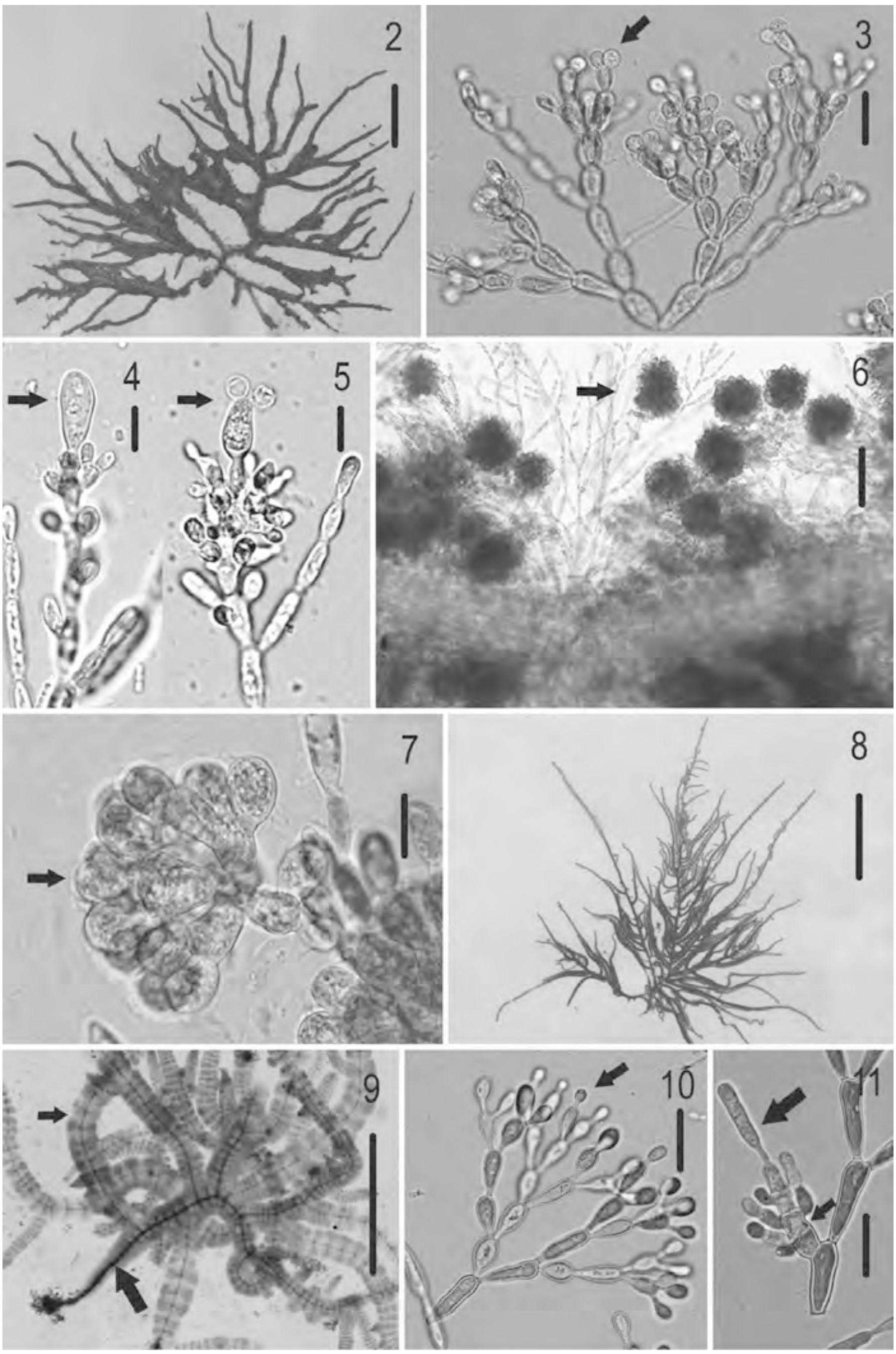
Batrachospermum gelatinosum (Linnaeus) De Candolle *Bull. Sci. Soc. Philom. Paris* 3: 21 (1801) **(Figs 2-7)**

Monoecious algae, richly mucilaginous, 1.5-6.0 cm ($\bar{x}$ = 3.0 µm) in length, whorls spherical or barrel-shaped, distant to confluent, sometimes compressed, 560-1350 µm ($\bar{x}$ = 998.0 µm) in diameter; primary fascicles with 8-18 cell-storeys. Spermatangia hyaline, elliptical to spherical, 2.5-7.5 µm ($\bar{x}$ = 5.1 µm) in diameter, two or three borne in distal cells of primary fascicles. Carpogonium born on an undifferentiated branch with 3-10 cells; carpogonium, 5.0-8.8 µm ($\bar{x}$ = 6.7 µm) in diameter, 11.0-35.0 µm ($\bar{x}$ = 22.6 µm) in length, with club shaped or lanceolated trichogynes 5.0-8.0 µm ($\bar{x}$ = 6.0 µm) in diameter. Peduncullate, spherical carposporophyte, 50-165 µm ($\bar{x}$ = 87.5 µm) in diameter; 5-18 carposporophytes exserted in the whorls at various distances from the axis. Gonimoblast filaments composed of 2-4 cylindrical cells; spherical or obovoidal carposporangia, 7.0-10.4 µm ($\bar{x}$ = 8.6 µm) in diameter, 7.5-11.7 µm ($\bar{x}$ = 9.7 µm) in length.

Distribution in Mexico. Examined specimens: 1) Mexico State, Jilotzingo, San Luis Ayucán, 5.i.1989, coll. *J. Carmona* PAL1 (FCME); 2) Tianguistenco, Zempoala, 11.xi.1990, coll. *G. Montejano* PA (FCME); 3) Valle de Bravo, Amanalco stream, 6.ii.2006, coll. *Y. Beltrán* VB64 (FCME). In literature (Sámano-Bishop & Sokoloff, 1931; Sánchez-Rodríguez, 1974; Sheath *et al.* 1992; Carmona *et al.*, 2004) – Mexico State, Valle de Bravo, 3.iv.1965, coll. *F. Sánchez Martínez* (ENCB); Presa Colorines, 5.iv.1965, coll. *F. Sánchez-Martínez* (ENCB); Villa del Carbón, Monte Peña, iii.1968, coll. *H. Huerta Silva* (ENCB).

Taxonomic remarks. This species has a wide range of morphological variation in North America, and the higher average whorl diameter, smaller fascicle length and smaller carpogonia diameter in the Mexican populations were similar to previous reports from deciduous forest populations in the southern U.S.A. (Vis *et al.*, 1996a). *Batrachospermum gelatinosum* can be distinguished from other species of *Batrachospermum* in Mexico by the presence of several carpogonia in the proximal

Figs 2-11. Morphological features of Batrachospermaceae. **2-7**. *Batrachospermum gelatinosum* (population, VB64). **2**. Habit of alga. **3**. Spermatangia (arrow) at fascicles branch tip. **4**. Carpogonium-bearing branch with a globose trichogyne (arrow). **5**. Fertilized carpogonium with attached spermatium (arrow). **6**. Main axis with whorls and numerous carposporophytes (arrow). **7**. Carposporophyte with carposporangia (arrow). **8-11**. *B. helminthosum* (population, VB13). **8**. Habitat of alga. **9**. Brownish main axis (arrow) and branch showing barrel-shaped whorls and confluent whorls (small arrow). **10**. Spermatangia (arrow) at fascicles branch tip. **11**. Carpogonium with a cylindrical, stalked trichogyne (arrow) and a differentiated carpogonium in branches with three barrels shaped cells (small arrow). Scale bars: 1 cm for Figs 2, 8 and 9; 10 µm for Figs 3-5, 7, 10 and 11; 50 µm for Fig. 6.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fascicles tips, with 3 to 13 cells and club shaped or lanceolated trichogynes. *Batrachospermum helminthosum* forms carpogonial branches from the main axis on pericentral and proximal fascicle cells with 2 to 4 cells and a cylindrical stalked trichogyne. *Batrachospermum arcuatum* is a dioecious alga and has carpogonia subtended by relatively short filaments of unmodified cells (Vis *et al.*, 1995). In contrast, *B. globosporum* has helically twisted carpogonial branches and is found in tropical regions of Mexico (Carmona *et al.*, 2004). *Batrachospermum vagum* has been reported in tropical regions, however, it has not been possible to examine the Mexican material and most of these taxa have been transferred to other sections such as *Contorta* (Sheath *et al.*, 1994b).

Batrachospermum helminthosum Bory. *Ann. Mus. Hist. Nat.* 12: 316 (1808)
(Figs 8-15)

Monoecious algae, lightly mucilaginous, 1.4-5.0 cm ($\bar{x}$ = 2.6 cm) in length, with brownish main axis; whorls barrel-shaped, confluent, 670-1,080 µm ($\bar{x}$ = 900 µm) in diameter, primary fascicles with 7-15 cell-storeys. Spermatangia spherical, 3.0-6.3 µm ($\bar{x}$ = 5.3 µm) in diameter, borne singly or in pairs on branches from the apical filaments of the whorls. Carpogonium borne on branches composed of 1-5 short cells arising from periaxial cells of fascicles filaments; carpogonium, 7.5-10.0 µm ($\bar{x}$ = 8.4 µm) in diameter, 36.2-62.5 µm ($\bar{x}$ = 53.8 µm) in length, with pedicellate, cylindrical to slightly club-shaped trichogynes, 7.5-10.7 µm ($\bar{x}$ = 8.6 µm) in diameter. Elliptical carposporophyte, 160-380 µm ($\bar{x}$ = 260 µm) in diameter, with 3-8 cylindrical gonimoblast cells; obovoidal carposporangia, 7.0-12.5 µm ($\bar{x}$ = 9.4 µm) in diameter and 12.6-16.3 µm ($\bar{x}$ = 14.4 µm) in length.

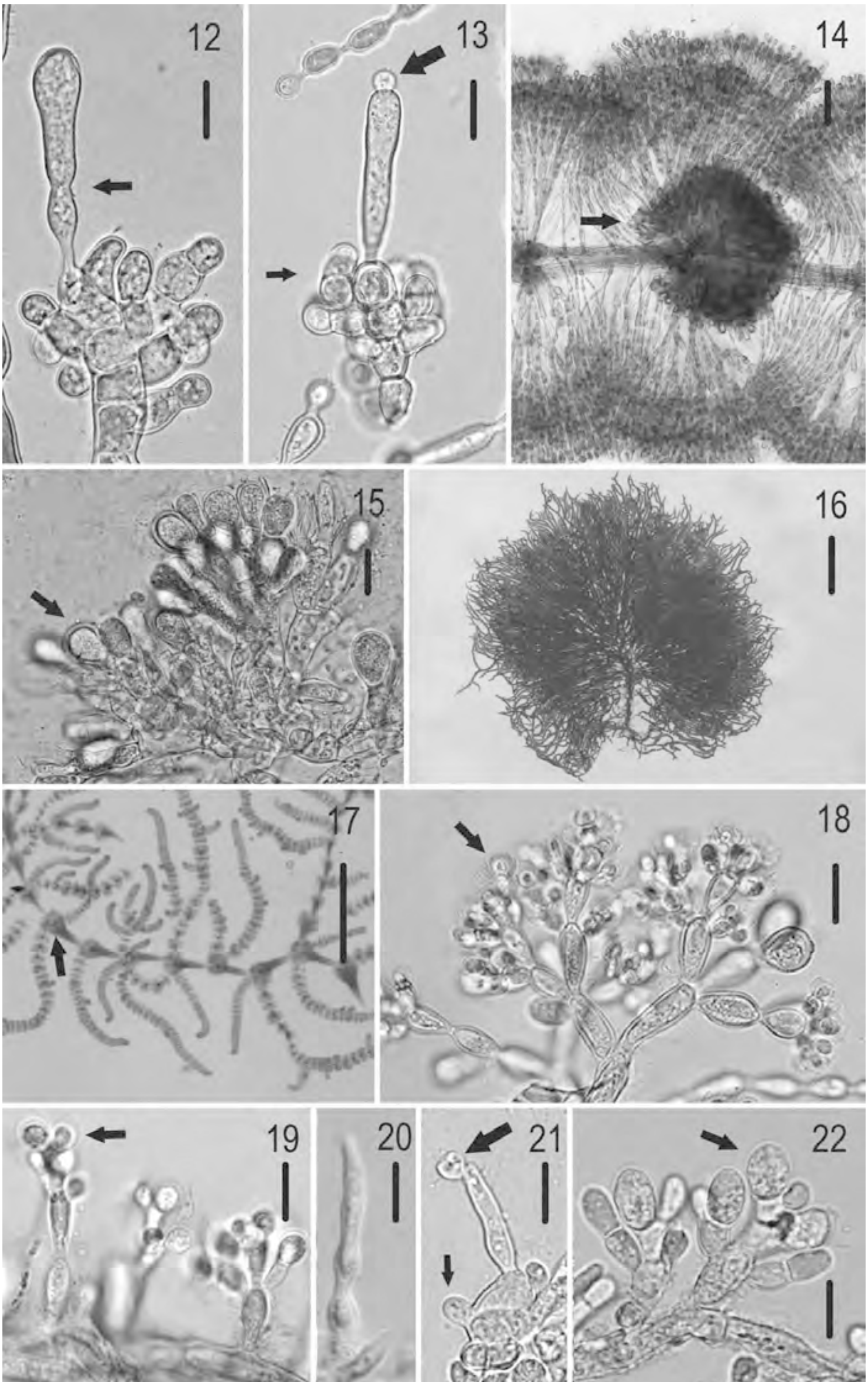
Distribution in Mexico. Examined specimens: 4) Mexico State, Valle de Bravo, González spring, 9.vi.2005, coll. *J. Carmona*, VB13 (FCME); 5) Acámbaro, El Borbollón, 6.ii.2006, coll. *M. Bojorge* VB74 (FCME). In literature: (Sheath *et al.*, 1994a) – Mexico State, Valle de Bravo, 3.iv.1965, coll. *R. Sheath* (ENCB).

Taxonomic remarks. The whorls in Mexican populations were considerably wider than those reported from North America (306-746 µm, Sheath *et al.*, 1994a). However, Vis *et al.* (2001) and Chiasson *et al.* (2003) showed that *B. helminthosum* is a morphologically plastic species, with some genetic variation, and we do not consider that morphological variation is taxonomically significant.

Sirodotia suecica Kylin. *Nova Acta Reg. Soc. Sci. Upsal., Ser. 4,* 3: 38 (1912)
(Figs 16-22)

Monoecious algae, richly mucilaginous, 2-8 cm ($\bar{x}$ = 5.5 cm) in length, abundantly and irregularly branched, whorls barrel-shaped to pear-shaped,

Figs 12-22. Morphological features of Batrachospermaceae. **12-15.** *B. helminthosum* (population, VB13). **12.** Carpogonium with cylindrical stalked trichogyne (arrow). **13.** Fertilized carpogonium with attached spermatangia (arrow) and initial gonimoblast (small arrow) arising from the basal protuberance side of the carpogonium base. **14.** Main axis, confluent whorls and axial carposporophyte (arrow). **15.** Cylindrical gonimoblast cells (arrow) and obovoid carposporangia (small arrow). **16-22.** *Sirodotia suecica* (population, VB26). **16.** Habit of alga. **17.** Main axis with truncate-pyramidal whorls (arrow). **18.** Spermatangia terminal on primary fascicles (arrow). **19.** Spermatangia terminal on secondary fascicle (arrow). **20.** Carpogonium with irregular trichogyne (arrow). **21.** Fertilized carpogonium (arrow) and origin of gonimoblast initial from non-protuberant side of carpogonium (arrow small). **22.** Mature carposporophyte with an indeterminate prostrate gonimoblast filament and carposporangia (arrow). Scale bars: 1 cm for Fig. 16; 0.5 cm for Fig. 17; 50 µm for Fig. 14; 10 µm for Figs 12, 13, 15, 18-22.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separate or confluent, 200-410 µm ($\bar{x}$ = 323 µm) in diameter; primary fascicles with 8-12 cell-storeys; terminal hairs present. Spermatangia hyaline, spherical, abundant in dense clusters of distal cells in primary and secondary fascicles, 3.7-7.5 µm ($\bar{x}$ = 5.3 µm) in diameter. Carpogonia borne in short branches, consisting of 2-5 barrel shaped more or less isodiametric cells. Carpogonium with a hemispherical protuberance on one side of basal portion, 20.0-31.3 µm ($\bar{x}$ = 25.3 µm) in length, 7.5-10.7 µm ($\bar{x}$ = 9.0 µm) in diameter, trichogyne ellipsoidal, finally cylindrical and more or less distinctly stalked. Carposporophyte indefinite in shape, gonimoblast filament irregularly branched, arising from the opposite side of a basal hemispherical protuberance of the carpogonium, creeping along cortical filaments; obovoidal carposporangia, 7.5-10.0 µm ($\bar{x}$ = 8.2 µm) in diameter, 8.7-15.0 µm ($\bar{x}$ = 11.3 µm) in length.

Distribution in Mexico. Examined specimens: 6) Oaxaca, Teotitlán del Camino, 1.v.1982, coll. *R. Tavera* PAP335 (FCME); 7) Mexico State, Valle de Bravo, Amanalco stream, 30.ix.2005, coll. *M. Bojorge*, VB26 (FCME). In literature – first description of the species.

Taxonomic remarks. The arrangement of spermatangia in the Mexican populations was extremely variable, with one to three spermatangia in distal cells from primary or secondary fascicles, similar to previous reports by Entwisle & Foard (1999) for this species in Australia and New Zealand. However, the high variability in spermatangia arrangement has no impact on the taxonomic system proposed by Necchi *et al.* (1993) and Vis & Sheath (1999), and may be related to different environmental conditions, particularly to current velocity.

Sirodotia suecica is distinguished from other species of *Sirodotia* in Mexico by its gonimoblast initial arising from the non-protuberant side of the carpogonium, being monoecious and its temperate distribution. In contrast, *S. huillensis* has the gonimoblast initial arising from the protuberance side of the carpogonial base, individuals are dioecious and have a tropical distribution (Necchi *et al.*, 1993; Carmona *et al.*, 2004; Carmona *et al.*, 2006).

Ecology and distribution

In terms of environmental variables (Tables 1 and 2), all populations were found in mild temperatures (9.0-20.4°C), moderately acidic to alkaline waters (pH 6.0-8.2), relatively low ionic content (total dissolved solids or salinity, 0.1 a 0.2 g l^{-1}; specific conductance 77-270 µS cm^{-1}), shallow (depth 1-10 cm) and slow to fast flowing waters (8-137 cm s^{-1}); the stream segment where it has been observed are shaded or partly shaded, on rocky substrata (mostly bedrock) and with a variable percentage of oxygen saturation (66-168%). Temperatures are similar to those reported by Vis *et al.* (1996a) for *B. gelatinosum* (1-27°C) and Sheath *et al.* (1994a) for *B. helminthosum* (< 20°C), but higher than those reported by Necchi *et al.* (1993) for *S. suecica* (< 13°C, cf. Table 1). All populations were collected (or observed) in low to moderate alkalinity and hardness (≤ 126 mg $CaCO_3$ l^{-1}), and the waters showed a dominance of bicarbonate/ magnesium-calcium, with very low sulfate values. According to the trophic level, we recognize two main groups, the first (González and Borbollón springs) with populations of *B. helminthosum* growing in cleaner conditions (dissolved reactive phosphorous, DRP, 0.037 mg l^{-1}; N-NO_3^-, 0.27 mg l^{-1}; N-NH_4^+, 0.15 mg l^{-1}, and chemical oxygen demand < 4 mg O l^{-1}); in fact, the association of *B. helminthosum* and *Prasiola mexicana* J. Agardh (Chlorophyta) can be taken as indicative of oligotrophy (Kumano, 2002; Ramírez & Cantoral, 2003). The second group is found in Amanalco stream, with populations of *B. gelatinosum* and *S. suecica* growing in more polluted, eutrophic conditions (DRP, 1.89 mg l^{-1}; N-NO_3^-,

Table 1. Physical characteristics, conductance (K_{25}) and pH of streams containing Batrachospermaceae in central Mexico.

	1. San Luis Ayucán	*2. Zempoala*	*3. Amanalco*	*4. González spring*	*5. El Borbollón*	*6. Teotitlán del camino*
Taxa [a]	Bg	Bg	Bg, Sc.	Bh	Bh	Sc
Date	05.i.1989	11.xi.1990	09.vi.2005 29.ix.2005	09.vi.2005 06.ii.2006	06.ii.2006	01.v.1982
Depth (cm)	10	5	1-10	5-13	4	2
Temperature (°C)	9.0	12.0	18.4-19.2	15.7-20.4	12.2	16.0
Irradiance (μmol photons m^{-2} s^{-1})	–	–	62-102	29-114	153-202	–
Current velocity (cm s^{-1})	30	–	8-137	6-15	40	10
Specific conductance (μS cm^{-1})	77	–	174-226	88-90	270	–
pH	6.0	6.0	7.2-7.6	7.5-7.6	8.2	6.0

[a] Bg= *Batrachospermum gelatinosum*, Bh= *B. helminthosum*, Sc= *Sirodotia suecica*.

0.84 mg l^{-1}; N-NH_4^+, 0.54 mg l^{-1}, and chemical oxygen demand < 33 mg O l^{-1}); in Mexico, *B. gelatinosum* has been collected with another red alga, *Paralemanea mexicana* (Kützing) Vis *et* Sheath, in two streams with similar conditions (Carmona & Necchi, 2002).

Sirodotia suecica is described for the first time for Mexico, confirming that the distribution of the three species reported in this study might be broader than formerly observed, as is the case for other temperate North American red algal species in central Mexico, e.g., *B. arcuatum* (Vis *et al.*, 1996b) and *Paralemanea annulata* (Kützing) Vis *et* Sheath (Carmona & Necchi, 2002). *Batrachospermum gelatinosum* and *S. suecica* were collected in streams close to and similar in conditions to the previous records (Israelson, 1942; Vis *et al.*, 1996a). This study has demonstrated that these species are not restricted to a single hydrological system. *Batrachospermum gelatinosum* appears to be global in its distribution, probably due to its ability to tolerate a wide range of chemical and physical characteristics in their stream locations, urban pollution included (Vis & Sheath, 1998; Kwandrans *et al.*, 2002). Only *B. helminthosum* has been found in the northwestern U.S.A. in temperate habitats; besides, most occurrences are from the lowland streams of the world (Sheath *et al.*, 1994a; Kumano, 2002). The affinities of Batrachospermaceae species between MVB and temperate eastern North America may indicate a possible biogeographical connection with the neartic region with similar environmental requirements.

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Table 2. Chemical characteristics of some of the streams with observed Batrachospermaceae in central Mexico (DRP, Dissolved Reactive Phosphorus; TIN, Total Inorganic Nitrogen).

	3. Amanalco	*4. González spring*	*5. El Borbollón*
Taxa [a]	Bg, Sc.	Bh	Bh
Date	09.vi.2005 29.ix.2005	09.vi.2005 06.ii.2006	06.ii.2006
Total Dissolved Solids (mg l^{-1})	187-205	83-84	158
Total alkalinity (mg $CaCO_3$ l^{-1})	72-83	44-48	131
HCO_3^- (mg l^{-1})	87-101	53-58	151
$CO_3^=$ (mg l^{-1})	0	0	5
Cl^- (mg l^{-1})	7-12	1-2	1
$SO_4^=$ (mg l^{-1})	5-11	≤ 1	1
Si-SiO_2 (mg l^{-1})	46-48	29-30	23
Total hardness (mg $CaCO_3$ l^{-1})	74-76	40-42	126
Ca^{++} hardness (mg $CaCO_3$ l^{-1})	32-34	18-20	92
Mg^{++} hardness (mg $CaCO_3$ l^{-1})	42-43	20-22	34
Ca^{++} (mg l^{-1})	13	8	37
Mg^{++} (mg l^{-1})	10	5	8
Na^+ (mg l^{-1})	12-18	4-5	11
K^+ (mg l^{-1})	3.5-5.0	2	1
Ionic dominance (meq l^{-1})	$Mg^{++} > Na^+ \geq Ca^{++} > K^+$ $HCO_3^- > Cl^- > SO_4^=$	$Mg^{++} \geq Ca^{++} > Na^+ > K^+$ $HCO_3^- > Cl^- > SO_4^=$	$Ca^{++} > Mg^{++} > Na^+ > K^+$ $HCO_3^- > CO_3^= > Cl^- > SO_4^=$
DRP (mg l^{-1})	1.889	0.037	–
N-NO_3^- (mg l^{-1})	0.84	0.27	–
N-NO_2^- (mg l^{-1})	0.010	0.013	–
N-NH_3^- (mg l^{-1})	0.54	0.15	–
TIN/DRP (on molar relationship)	2	26	–
Dissolved Oxygen (mg l^{-1})	7.1-8.0	12.3-12.4	–
Oxygen Saturation (%)	66-105	153-168	–
DBO_5 (mg O l^{-1})	≤ 2	≤ 2	≤ 2
DQO (mg O l^{-1})	24-33	≤ 4	4

[a] Bg= *Batrachospermum gelatinosum*, Bh= *B. helminthosum*, Sc= *Sirodotia suecica*.

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