A new species and expanded distributions of freshwater *Audouinella* (Acrochaetiaceae, Rhodophyta) from Central Mexico and south-eastern Brazil

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Eighteen collections of red-coloured *Audouinella* from Central Mexico and southeastern Brazil detected three species. The most common species, *A. eugenea*, is characterized by macroscopic thalli, the erect system consisting of filaments with cylindrical cells, undifferentiated into proximal and distal parts, and relatively large monosporangia ($\geqslant$ 12·0 μm long). Spermatangia and possible propagules were observed in some Mexican populations. This is the third *Audouinella* species observed to have gametangia and the first member of the Acrochaetiales with putative propagules. The second species, from Central Mexico, was characterized by the following features: macroscopic thalli, the erect system differentiated into proximal parts with cylindrical cells, unbranched or rarely branched, and distal parts with barrel-shaped cells, abundantly branched to form dense fascicles, with alternate or dichotomous branching, some at right-angles to the axis, and relatively large monosporangia ($\geqslant$ 12·0 μm long). The morphologically distinct proximal and distal portions of the erect system, the latter forming dense fascicles, was a consistent character so far unknown in *Audouinella*; thus, we propose a new species, *A. huastecana* sp. nov. The third species is a microscopic epiphyte, *A. meiospora*, with a well-developed prostrate system composed of creeping and loosely aggregated filaments, and a short homogeneous erect system ($\leqslant$ 15 cells) of filaments with cylindrical or barrel-shaped cells and small monosporangia ($\leqslant$ 13·0 μm long). *A. eugenea* and *A. meiospora* are characterized for the first time from the Southern and Northern Hemispheres, respectively, both occurring mostly in areas of tropical or subtropical rainforests. *A. meiospora* is reported from new macroalgal hosts. *A. eugenea* and *A. huastecana* tended to occur in warm, alkaline waters with a high ion content that were moderate to fast flowing, whereas *A. meiospora* was not associated with particular habitats.

Key words: Acrochaetiaceae, *Audouinella*, *Audouinella huastecana*, Brazil, Mexico, Rhodophyta, stream

Introduction

Freshwater members of *Audouinella* have recently been divided into two groups (Necchi *et al.*, 1993*a*, *b*; Necchi & Zucchi, 1995, 1997): the red-coloured and the bluish species. The reddish species are independent and capable of producing gametangia, carposporangia and tetrasporangia (Necchi *et al.*, 1993*a*; Necchi & Zucchi, 1995). The bluish representatives are commonly accepted as the alternate life-history phase of batrachospermalean taxa, called the 'Chantransia' stage, and typically have young gametophytes differentiating on some filaments (Necchi & Zucchi, 1997). However, neither sexual reproduction nor young gametophytes are often observed in freshwater acrochaetioid algae under natural conditions (Korch & Sheath, 1989; Necchi *et al.*, 1993*a*, *b*; Necchi & Zucchi, 1995, 1997). Four red-coloured species have been recognized in recent studies (Necchi *et al.*, 1993*a*; Necchi & Zucchi, 1995): *A. eugenea* (Skuja) Jao, *A. hermannii* (Roth) Duby, *A. meiospora* (Skuja) Garbary and *A. tenella* (Skuja) Papenfuss. Sexual reproductive structures or tetrasporangia have been reported in *A. hermannii* (Drew, 1935; Israelson, 1942; Reis, 1961; Starmach, 1985; Korch & Sheath, 1989; Compère, 1991; Necchi *et al.*, 1993*a*), *A. meiospora* (Skuja, 1944) and *A. tenella* (Necchi *et al.*, 1993*a*; Necchi & Zucchi, 1995) but not in *A. eugenea*.

The red-coloured *Audouinella* species have been poorly documented in Mexico. Sánchez-Rodriguez (1974) reported *A. hermannii* [as *A. violacea* (Kützing) Hamel] in a high mountain river. Necchi *et al.* (1993*a*) described morphometric and environmental characteristics of two Mexican populations

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of *A. eugenea*, and Montejano *et al.* (1999) listed this same species as a component of the stream algal flora of the region of La Huasteca. In Brazil, the genus has been more intensively studied. Necchi & Zucchi (1995) provided data on the distribution, morphology and habitat of *A. hermannii*, *A. meiospora* and *A. tenella*. Necchi *et al.* (1998) presented additional records for the distribution of *A. meiospora* from a tropical rainforest island and Necchi *et al.* (1999) listed *A. eugenea* from São Paulo State, including environmental data but without any morphological description.

The present investigation was carried out to evaluate the taxonomic characters, the environment of occurrence and the geographic distribution of red-coloured populations of *Audouinella*, along with previous reports from the central region of Mexico (La Huasteca) and southeastern Brazil (São Paulo State). The two regions are situated in similar latitudes in North and South Americas and have been surveyed using standardized sampling procedures, allowing comparisons.

Materials and methods

Eighteen red-coloured collections of freshwater *Audouinella* were analysed in this study. Eleven samples were collected from the region of La Huasteca, central Mexico (21–22 °N, 98–100 °W) from 51 sites with red algae (Carmona, 1997) at altitudes of 100–1000 m (Fig. 1). Seven samples were collected from São Paulo State, southeastern Brazil (22–25 °S, 45–51 °W) from 104 stream segments containing red algae (Necchi *et al.*, 1999) at altitudes of 40–740 m (Fig. 1). The sampling programs aimed to include the main biomes (basically rainforest and Cerrado 'Brazilian savanna' areas) and geological regions (hard-water areas, draining calcareous rocks) particularly in the best-preserved areas. Sites were visited at least once and were 10–40 km apart. Each sampling site consisted of a 10 m length reach in streams of different sizes (first to fifth order), which was thoroughly examined for the presence of macroscopic red algal representatives and abundance estimated in terms of percentage cover (Necchi *et al.*, 1999). At each site, one mixed algal sample was collected, including at least five specimens (tufts in the case of *Audouinella* species) of each visually recognizable macroalgal morphological type. Samples were fixed immediately after collection in 4% formaldehyde and included in the herbaria **FCME** and **SJRP** (Holmgren *et al.*, 1990; Holmgren & Holmgren, 1993). The following environmental variables were recorded for each sampling site (according to procedures described in Carmona, 1997 and Necchi *et al.*, 1999): temperature, specific conductance, current velocity, pH, depth and type of substratum.

We documented all morphological characters previously considered to be of taxonomic importance in this genus, and microscopic analyses followed the procedures described by Necchi *et al.* (1993*a*) and Necchi & Zucchi (1995). For the algae in populations 8–10, with differentiated proximal and distal parts, we described separately the characters from the axis and fascicles. From each sample, five plants were taken, from which observations were made and morphometric characters measured in replicates of 20. Student's *t*-test was applied to some data for monosporangia, spermatangia and vegetative cells. A key was constructed for all freshwater *Audouinella* species from the Americas, using data from Necchi *et al.* (1993*a*), Necchi & Zucchi (1995) and information from this study.

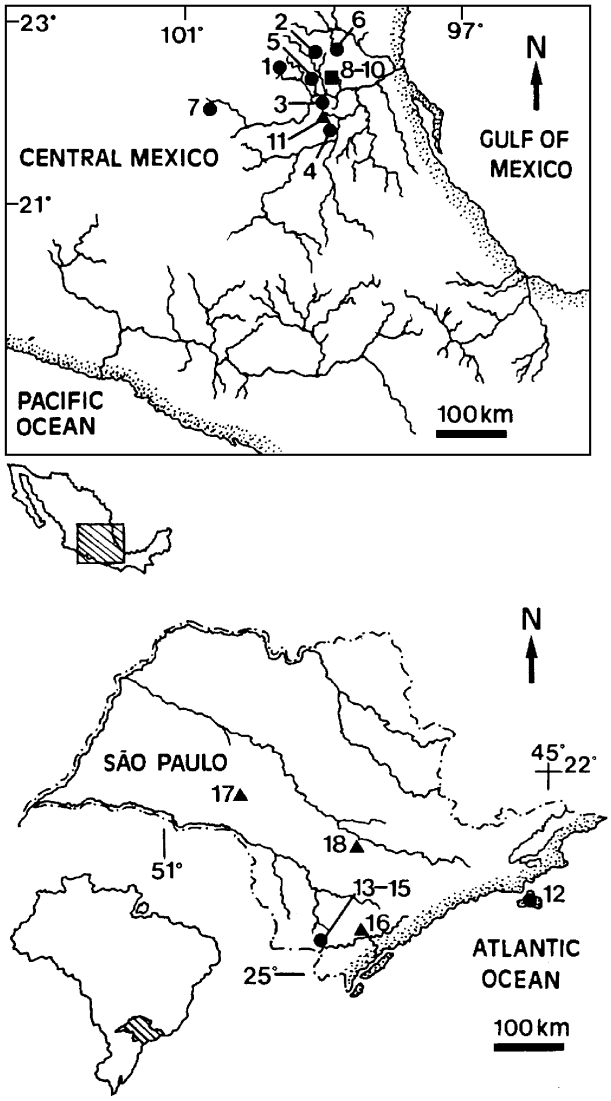


Fig. 1. Location of the study regions in Central Mexico (La Huasteca) and southeastern Brazil (São Paulo State) with indication of the sites with red-coloured populations of freshwater *Audouinella*: circles, *A. eugenea*; squares, *A. huastecana*; triangles, *A. meiospora*.

Results and discussion

Morphological analysis

Three distinct groups of red-coloured freshwater *Audouinella* collections were recognized from Central Mexico and southeastern Brazil (Table 1, Figs 1–15). The first group (Figs 2–7), of 11 samples

(seven from Central Mexico and four from southeastern Brazil), fits within the circumscription of *A. eugenea* as described by Skuja (1934) and Necchi *et al.* (1993*a*). It is characterized by macroscopic thalli, the erect system undifferentiated into proximal and distal parts, filaments with cylindrical cells and relatively large monosporangia ($\geqslant$ 12·0 μm long).

Two important morphological features were observed in some Mexican populations of *A. eugenea*. Branches contained fascicles with two or three hyaline, elliptical or obovoidal terminal spermatangia (Table 1, Figs 3–4). These characteristics agree with the general spermatangial arrangement for the Acrochaetiaceae described by Woelkerling (1983). Interestingly, we found no structures that could unequivocally be described as carpogonia. This is only the third freshwater species of *Audouinella* reported with gametangia and it supports the contention that this entity is not a 'Chantransia' stage. Spermatangia were significantly smaller ($p < 0{\cdot}001$) than the monosporangia from the same populations (Table 1). On the other hand, they were considerably larger than those reported for another freshwater species, *A. hermannii* (2·8–6·0 μm in diameter, as summarized by Necchi *et al.*, 1993*a*).

The second novelty was the presence of possible propagules (Table 1, Figs 3, 5–7). They are pear- to club-shaped or irregular in shape, and consist of one to three cells with thickened cell walls and granulated and vacuolated cytoplasm. They are formed in mid-cells of filaments or less often terminally, from vegetative cells which undergo a special division resulting in the complete development of the propagule. Propagules have been described in the Gigartinales and Ceramiales (Guiry, 1990) and the Batrachospermales (Sheath & Whittick, 1995) but this is the first report for the Acrochaetiales. The occurrence of structures resembling propagules suggests that they possibly represent an alternative mode of vegetative reproduction, which might be important to population maintenance in stream habitats, but we have not observed germination, and further cytological studies are necessary to clarify development and function.

The second group, of three collections from Central Mexico (Table 1, Figs 8–13), is characterized as follows: thalli macroscopic, the erect system differentiated into proximal and distal parts, the proximal with cylindrical cells, unbranched or rarely branched, the distal with barrel-shaped cells, abundantly branched to form dense fascicles, with alternate or dichotomous branches, some at right-angles to the axis, and relatively large monosporangia ($\geqslant$ 12·0 μm long). Cells of proximal and distal parts were significantly ($p < 0{\cdot}001$) different. The presence of proximal and distal portions in the erect system, the latter forming dense fascicles, was a consistent character so far unknown in *Audouinella*. We considered it of sufficient taxonomic importance to propose a new species. '*In situ*' monospore germination was often observed in this species (Figs 12–13). The occurrence of '*in situ*' monospore germination has not been reported in Acrochaetiaceae and seems to represent a reproductive strategy to enhance the probability of new filament growth, which is particularly important for survival under the high current velocities ($\geqslant$ 90 cm s^{-1}) in the species' habitat.

The third group (of one Mexican and three Brazilian collections; Table 1, Figs 14–15) is characterized by microscopic thalli, with a well-developed prostrate system composed of creeping and loosely aggregated filaments, and a short erect system, of up to 15 cells, undifferentiated into proximal and distal parts, filaments with cylindrical or barrel-shaped cells, branch angles $< 25°$ and small monosporangia ($\leqslant$ 13·0 μm long). The characters for these populations agree with the descriptions of *A. meiospora* by Skuja (1944) and Necchi & Zucchi (1995). The species was also observed on hosts other than those previously reported (Table 2): *Blennothrix ganeshii* (Cyanophyta), *Compsopogon coeruleus* (Rhodophyta) and *Vaucheria* spp. (Xanthophyta).

Descriptions and taxonomic proposals

Audouinella eugenea (Skuja) Jao, *Sinensia*, **10**: 362, 1941 (Basionym: *Chantransia eugenea* Skuja, *Beih. Bot. Cbl.*, **52**: 177, 1934). Figs 2–7

Plants macroscopic, up to 10 mm high, and consisting of > 50 cells, red-coloured; basal system composed of an irregular prostrate mass with aggregated filaments; erect system with no differentiation into proximal and distal parts, composed of filaments with cylindrical vegetative cells, 11·5–60·0 μm long, 7·5–16·0 μm in diameter; branch angles $\leqslant 25°$; chloroplast reticulate, covering most of the cell volume; monosporangia arranged in fascicles, obovoidal to subspherical, 12·0–18·0 μm long, 7·5–18·0 μm in diameter. Spermatangia 2 or 3 per branch, elliptical to obovoidal, hyaline, 8·0–12·0 μm long, 6·0–12·0 μm in diameter. Putative propagules consisting of 1–3 cells, pear- to club-shaped or irregular, 22·0–48·0 μm long, 16·0–38·0 μm in diameter. Carpogonia, carposporangia and tetrasporangia not observed.

Specimens examined: Mexico: (1) San Luis Potosí, Tamasopo, Puente de Dios, coll. G. Montejano, 17.i.1984 (**FCME** PA1799); (2) Ciudad Valles, Micos, coll. G. Montejano, 26.iii.1987 (**FCME** PA2693); (3) Puente de Dios II, coll. J. Carmona, 8.ix.1989 (**FCME** PA3154); (4)

Table 1. Characteristics of freshwater red-coloured populations of *Audouinella* from Central Mexico and south-eastern Brazil

Populations	Plant length (mm)	Basal system	Branch angle (degrees)	Vegetative cell		Fascicle cell		Monosporangia		Spermatangia		Propagules?	
				Length	Diameter	Length	Diameter	Length	Diameter	Length	Diameter	Length	Diameter
Mexican populations													
Audouinella eugenea													
1. PA1799	2	IP	< 25	28·1–52·0	11·3–17·6	–	–	13·3–22·6	7·5–15·3	–	–	–	–
Puente de Dios				39·2 ± 4·8	13·9 ± 1·4			17·0 ± 1·8	11·9 ± 2·1				
2. PA2693	10	IP	⩽ 25	11·5–45·9	7·5–14·8	–	–	12·0–28·0	10·0–20·0	8·0–12·0	6·0–12·0	22·0–44·0	16·0–38·0
Micos				27·8 ± 10·7	9·8 ± 1·6			17·6 ± 4·8	13·6 ± 3·39	10·1 ± 1·7	8·9 ± 1·9	31·7 ± 4·9	22·6 ± 6·31
3. PA3154	2	IP	⩽ 25	24·1–60·1	9·3–18·0	–	–	13·5–24·8	9·7–18·0	–	–	26·0–48·0	18·0–30·0
Puente de Dios II				44·8 ± 9·6	13·0 ± 2·2			19·1 ± 1·9	15·1 ± 1·7			33·5 ± 6·1	23·9 ± 3·3
4. PA3215	1	IP	< 25	13·0–36·0	7·5–15·2	–	–	14·5–24·2	7·9–16·6	–	–	–	–
Tancuilín				22·7 ± 5·4	11·2 ± 2·0			19·9 ± 2·6	14·0 ± 2·2				
5. PA3356	3	IP	< 25	16·0–46·0	8·0–13·0	–	–	14·0–18·0	8·0–12·0	8·0–12·0	6·0–12·0	22·0–36·0	18·0–22·0
Santa Anita				29·1 ± 7·6	10·1 ± 1·3			16·6 ± 1·9	10·8 ± 1·3	10·8 ± 1·3	8·5 ± 1·8	29·0 ± 5·0	19·5 ± 1·6
6. PA3435	1	IP	< 25	15·0–55·0	7·3–11·5	–	–	16·0–26·0	10·0–16·0	–	–	–	–
Nacimiento del Mante				35·6 ± 14·2	7·4 ± 3·3			19·7 ± 3·2	11·9 ± 1·6				
7. PA3490	1	IP	< 25	9·5–34·6	8·4–12·4	–	–	13·0–20·0	7·5–11·2	–	–	–	–
La Media Luna				16·6 ± 3·4	9·2 ± 1·6			17·0 ± 2·4	10·8 ± 0·6				
Audouinella huastecana													
8. PA3163	5	IP	⩽ 25	20·0–28·0	10·0–16·0	6·0–16·0	6·0–12·0	12·0–16·0	10·0–14·0	–	–	–	–
Choy A				23·7 ± 2·9	12·8 ± 1·8	8·8 ± 2·9	8·6 ± 2·1	14·0 ± 1·6	12·6 ± 1·8				
9. PA3261	5	IP	⩽ 25	16·0–28·0	10·0–12·0	6·0–14·0	6·0–10·0	12·0–20·0	10·0–14·0	–	–	–	–
Choy B				22·4 ± 3·2	10·7 ± 0·9	8·0 ± 2·3	7·0 ± 1·5	17·1 ± 2·8	12·1 ± 1·5				
10. PA3584	7	IP	⩽ 25	18·0–36·0	10·0–16·0	7·0–20·0	6·0–10·0	12·0–22·0	8·0–14·0	–	–	–	–
Choy C				26·6 ± 5·1	11·5 ± 1·9	10·5 ± 4·3	7·8 ± 1·0	16·0 ± 2·9	11·0 ± 2·0				
Audouinella meiospora													
11. PA3622	100 µm	CF	< 25	8·0–16·0	6·0–11·0	–	–	8·0–13·0	7·0–11·0	–	–	–	–
Tampaque				11·2 ± 2·2	8·8 ± 1·1			10·7 ± 1·4	8·8 ± 1·1				

Brazilian populations													
Audouinella eugenea													
12. MA20	1	IP	< 25	27·5–40·0	10·0–12·5	–	–	12·5–17·0	8·0–10·0	–	–	–	–
Ilhabela				33·5 ± 4·3	10·8 ± 0·9			14·7 ± 2·2	9·0 ± 1·0				
13. SP12	1	IP	< 25	34·0–52·0	12·0–15·0	–	–	14·0–21·0	12·0–16·0	–	–	–	–
Apiaí (km 15)				43·1 ± 5·1	13·1 ± 0·9			17·1 ± 1·8	13·0 ± 1·0				
14. SP13	1	IP	< 25	19·0–34·0	11·0–16·0	–	–	14·0–16·0	12·0–14·0	–	–	–	–
Apiaí (km 30)				24·2 ± 4·1	14·2 ± 1·4			15·2 ± 0·97	12·8 ± 0·7				
15. SP14	1	IP	< 25	32·0–51·0	12·0–16·0	–	–	17·0–20·0	10·0–14·0	–	–	–	–
River Betari				41·5 ± 4·8	13·9 ± 1·3			18·8 ± 1·2	12·7 ± 1·4				
Audouinella meiospora													
16. SP20	375 µm	CF	< 25	12·0–13·0	8·0–10·0	–	–	–	–	–	–	–	–
Juquiá				11·3 ± 2·1	9·1 ± 1·0								
17. SP49	100 µm	CF	< 25	9·5–18·0	7·0–10·0	–	–	–	–	–	–	–	–
Echaporã				13·6 ± 3·0	8·1 ± 0·8								
18. SP72	100 µm	CF	< 25	12·0–18·0	8·0–12·0	–	–	13·0	8·0	–	–	–	–
Conchas				15·1 ± 2·1	9·7 ± 1·5								

Measurements are in micrometres (unless otherwise specified) and represent range, mean and standard deviation.
CF, creeping filaments; IP, irregular prostrate mass.

Tamazunchale, Tancuilín, coll. J. Carmona, 5.xi.1990 (**FCME** PA3215); (5) Aquismón, Santa Anita, coll. G. Montejano, 20.ii.1992 (**FCME** PA3356); (6) Rio Verde, La Media Luna, coll. C. Candelaria, 23.v.1993 (**FCME** PA3490); (7) Tamaulipas, Ciudad Mante, nacimiento del Mante, coll. J. Carmona, 27.v.1993 (**FCME** PA3435). BRAZIL: (12) Ilhabela, Ilha de São Sebastião, road towards north, Ponta das Canoas, coll. O. Necchi Jr and C.C.Z. Branco, 21.viii.1993 (**SJRP** MA22); (13) Apiaí, Route SP-165, 15 km from the town, coll. O. Necchi Jr and C.C.Z. Branco, 9.x.1996 (**SJRP** SP12); (14) Iporanga, Route SP-165, 30 km from Apiaí, coll. O. Necchi Jr and C.C.Z. Branco, 9.x.1996 (**SJRP** SP13); (15) Iporanga, Route SP-165, 5 km from the town, Betari River, coll. O. Necchi Jr and C.C.Z. Branco, 9.x.1996 (**SJRP** SP14).

Audouinella huastecana Carmona *et* Necchi, sp. nov. Figs 8–13

DIAGNOSIS: Frons heterotricha, macroscopica, ad 7 mm alta. Partes proximales et distales systematis erecti dissimiles; fila proximalia cellulis cylindraceis, non vel raro ramosa; fila distalia cellulis doliiformibus, abundanter ramosa fasciculos densos facientesque; rami alternati dichotomive, interdum ab axe ad angulum 90° divergentes.

Monosporangia elliptica vel obovoidea, in filis distalibus terminalia, solitaria, 12·0–22·0 µm longa, 10·0–14·0 µm diametro.

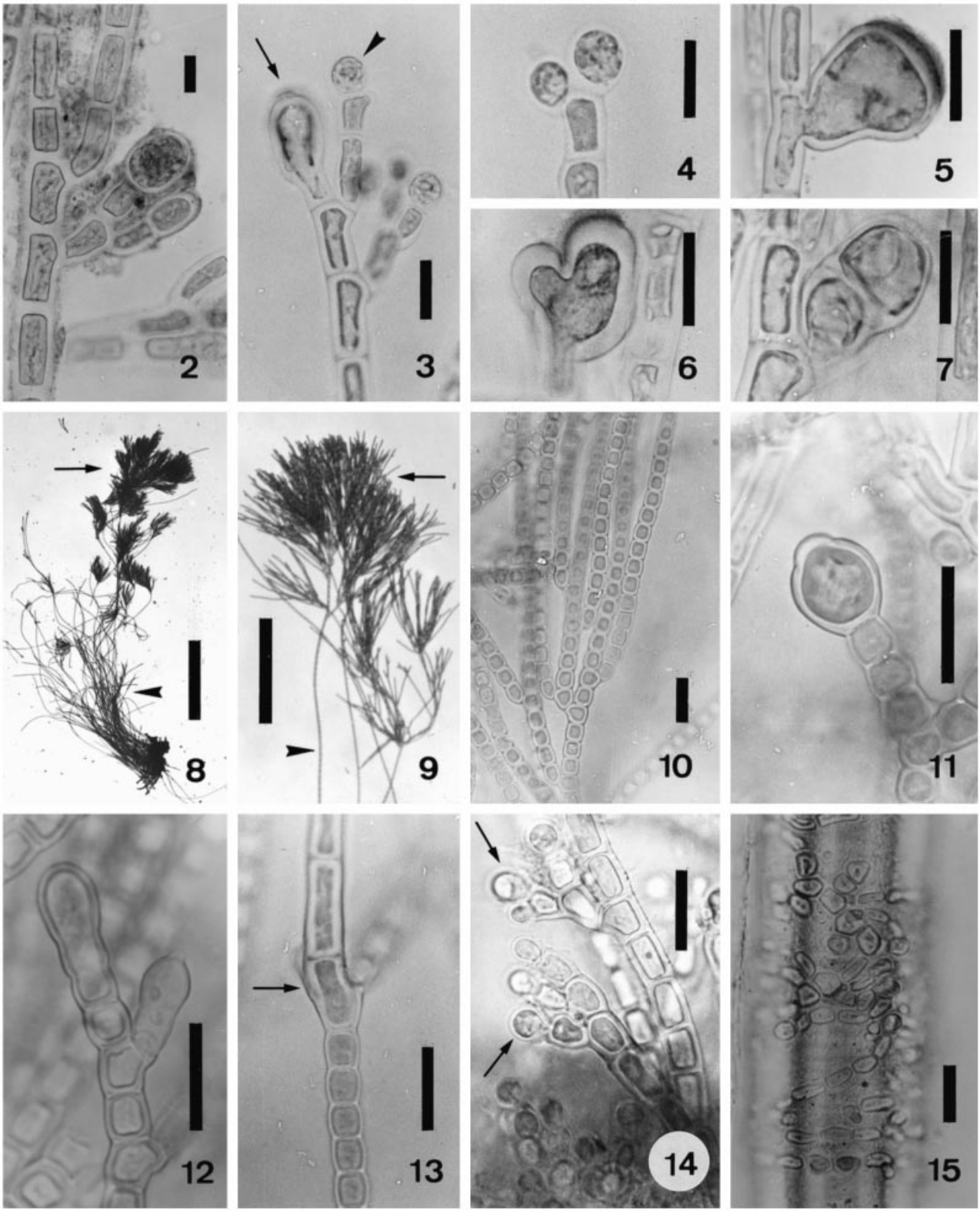
Plants macroscopic, up to 7 mm high, and consisting of > 50 cells, red-coloured; basal system composed of an irregular prostrate mass with aggregated filaments; erect system differentiated into proximal and distal parts; proximal filaments with cylindrical vegetative cells, 16·0–36 µm long, 10·0–16·0 µm in diameter, unbranched or rarely branched; distal filaments with barrel-shaped cells 6·0–20 µm long, 6·0–12·0 µm in diameter, abundantly branched to form dense fascicles; branches alternate or dichotomous, some at right-angles to the axis; chloroplast reticulate, covering most of the cell volume; monosporangia elliptical or obovoidal, 12·0–22·0 µm long, terminal on distal filaments, single, 10·0–14·0 µm in diameter. Gametangia, carposporangia and tetrasporangia not observed.

HOLOTYPE: (8) coll. J. Carmona and G. Montejano, 9.ix.1989 (**FCME** PA3261).

TYPE LOCALITY: MEXICO: San Luis Potosí, Ciudad Valles, Choy.

ETYMOLOGY: The specific epithet is based on the pre-Hispanic culture called 'Huasteca' of the people inhabiting the region where the type locality is located.

ADDITIONAL SPECIMENS EXAMINED, FROM SAME LOCALITY: (9) coll. J. Carmona and G. Montejano,



Figs 2–15. Morphological features of red-coloured freshwater species of *Audouinella*. Figs 2–7. *A. eugenea*. Fig. 2. Filament with a monosporangium (**FCME** PA3215). Fig. 3. Initial apparent propagule (arrow) and spermatangia (arrowhead) (**FCME** PA2693). Fig. 4. Detail of spermatangia (**FCME** PA2693). Figs 5–7. Details of possible propagules (**FCME** PA2693). Fig. 5. Pear-shaped propagule. Fig. 6. Irregular-shaped propagule. Fig. 7. Two-celled propagule. Figs 8–13. *A. huastecana*. Fig. 8. General view showing dense fascicles in distal parts (arrow) and unbranched proximal parts (arrowhead) (**FCME** PA3584). Fig. 9. Detail of an erect branch showing a dense fascicle (arrow) and an unbranched proximal part (arrowhead). Fig. 10. Detail of distal filaments from a fascicle (**FCME** PA3261). Fig. 11. Detail of a monosporangium (**FCME** PA3261). Figs 12–13. '*In situ*' monospore germination (**FCME** PA3261). Fig. 12. Initial stage. Fig. 13. Germinating filament with rest of monosporangium cell wall (arrow). Figs 14–15. *A. meiospora* (**FCME** PA3622). Fig. 14. Erect filaments with monosporangia (arrows). Fig. 15. Creeping filaments developing epiphytically around a filament of *Blennothrix ganeshii*. Scale bars represent: Figs 1, 8, 1 cm; Fig. 9, 5 mm; Figs 2, 5–7, 10–15, 20 μm; Figs 3–4, 10 μm.

1.v.1991 (**FCME** PA3261); (10) coll. J. Carmona, 7.vii.1995 (**FCME** PA3584).

Audouinella meiospora (Skuja) Garbary, *Bibl. Phycol.*, **77**: 112, 1987 (Basionym: *Balbiania meiospora* Skuja, *Acta Hort. Bot. Univ. Latv.*, **14**: 10, 1944). Figs 14–15

Plants microscopic, up to 400 μm high, and consisting of ⩽ 15 cells, red-coloured; basal system well developed, composed of creeping and loosely aggregated filaments with cylindrical or barrel-shaped cells, 5·0–18·0 μm long, 4·0–10·0 μm in diameter; erect system composed of filaments with barrel-shaped to cylindrical vegetative cells, 8·0–18·0 μm long, 6·0–12·0 μm in diameter; branch angles $< 25°$; chloroplast reticulate, filling most of the cell volume; monosporangia obovoidal to spherical, 8·0–13·0 μm long, 7·0–11·0 μm in diameter. Gametangia, carposporangia and tetrasporangia not observed.

Specimens examined: Mexico: (11) San Luis Potosí, Aquismón, Tampaque, coll. G. Montejano, 25.xi.1995 (**FCME** PA3622). Brazil: (16) Juquiá, Route to Sete Barras, coll. O. Necchi Jr and C.C.Z. Branco, 11.x.1996 (**SJRP** SP20); (17) Echaporã, Faz Rancho dos Ipês, Route SP-333, coll. O. Necchi Jr *et al.*, 16.vii.1997 (**SJRP** SP49); (18) Conchas, Ribeirão Muquém, 2 km from Route SP-300, coll. O. Necchi Jr *et al.*, 18.ix.1997 (**SJRP** SP72).

Remarks: This species was originally described within the genus *Balbiania*, whose type species [*B. investiens* (Lenormand) Sirodot] was recently transferred to the new order Balbianiales (Sheath & Müller, 1999). The major distinguishing morphological feature of the genus *Balbiania* is the production of spermatangia on the tips of specialized, elongate cells, which are cut off in a cluster. In contrast, the spermatangia of *A. meiospora* are produced terminally on unspecialized filaments, singly or in pairs (Skuja, 1944) and, thus, it should be kept in *Audouinella* as proposed by Garbary (1987).

Key to freshwater species of Audouinella *from the Americas*

1. Plants microscopic (⩽ 400 μm high, ⩽ 30 cells long), with a well-developed basal system composed of creeping filaments *A. meiospora*
1. Plants macroscopic (⩾ 1 mm high, $<$ 50 cells long), with basal system composed of an irregular prostrate mass with aggregated filaments 2
2. Erect system differentiated into proximal and distal parts; proximal part with cylindrical cells, unbranched or rarely branched; distal part with barrel-shaped cells, profusely branched and forming dense fascicles *A. huastecana*
2. Erect system undifferentiated into proximal and distal parts, composed exclusively of cylindrical cells 3
3. Mean diameter of vegetative cells $<$ 6·0 μm *A. tenella*
3. Mean diameter of vegetative cells $>$ 7·0 μm 4
4. Mean diameter of monosporangia $>$ 12·0 μm *A. eugenea*
4. Mean diameter of monosporangia $<$ 12·0 μm *A. hermannii*

Distribution

This is one of the first unequivocal records of *Audouinella eugenea* in the Southern Hemisphere, following that of Necchi *et al.* (1999). Although Cribb (1965) reported its occurrence in a semi-marine cavern from Queensland, Australia, that description and habitat are in disagreement with previous records. *A. meiospora* is reported for the first time from the Northern Hemisphere. On the basis of these new findings one may suspect that the two species have a much wider geographical distribution than the original records suggested. However, they are not so widely distributed as *A. hermannii* in temperate to boreal regions in the Northern Hemisphere (Israelson, 1942; Necchi *et al.*, 1993*a*). The regions from which they were collected and previously reported (Skuja, 1934, 1944; Jao, 1941; Necchi *et al.*, 1993*a*; Necchi & Zucchi, 1995) consist of tropical to subtropical rainforests. The occurrence of *A. meiospora* on hosts other than Rhodophyta suggests it may be more widespread than existing records indicate. The species of *Audouinella* occurred together with a variety of other stream algae, with no clear association (Table 2).

In terms of environmental characteristics (Table 2), *A. eugenea* and *A. huastecana* tended to occur in warm, alkaline waters with a high ion content that were moderate to fast-flowing: temperature 16·3–29·0 °C, specific conductance 128–1,357 μS cm^{-1}, pH 7·0–8·5 and current velocity 27–130 cm s^{-1}. These data are similar to those reported for *A. eugenea* environments in North America by Necchi *et al.* (1993*a*). Most streams and rivers containing populations of *A. eugenea* in Central Mexico and southeastern Brazil had rocky substrata (bedrock or boulders) and were shaded or heavily shaded. It occurred in shallow streams (typically $<$ 50 cm in depth), but in two sites it was collected in much deeper habitats (3–12 m). *A. huastecana* was collected exclusively on the bedrock of a spring with fast-flowing waters emerging from a cave. On the other hand, the records for *A. meiospora* revealed no clear trend for environmental occurrence, and its distribution seems to be more closely related to the presence of suitable hosts than to water quality.

Table 2. Physical and chemical characteristics of streams containing freshwater red-coloured populations of *Audouinella* in Central Mexico and south-eastern Brazil

Sampling site no.	Temperature (°C)	Specific conductance (μS cm^{-1})	Shading[a]	Current velocity (cm s^{-1})	pH	Depth (cm)	Substratum[b]	Associated species	% cover
Mexican streams									
Audouinella eugenea									
1. PA1799, Puente de Dios	25·0	–	D	–	–	10	1	*Cladophora glomerata* (Linnaeus) Kützing, *Oedogonium* sp.	10
2. PA2693, Micos	25·0	900	C	35	7·0	6	1	*Cladophora* sp., *Oscillatoria* spp., *Lyngbya* spp.	20
3. PA3154, Puente de Dios II	27·0	900	B	50	7·2	30	2	*Cladophora* sp., *Lyngbya* spp.	10
4. PA3215, Tancuilín	25·0	455	C	35	7·5	5	1	*Cladophora* sp.	10
5. PA3356, Santa Anita	23·0	1,237	B	35	7·5	40	2	*Sirodotia huillensis* (West *et* West) Skuja, *Thorea violacea* Bory, *Hildenbrandia angolensis* West *et* West	5
6. PA3435, Nacimiento del Mante	26·8	1,367	C	60	7·0	300	1	*Spirogyra* sp., *Phormidium* sp.	15
7. PA3490, La Media Luna	29·0	–	B	35	7·5	1,200	3	*Chamaesiphon confervicola* Rabenhorst, *Lyngbya* spp.	5
Audouinella huastecana									
8. PA3163, Choy A	26·0	900	D	130	7·6	50	1	*Audouinella pygmaea* (Kützing) Weber-van Bosse, *Hyella fontana* Huber *et* Jardin, *H. angolensis*	25
9. PA3261, Choy B	27·0	1,128	D	120	7·2	55	1	*A. pygmaea*, *H. angolensis*, *H. fontana*	25
10. PA3584, Choy C	26·0	1,100	D	90	7·0	20	1	*A. pygmaea*, *H. angolensis*, *H. fontana*	30
Audouinella meiospora									
11. PA3622, Tampaque	24·0	400	C	35	7·5	5	1	*Blennothrix ganeshii* Watanabe *et* Komárek (basiphyte)	–

Brazilian streams									
Audouinella eugenea									
12. MA20, Ilhabela	17·3	128·6	D	27	8·0	7	2	*Pleurocapsa fluviatilis* Langerheim, *Pleurosira laevis* (Ehrenberg) Compère	
13. SP12, Apiaí (km 15)	16·3	168	D	54	8·2	19	2	*Microcoleus subtorulosus* Gomont, *Phormidium aerugineo-caeruleum* (Gomont) Anagnostidis *et* Komárek	< 1
14. SP13, Apiaí (km 30)	18·7	286	B	65	8·0	30	2	*Phormidium cebennense* Gomont, *Vaucheria* sp.	15
15. SP14, River Betari	19·7	218	C	108	8·6	26	2	*Lyngbya subconfervoides* Borge, *M. subtorulosus*, *Melosira lineata* (Dillwyn) C. Agardh	< 1
Audouinella meiospora									
16. SP20, Juquiá	20·9	65	B	58·5	7·0	11	3	*Compsopogon leptocladus* Montagne (basiphyte), *Spirogyra* sp.	–
17. SP49, Echaporã	22·6	80	C	42	7·5	9	2	*Compsopogon coeruleus* (C. Agardh) Montagne (basiphyte), *Vaucheria* sp. (basiphyte), *Phormidium* cf. *retzii* (C. Agardh) Gomont, *Rhizoclonium hieroglyphicum* (C. Agardh) Kützing	–
18. SP72, Conchas	17·6	435	C	33	7·8	14	2	*C. coeruleus* (basiphyte), *Thorea violacea*, *Batrachospermum vogesiacum* Skuja, *Vaucheria bursata* (Müller) C. Agardh (basiphyte)	–

[a] A, open; B, partly shaded; C, shaded; D, heavily shaded.
[b] 1, predominantly bedrock; 2, predominantly boulder; 3, predominantly fallen tree trunks.

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