

SOME CHAROPHYTES (CHARALES) FROM PAKISTAN

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The present work gives a review of some charophytes collected in Pakistan in the period 1996–99. A total of 17 species are reported. This article presents a short description of each species found, observed variation and biology, some ecological information, and the known distribution of these species in Pakistan. Species new to Pakistan are: *Chara connivens*, *C. gymnophylla*, *C. flaccida*, *Nitella confervacea*, *N. dictyosperma*, and *Nitellopsis obtusa*.

Key words: charophytes, freshwater algae, *Chara*, *Lamprothamnium*, *Nitella*, *Nitellopsis*, Pakistan

INTRODUCTION

The charophyte flora of Pakistan has only been investigated to a limited extent. GROVES (1923) reported 5 species from the area which is Pakistan today. One of these species, *Chara infirma* A. Braun was not accepted by FARIDI (1955). FARIDI (1955) added nine more species and later he (FARIDI 1956) described a new species, *Nitella pakistanica* Faridi from the area. PAL *et al.* (1962) reported three more species from Pakistan (West Pakistan).

The species reported by the above three authors include: *Chara braunii* Gmelin, *C. canescens* Desv. et Lois. in Lois., *C. contraria* A. Braun ex Kützing, *C. corallina* Klein ex Willd., *C. globularis* Thuill., *C. setosa* Klein ex Willd. (= *C. brachypus* A. Braun), *C. vulgaris* L., *C. virgata* Kützing (= *C. delicatula* Agardh), *C. wallichii* A. Braun, *C. zeylanica* Klein ex Willd., *Lamprothamnium succinctum* (A. Braun) R. D. Wood, *Nitella hyalina* (DC.) Agardh, *N. mucronata* (A. Braun) Miquel, *N. oligospira* A. Braun, *N. pakistanica* Faridi, *Tolypella prolifera* (Ziz ex A. Braun) Leonh. and *T. glomerata* (Desv. in Lois.) Leonh.

Two later works on charophytes from Pakistan, SARIM (1991), and AISHA and SHAMEEL (1995) are not accepted here. SARIM (1991) reported *Tolypella intricata* Leonh. from Lahore, *Nitella batrachosperma* A. Braun from Mardan, *Chara nuda* Pal from Peshawar, *C. gymnopytis* A. Braun from Hyderabad, *C. elegans* Robinson from Chitral, *C. excelsa* T. F. Allen from Quetta, *C. schweinitzii* A. Braun from Peshawar and *C. sejunta* A. Braun from Mardan. However, since the descriptions and illustrations accompanying these reports are mere copies of descriptions and illustrations in PRESCOTT (1951) or in PAL *et al.* (1962) we cannot have any confidence that these taxa actually occur in Pakistan and we prefer not to

take these reports into account. On the other hand, AISHA and SHAMEEL (1995) reported on the occurrence, in Gajar village, Baluchistan, of two forms (sensu WOOD 1965) of *Chara vulgaris*: *C. vulgaris* f. *atrovirens* (Lowe) H. et J. Groves and *C. vulgaris* f. *calveraensis* R. D. Wood, but their descriptions fail to mention or even contradict the diagnostic characters of these taxa (dark green unincrusted plants with swollen bract-cells for f. *atrovirens*, plant with irregular stipulodes, elongate to 1600 μm long for f. *calveraensis*); therefore it is clear that the Pakistani specimens cannot belong to the cited forms, but the poor quality of the illustrations does not allow a precise identification; here also it is not possible to take these reports into account.

The investigated areas

The areas investigated are from Sindh province in South Pakistan where most of the collections were made, around Quetta in Baluchistan, Lahore in Punjab and an area around Peshawar in Northwest Frontier province in North Pakistan.

We have also added one specimen deposited in the Botanical Museum, Bergen, Norway (BG). We believe that many specimens of Pakistani charophytes can be found in different herbaria around the world, but we have not yet examined this.

Figure 1 shows the land forms and occurrence of water in Pakistan. The best conditions for charophytes are found in the eastern parts of the country, the foothill area and agriculture land as marked on the figure. The same areas are in intensive agriculture use and artificially irrigated and thus subject to human influences with consequences for the occurrence and distribution of charophytes in Pakistan.

The field work was done by S. M. Leghari in the years 1996–1999. Species have been determined by A. Langangen. Liquid material of the studied species is deposited in the Botanical Museum, University of Oslo, Oslo, Norway (O). Duplicates of all species (except *Chara gymnophylla*) and specimens from most of the localities are deposited in the Hungarian Natural History Museum, Budapest, Hungary (BP).

OBSERVATIONS

Our knowledge of the charophyte flora of Pakistan is still incomplete and based on sources given above. The species found in this investigation are:

Nitella dictyosperma H. et J. Groves

Locality (1): Prov. Sindh: Sanghar, on the bank of Nara canal near Bakar lake, 4.9.1998.

References to Pakistan: None.

General: *Nitella dictyosperma* is closely related to *N. mucronata* (A. Braun) Miquel, *N. oligospira* A. Braun and *N. pakistanica* Faridi, but separated mainly by

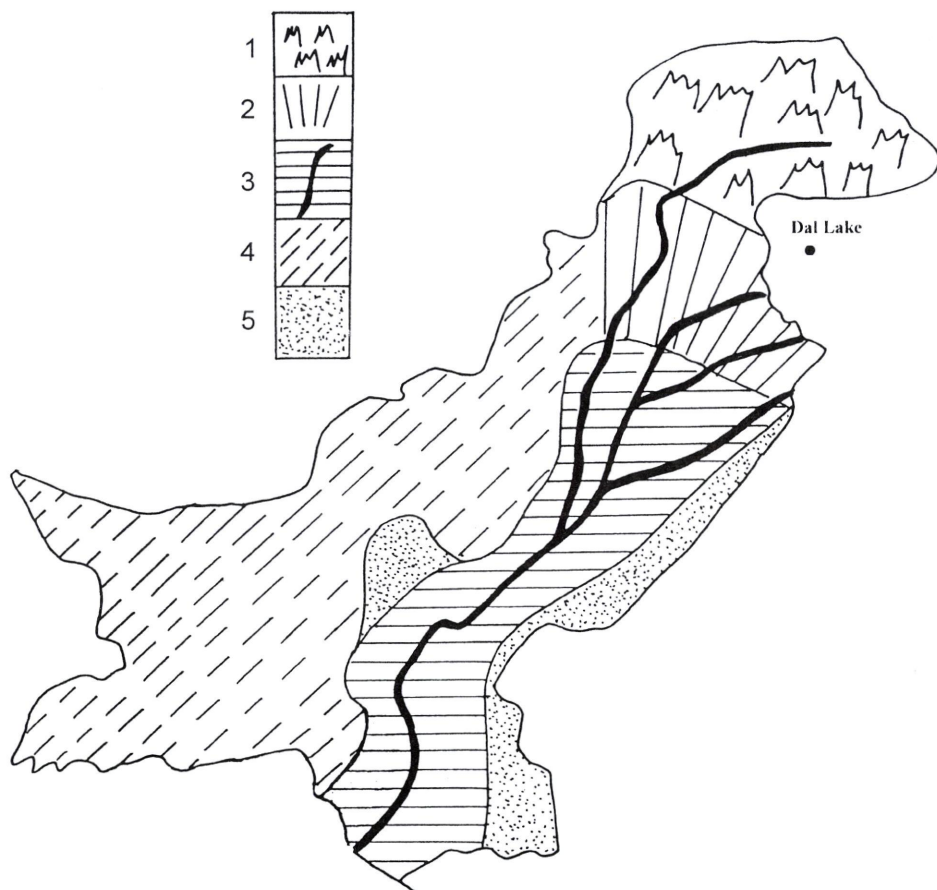


Fig. 1. Land forms and distribution of water in Pakistan. The occurrence of charophytes is strongly correlated to these factors. Dal lake in Kashmir is marked. Dal lake has a very rich flora of charophytes. (Drawing by Werner Krause, Germany, 1999). Legends: 1 = high mountains, much water in lakes and rivers; 2 = foothill area with water in abundance. Good conditions for charophytes; 3 = agriculture land, natural and artificial water courses. Optimal conditions for charophytes; 4 = dry highland with few water courses. Calcareous springs; 5 = desert.

having uniformly 2-celled rays. According to WOOD (1965) the two species, *N. oligospira* and *N. dictyosperma*, differ from *N. mucronata* by having solitary oogonia. *Nitella oligospira* has according to ZANEVELD (1940) abbreviated dactyls, which *N. dictyosperma* does not have. These characters have been used for determination here. The value of these characters as distinctive for species can be discussed. This is also stressed by WOOD (1965).

Comments on studied plants: Specimens monoecious with solitary oogonia. Three secondary rays, and all rays uniformly 2-celled. No abbreviated dactyls observed.

Ecology: In freshwater (with *Typha domingensis*).

Distribution: Originally described from Antigua in the West Indies (GROVES and GROVES 1898) and later found in a few other localities in North and South America (WOOD 1965), and in Burma (PAL 1931). Recently the species has also been found scattered through India (PATEL and JAWALE 1981), and in Bangladesh (ISLAM and SARMA 1976). The most interesting findings are from Gujarat province in India (PATEL and JAWALE 1981) on the border with Sindh province in Pakistan. The species has also been reported from China (LU 1987), but judged from his drawings which show specimens with many abbreviated dactyls, this is more probably *N. oligospira*. The locality of *N. dictyosperma* is shown in Figure 2.

Note: The closely related species, *Nitella mucronata* and *N. oligospira*, have been found scattered through the Indian subcontinent (PAL *et al.* 1962). In Pakistan both species have been found in the Lahore area. *Nitella pakistanica* which originally was described as dioecious, is according to WOOD and IMAHORI (1965) monoecious and is therefore presumably synonymous with *N. mucronata*. *Nitella pakistanica* is only reported from two localities in Lahore (WOOD 1965).

An evaluation of the determinations and occurrence of these four related species in Pakistan is necessary.

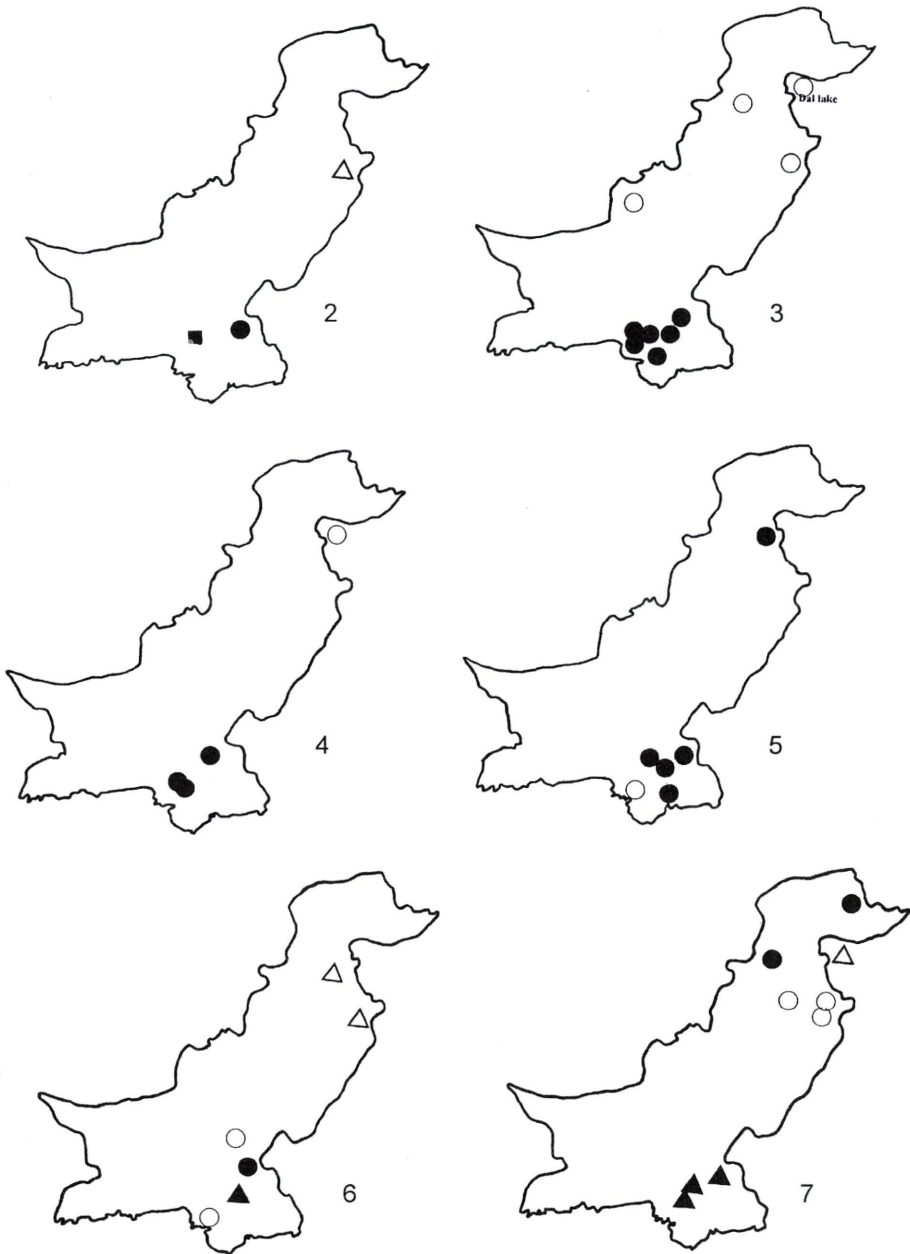
Nitella confervacea (Bréb.) A. Braun

Locality (1): Prov. Sindh: Dadu, Rani Kot springs, 8.4.1999.

References to Pakistan: None.

General: Plants small, to 5 cm high. Dactyls 3–5, uniformly 2-celled. Monoecious. Gametangia at all fertile branchlet nodes. Oospore with granulate membrane.

Comments on studied plants: Plants to 5 cm high, with stem diameter 0.25 mm. 5–6 branchlets in each whorl, 1–2 furcate. Dactyls 4, 2-celled. End-cell short, tapering to mucronate. Gametangia solitary, at first and second branchlet nodium,



Figs 2–7. 2 = *Nitella dictyosperma* ●, *N. confervacea* ■ and other species (*N. mucronata*, *N. oligospora*, *N. pakistanica*) △; 3 = *N. hyalina*; 4 = *Nitellopsis obtusa*; 5 = *Lamprothamnium succinctum*; 6 = *Chara corallina* ●○, *C. wallichii* ▲△; 7 = *C. braunii* ●○, *C. flaccida* ▲△. (Filled symbols: our own findings; open symbols: literature records.)

monoecious, without mucus. Oospore brown, 0.2 mm long, 0.15 mm wide, with 7 ridges, granulated to punctated membrane, with fossae 0.0375 mm broad.

Distribution: *N. confervacea* is found in India (DIXIT 1942, PAL *et al.* 1962). Distribution in Pakistan is shown in Figure 2.

Note: WOOD (1965) is uncertain of the status of this taxon, as depauperate forms of *N. tenuissima* (Desv.) Kützing can be very similar to *N. confervacea*.

Nitella hyalina (DC.) Agardh

Localities (9): 1. Prov. Sindh: Thatta, Kinjhar lake, 21.12.1996, 24.2.1998, 5.8.1998, 13.12.1999; 2. Prov. Sindh: Thatta, Sonda, 24.2.1998; 3. Prov. Sindh: Dadu, Nain Baran super highway, 2.2.1998; 4. Prov. Sindh: Hyderabad, Chalgari pond, River Indus (near Matiari), in flood water from Indus, 10.2.1998; 5. Prov. Sindh: Karachi, Hub dam, 11.3.1998, 29.11.1999; 6. Prov. Sindh: Sanghar, Khorri pond, 15.5.1998; 7. Prov. Sindh: Sanghar, Tando Mitha Khan, on the side pond of Nara canal, 24.3.1999; 8. Prov. Sindh: Dadu, Thano Bola Khan, Ali Mohammad breja spring, 15.4.1999; 9. Prov. Sindh: Badin, Karoahangro lake, 30.9.1999.

References to Pakistan: ALLEN (1928), FARIDI (1955), PAL *et al.* (1962).

General: Plants 15–30 cm high. Axes up to 0.7 mm in diameter. Easily distinguishable from other species by the accessory branchlets which are shorter than the other branchlets. Monoecious.

Comments on studied plants: Typical forms, encrusted with lime, to 18 cm high. Development optimal in February, with richly fertile plants, but with few ripe, brown oospores. The ripening of oospores is infrequent in the studied material.

From Kinjhar lake several collections show:

- 21.12.1996, richly fertile, no ripe oospores,
- 24.2.1998, richly fertile, few brown oospores, 0.35 mm long, 0.3 mm wide. Membrane with 8 ridges, coarse granulate. Fossae 0.038 mm,
- 15.8.1998, some brown oospores. Overgrown with filamentous algae (*Spirogyra* sp.),
- 13.4.1999, brown oospores.

Specimens from Chalgari pond: up to 18 cm high with axes up to 0.5 mm in diameter and internodes to 4 cm long. Branchlets in two series (heteroclemous), both primary and accessory whorls having fertile branchlets. Eight primary branchlets at a node with many accessory branchlets. Total branchlet length 5.5 mm with primary rays up to 3.5 mm long. Ten secondary rays, 5 tertiary rays and 4 quaternary rays. Dactyls 2-celled, each with a short, conical, acute end-cell.

Gametangia conjoined on the second and third node and on the accessory branchlets. Oogonia 0.45 mm long, 0.3 mm wide, with 9 convolutions. Oospores are brown. Antheridia range to 0.25 mm in diameter.

Ecology: Normally in freshwater, in Pakistan also found in brackish water. Findings in brackish water are reported from India (DIXIT 1931), and the Baltic Sea (LANGANGEN and KOISTINEN 2001).

Distribution: FARIDI (1955) reports *Nitella hyalina* from many places in Pakistan (Fig. 3). It seems to be common in India (PAL *et al.* 1962).

Nitellopsis obtusa (Desv.) J. Groves (= *Tolypellopsis stelligera* Migula)

Localities (3): 1. Prov. Sindh: Sanghar, Bakar lake, 2.7.1997, 5.2.1998; 2. Prov. Sindh: Thatta, Kinjhar lake, 24.2.1998, 5.8.1998; 3. Prov. Sindh: Dadu, Thano Bola Khan, Ali Mohammad breja spring, 15.4.1999.

References to Pakistan: None.

General: Plants up to 60 cm high, dark green. Axis up to 1.5 mm in diameter. Dioecious. Ecorticated. Stellate bulbils. Branchlets very long, 2–3 segments, the ultimate segment elongated, acuminate or mucronate.

Comments on studied plants: Specimens encrusted (*zonata incrustata*) and up to 30 cm long, with internodes to 7 cm long and branchlets to 4 cm long. Strawberry-like, stellate bulbils at old nodia. Fertile specimens in both localities. Female, unripe plants in Bakar lake in July. Here new shoots came from old plants. New plants up to 15 cm long. Oogonia singly or in pairs at the first node of the branchlets. Oogonia 1.25 mm long and 1.1 mm wide. Male plants found in Kinjhar lake in August. Antheridia 1.2 mm in diameter.

Ecology: The growth of this species seems to be optimal in autumn; freshwater.

Distribution: *Nitellopsis obtusa* is a new species to Pakistan (Fig. 4). It is also found in Dal lake in Kashmir (GROVES 1923, MUKERJI 1934).

Lamprothamnium succinctum (A. Braun) R. D. Wood

Localities (7): 1. Prov. Punjab: Rawalpindi, Kalankhar in saline lake, 21.4.1999; 2. Prov. Sindh: Badin, Karoghangro, saline lake (brackish water), 16.9.1997; 3. Prov. Sindh: Badin, Lake Pateji (brackish water), 18.8.1997; 4. Prov. Sindh: Dadu, Sehwan, Lakki hot spring, 12.10.1999; 5. Prov. Sindh: Dadu, Thano Bola Khan, Nain Baran at Dao dam, 1.6.1998, 7.2.1999; 6. Prov. Sindh: Hyderabad, Old Phulali and Tando Syedpur Takur, 16.2.1997; 7. Prov. Sindh: Sanghar, Alam Rajar pond at the edge of Thar desert, 18.10.1996.

References to Pakistan: PAL *et al.* (1962) gives one locality in Lyaree river, Karachi.

General: Plants monoecious, up to 20 cm high. Totally ecorticated, stipulodes in a single tier, short, irregular. Gametangia normally sejoined.

Comments on studied plants: Up to 30 cm high. Slightly encrusted specimens in localities 2, 4 and 5. Stipulodes missing or only partly developed. Bract-cells developed on branchlet nodia and are as long as the oogonia. Specimens normally richly fertile. Oogonia at base of whorl, both on the inside and the outside. On the outside they replace the stipulodes. Oogonia also solitary on branchlet nodes. Antheridia normally solitary on the first branchlet nodes. Both antheridia and oogonia stipitated. Ripe, black oospores found in March, September and October. Round, white bulbils, 0.75 mm in diameter in material from localities 3 and 4.

Ecology: Saline and brackish water. In Lakki sulphur hot spring the species has been found in water to 35 °C (KHUHAWAR *et. al.* 1986).

Distribution: *Lamprothamnium succinctum* is not common in the Indian continent. It was first reported by DIXIT (1931) in saline water in Salsette, Bombay, and later from Lyaree river near Karachi (PAL *et al.* 1962). Later it has also been found in Bihar province of India (KHAN 1980). The distribution in Pakistan is shown in Figure 5.

Chara wallichii A. Braun

Locality (1): Prov. Sindh: Hyderabad, Chalgari, River Indus (flood water pond), 10.2.1998.

References to Pakistan: FARIDI (1955).

General: Dioecious, up to 25 cm high. Axes to 1.1 mm in diameter. Totally ecorticated. Stipulodes rudimentary. Bract-cells large, verticillate. Gametangia at base of whorl as well as on lower branchlet nodes. Antheridia to 1 mm in diameter, tetrascutate.

Comments on studied plants: Up to 10 cm long with axes of 0.6 mm and internodia up to 3 cm long. Stipulodes absent. Plants slightly encrusted. Only male plants, all with antheridia in abundance. Antheridia clustered at base of the whorls and at all nodia of the branchlets. At the basal nodium antheridia both on the outside and the inside. Antheridia up to 1 mm in diameter.

Ecology: Freshwater, often in flood water ponds.

Distribution: FARIDI (1955) reports the species from northern Pakistan (Lahore, Rawalpindi) (Fig. 6). It is elsewhere found in India (PAL *et al.* 1962), and in Burma (PAL 1931).

Chara corallina Klein ex Willd.

Locality (1): Prov. Sindh: Sanghar, near Bakar lake, 5.2.1998.

References to Pakistan: FARIDI (1955), PAL *et al.* (1962).

General: Similar to *C. wallichii*, but monoecious. Gametangia both at base of whorls and at branchlet nodes.

Comments on studied plants: The examined specimens are new shoots up to 7 cm high from old plants and are slightly encrusted. Stipulodes few and poorly developed, in one row, short, acute and to 0.4 mm long. In each whorl up to 6 branchlets up to 17 mm long, and with 2–3 segments. End-cell short, acute, mucronate, and 0.25 mm long. Bract-cells short and acute. Specimens richly fertile. Oogonia up to 1 mm long and 0.75 mm wide. Oospores black, 0.75 mm long and 0.55 mm wide. Antheridia 0.6 mm in diameter. Gametangia on basal nodia both outside and inside of these, often very numerous. Gametangia also on the first and second nodes of branchlets.

Ecology: Freshwater.

Distribution: *Chara corallina* is found scattered from Sri Lanka through India to Pakistan (FARIDI 1955, PAL *et al.* 1962). Our records correspond with other findings in Pakistan (FARIDI 1955). The known distribution in Pakistan can be seen in Figure 6.

Chara braunii Gmelin

Localities (3): 1. Prov. Karakoram (Kashmir, India), Nagar Village (altitude 2300 m), 10.9.1960, leg.: O. Polunin (BG); 2. Prov. Northwest Frontier: Swat valley, Khuza Khela Swat, paddy field, 23.10.1998; 3. Prov. Northwest Frontier: Swat valley, River Swat near Mangora, side water 23.10.1998.

References to Pakistan: FARIDI (1955), PAL *et al.* (1962).

General: Monoecious. Totally ecorticated species. Stipulodes in one ring. Differs from *Chara corallina* mostly by not having gametangia at base of whorls. The end-cell and the surrounding bract-cells form a characteristic corona.

Comments on studied plants: The examined specimens were morphologically typical, and richly fertile, but no ripe oospores were observed.

Ecology: Freshwater.

Distribution: *Chara braunii* is a cosmopolitan species (WOOD and IMAHORI 1965). It is found scattered both in India and Pakistan (FARIDI 1955, PAL *et al.* 1962). The known distribution in Pakistan can be seen in Figure 7.

Chara flaccida A. Braun

Localities (5): 1. Prov. Sindh: Dadu, Kumb spring, Sehwan to Bajara road, 12.10.1999; 2. Prov. Sindh: Dadu, Sehwan, Kai sulphur spring, 12.10.1999; 3. Prov. Sindh: Sanghar, Awad Bridge pond, 4.5.1998, 17.8.1999; 4. Prov. Sindh: Thatta, Halej lake, 13.12.1999; 5. Prov. Sindh: Thatta, Kinjhar lake, 21.12.1996, 24.2.1998, 5.8.1998.

References to Pakistan: None.

General: Together with *Chara wallichii*, *C. corallina* and *C. braunii*, *Chara flaccida* belong to the haplostephanous species, *i.e.* with stipulodes in one row. Of these only *C. flaccida* has cortex. Monoecious. Oospores brown.

Comments on studied plants: Specimens 9–15 cm high with axis diameters of 0.5–0.6 mm. Internode length up to 2 cm. Moderately to strongly encrusted with lime. Cortex diplostichous, isostichous to tylacanthous. Spine-cells scattered and solitary, acute, and normally not longer than the stem diameter, but in some specimens to 0.8 mm. One row of stipulodes, as long as 2 mm. 8–10 branchlets in each whorl, each up to 13 mm long, and 0.5–1 times the length of internodes. Branchlets of 3–4 segments, each having an end-segment of 1–2 cells. All branchlets ecorticated. The bract-cells up to 1.5 mm long and verticillate. Plants very richly fertile. Oogonia up to 0.75 mm in length, 0.35 mm wide, with 8 spiral cells. Coronula 0.1 mm long, and 0.15 mm wide. Oospores to 0.4 mm long and 0.25 mm wide, light brown to brown in colour, with 8 low ridges. Membrane finely granulated. Antheridia up to 0.35 mm in diameter. Ripe oospores are found in February–May and in October. They were not found in specimens collected in December and August.

Note: ZANEVELD (1940) united three species *C. benthamii* A. Braun, *C. gymnopytis* A. Braun and *C. flaccida* into one species, *Chara fibrosa* Agardh ex Bruz. But because the specimens from Pakistan have brown oospores, which is characteristic for *C. flaccida*, we prefer to keep this as a distinct species (see also PAL *et al.* 1962).

Ecology: Freshwater.

Distribution: *Chara flaccida* is found throughout India (PAL *et al.* 1962). The known distribution in Pakistan is shown in Figure 7.

Chara canescens Desv. et Lois. in Lois. (= *Chara crinita* Wallroth)

Localities (4): 1. Prov. Northwest Frontier: Peshawar valley, Warsk, in pond of River Kabul above the Warsk dam, 22.10.1998; 2. Prov. Sindh: Sanghar, Tando Mitha Khan, Serin Wari, 24.3.1999; 3. Prov. Sindh: Sanghar, Tando Mitha Khan, Jati pond, 20.1.1998; 4. Prov. Sindh: Sanghar: Garhar Bridge pond, beside Khipro canal, 22.5.1996.

References to Pakistan: ALLEN (1928), FARIDI (1955), PAL *et al.* (1962).

General: Dioecious or parthenogenetic. Cortex haplostichous. Spine-cells abundant single, in pair or clustered. Stipulodes well developed in two tiers.

Comments on studied plants: The description is based on specimens from Jati (loc. 3). Plants coarse, up to 25 cm long, and axis to 0.75 mm thick. Cortex regularly haplostichous. Spine-cells abundant, single, in pairs, or clustered, densely covering young internodes, and from 1–1.5 times the stem diameter in length. Stipulodes well developed in both rows, 0.6 mm in upper and 0.5 mm long in the lower row. Branchlets 9–10 in each whorl, up to 10 mm long with 5 segments. Bract-cells verticillate to 1 mm long. Only female plants were found, richly fertile with ripe, black oospores. Oogonia 0.75 mm long, 0.4 mm wide, on branchlet nodia 2–4. Oospores 0.6 mm long, 0.3 mm wide. Ripe oospores also found in specimens from all three localities.

Note: Male plants are known from Pakistan (FARIDI 1955). In areas without male plants the species reproduces parthenogenetically. Dioecious *C. canescens* and parthenogenetic *C. canescens* are probably not conspecific. There may be two biological species here that have traditionally been considered as one (PROCTOR 1980).

Ecology: Brackish water.

Distribution: The species is found in several places in Pakistan (FARIDI 1955) (Fig. 8), but is not known from India (PAL *et al.* 1962). The species is mainly found in Europe, with a few records in China and North America (CORILLION 1957). The findings in Pakistan are the southernmost known localities.

Chara vulgaris L.

Localities (14): 1. Baluchistan: Quetta, Hunna lake (15 km from Quetta), 24.4.1999; 2. Baluchistan: Quetta, Huric spring (22 km from Quetta), 24.4.1999; 3. Baluchistan: Quetta, Kochlak, tube well water pond (25 km from Quetta), 23.4.1999; 4. Baluchistan: Quetta, Ziarat, rain water pond (80 km from Quetta), 22.4.1999; 5. Prov. Kashmir (India): Chatar area 1998; 6. Prov. Kashmir (India): Rawla Kot, Lake Manjosa, 19.10.1996, leg.: M. K. Leghari; 7. Prov. Northwest Frontier: Peshawar, Heripur, Tarbella dam, 21.4.1999; 8. Prov. Northwest Frontier: Peshawar valley; Warsk, rice field pond on the Warsk road side, 22.10.1998; 9. Prov. Punjab: Islamabad, Muree road, Rata hotar, spring water, 23.3.1999; 10. Prov. Punjab: Islamabad, Rawla lake, 24.3.1999; 11. Prov. Sindh: Sanghar, Bakar lake, 10.3.1996; 12. Prov. Sindh: Sanghar, Jati pond near Tando Mitha Khan, 28.12.1997; 13. Prov. Sindh: Sanghar, Tando Adam road to Kindiari near Nala bridge at MNV Drin, 20.2.1996; 14. Prov. Sindh: Sanghar, Tando Mitha Khan, above saline lake Patehal, 30.4.1995.

References to Pakistan: FARIDI (1955), PAL *et al.* (1962).

General: Monoecious. Diplostichous cortex, with secondary cortex cells more prominent than primary rows with spine-cells (aulacanthous cortex). Encrusted.

Comments on studied plants: Strongly encrusted (specimens from Sanghar) and up to 12 cm high. Cortex cells nearly isostichous. Bract-cells short, papillous. Stipulodes short in both rows. 9 branchlets in each whorl, up to 22 mm in length, with 4 segments. End-segment ecorticated. Bracteoles 50 mm long. Richly fertile, and ripe, brown oospores have been found in April. Specimens from this locality can be referred to *f. longibracteata* A. Braun.

Ecology: Freshwater.

Distribution: *Chara vulgaris* is found in many localities in Pakistan (FARIDI 1955) (Fig. 9), and in India (PAL *et al.* 1962).

Chara gymnophylla A. Braun

Locality (1): Baluchistan: Losali, Rara shim, Machen lake, 11.3.1996, leg.: Khamiso Khan.

References to Pakistan: None.

General: The species is very similar to *C. vulgaris*, but has gymnophyllous or nearly gymnophyllous branchlets, and gametangia are produced at nodes without cortex.

Comments on studied plants: Plants to 9 cm high, encrusted. Cortex aulacanthous, with short spine-cells. Branchlets ecorticated, or with one or two corticated segments. Anterior bract-cells long and broad, posterior bract-cells papillous. Sterile.

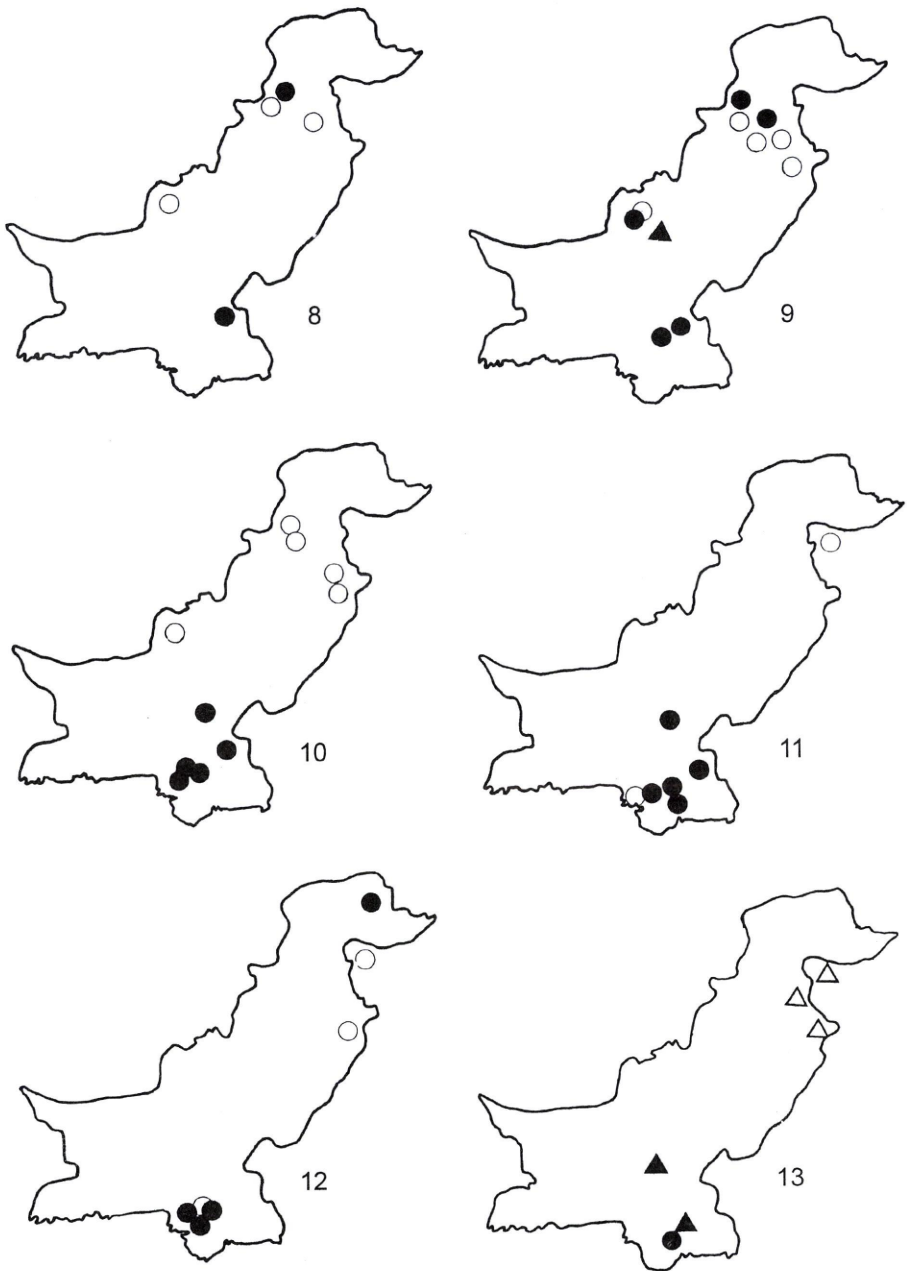
Note: The validity of this species is discussed, and both ZANEVELD (1940) and PAL *et al.* (1962) regard it as belonging to *C. vulgaris*.

Ecology: Freshwater.

Distribution: *Chara gymnophylla* has been reported from India by DIXIT (1935) and ZANEVELD (1940). The known distribution in Pakistan is shown in Figure 9.

Chara contraria A. Braun ex Kützing

Localities (23): 1. Prov. Sindh: Dadu, Kotri pond near K. B. Fedar canal, 20.1.1998, (*f. capillacea*); 2. Prov. Sindh: Dadu, Manchar lake, 6.7.1999; 3. Prov. Sindh: Dadu, Rani Kot springs, 8.4.1999; 4. Prov. Sindh: Dadu, Sehwan, freshwater pond near Aval wah, 8.4.1999; 5. Prov. Sindh: Dadu, Sindh University, Jamshoro, 9.2.1998; 6. Prov. Sindh: Dadu, Thanu Bola Khan, Ali Mohammad



Figs 8–13. 8 = *Chara canescens*; 9 = *C. vulgaris* ● ○, *C. gymnohylla* ▲; 10 = *C. contraria*; 11 = *C. zeylanica*; 12 = *C. globularis*; 13 = *C. connivens* ●, *C. setosa* ▲ △. (Filled symbols: our own findings; open symbols: literature records.)

breja spring, 15.4.1999; 7. Prov. Sindh: Dadu, Thano Bola Khan, Bareja spring, 5.9.1999, (form); 8. Prov. Sindh: Hyderabad, Hyd River, pond near airport, 21.4.1996; 9. Prov. Sindh: Nain Baran super highway bridge, 17.1.1997; 10. Prov. Sindh: Sanghar, Tando Mitha Khan, 5.2.1998; 11. Prov. Sindh: Sanghar, Jati pond (seepage water of Nara canal), 29.1.1997; 12. Prov. Sindh: Sanghar, Khinmbhro at edge of Thar desert, 29.1.1998; 13. Prov. Sindh: Sanghar, Khori pond, 15.5.1998; 14. Prov. Sindh: Sanghar, Peronmal, 24.3.1999; 15. Prov. Sindh: Sanghar, pond near Bakar lake, 5.2.1998; 16. Prov. Sindh: Sanghar, pond village Abdullah Leghari and Khori pond, 2.2.1998; 17. Prov. Sindh: Sanghar, Tado, Adam road, 8.2.1999; 18. Prov. Sindh: Sanghar, Tando Mitha Khan, Khori pond, 24.3.1999; 19. Prov. Sindh: Sanghar, Tando Mitha Khan, pond full with single species near the bridge of Nara canal, 5.2.1998; 20. Prov. Sindh: Sanghar, Tando Mitha Khan, Serin Wari, 24.3.1999; 21. Prov. Sindh: Shikarpur, Shikarpur in the ponds outside rice fields, 3.3.1998; 22. Prov. Sindh: Thatta, Kinjhar lake, 21.12.1996, 24.2.1998; 23. Prov. Sindh: Thatta, Sonda pond, 24.2.1998.

References to Pakistan: FARIDI (1955), PAL *et al.* (1962).

General: *Chara contraria* has much in common with *Chara vulgaris*, but has tylacanthous cortex. Normally both species are strongly encrusted. Monoecious.

Comments on studied plants: 7–25 cm in height. Stem diameter to 0.65 mm and internodes up to 4 cm long. Strongly encrusted with lime. Cortex diplostichous, from slightly to strongly tylacanthous, and spine-cells very short to papillous and solitary. Stipulodes papillous and in two series. Whorls consist of 7–10 branchlets, each up to 20 mm long, 1/6–1 times the length of internodes. Branchlets of 2–5 segments, the end-segments with 3–4 ecorticated cells. End-cell short, from 0.25–1.0 mm. Anterior bract-cells and bracteoles normally well developed, as long as the oogonium and up to 2 mm. Posterior bract-cells always papillous. Richly fertile, but ripe oospores were not common. Oogonia 0.6–1.0 mm long, 0.4–0.55 mm wide. Coronula 0.15 mm long, 0.25 mm wide. Oospore 0.6 mm long, 0.4 mm wide, and black, with 11 ridges. Antheridia 0.35 mm in diameter.

The specimens found in Peronmal (loc. 14) were especially full of ripe, black oospores.

Specimens collected in Bareja spring, Dadu, have branchlets which are gymnophyllous or partly so. Such specimens can be named *Chara grovesii* Pal, which has gymnophyllous branchlets and has been found in Burma, or *C. contraria* var. *nitelloides* A. Braun which have one or two abbreviated, corticated branchlet segments, and which is known from Bolivia. There are reasons to believe that such taxa are within the range of variation of *C. contraria*.

Ecology: Specimens found in Kotri pond (loc. 1) belong to f. *capillacea* Migula. They are found together with *Enteromorpha* sp. and *Monotroma* sp. This indicates saline or brackish water. The species is normally found in freshwater.

Distribution: *Chara contraria* seems to be common in Pakistan (Fig. 10). FARIDI (1955) also gives many localities from the country. It is also widely distributed in India (PAL *et al.* 1962).

Chara zeylanica Klein ex Willd.

Localities (29): 1. Prov. Sindh: Badin, Karoghangro, saline lake (brackish water), 6.7.1997, 16.9.1997; 2. Prov. Sindh: Dadu (near Karachi), Kadeji spring on the super highway, 17.4.1999; 3. Prov. Sindh: Dadu, Kunb village, Loani spring, 20 km from Sehwan, 12.10.1999; 4. Prov. Sindh: Dadu, Sehwan, Lal Bag spring, 5.9.1999; 5. Prov. Sindh: Dadu, Manchar lake, 22.3.1998; 6. Prov. Sindh: Dadu, Rani Kot springs, 8.4.1999; 7. Prov. Sindh: Dadu, Sehwan, small spring near Lakki hot spring, 5.9.1999; 8. Prov. Sindh: Dadu, Thanu Bola Khan, Ali Mohammad breja spring, 15.4.1999; 9. Prov. Sindh: Dadu, Thanu Bola Khan, Karoghar spring, 10.4.1999; 10. Prov. Sindh: Dadu, spring water on the road to Bajara village, Loani 20–22 km, 12.10.1999; 11. Prov. Sindh: Hyderabad, fish pond Ibrahim Shah (Hosri), 16.2.1998; 12. Prov. Sindh: Hyderabad, Jamshora road, 20.1.1998, 24.4.1998; 13. Prov. Sindh: Hyderabad, pond near River Indus, 15.5.1996; 14. Prov. Sindh: Hyderabad, Syedpur Takur, 26.4.1998; 15. Prov. Sindh: Karachi, Hub dam, 11.3.1998, 29.11.1999; 16. Prov. Sindh: Sanghar, Awad bridge pond, 4.5.1998, 17.8.1999; 17. Prov. Sindh: Sanghar, Bakar lake, 2.7.1997, 29.9.1997, 5.2.1998; 18. Prov. Sindh: Sanghar, drain near Sanghar, 3.5.1998, (f. *elegans*); 19. Prov. Sindh: Sanghar, Khoru pond, 15.5.1998; 20. Prov. Sindh: Sanghar, ponds near Bakar lake, 4.9.1998; 21. Prov. Sindh: Sanghar, Tando Adam road in MNV drain, 16.8.1999; 22. Prov. Sindh: Sanghar, Tando Mitha Khan and Khoru, 24.3.1999; 23. Prov. Sindh: Shikarpur, 5.10.1999, leg. M. A. Mahar; 24. Prov. Sindh: Shikarpur, Shikarpur, outside the rice field ponds, 3.3.1998, 21.9.1998; 25. Prov. Sindh: Thatta, Dhabeji spring, 4.8.1999, 13.12.1999; 26. Prov. Sindh: Thatta, Halej lake, 13.3.1999, 13.12.1999; 27. Prov. Sindh: Thatta, Kinjhar lake, 5.8.1998, 13.3.1999; 28. Prov. Sindh: Thatta, Sonda pond, 24.2.1998; 29. Prov. Sindh: Thatta, Sujawal, 6.7.1999.

References to Pakistan: PAL *et al.* (1962).

General: *Chara zeylanica* is a triplostichous species. Lack of cortex on the lowest branchlet segments separate it from the other species in this group. Monoecious. Many varieties and forms have been described.

Comments on studied plants: The examined material also shows a great variation. We have chosen not to determine forms and varieties, for all but two collections.

7–45 cm high, but most commonly less than 14 cm. Axes 0.55–0.85 mm in diameter and internodes to 3 cm long. Slightly encrusted with lime. Cortex regularly

triplostichous, isostichous to tylacanthous. Spine-cells short, acute, from 0.05–0.15 mm long, and solitary. Stipulodes in both rows, upper up to 0.6 mm and lower to 0.3 mm. 8–12 branchlets in a whorl, 16–34 mm long, 1–1.5 times the length of the internodia. 6–11 segments on each branchlet. End-segment 1–2 celled, 0.6–2.0 mm long. End-cell acute, 0.1–0.6 mm long. Bract-cells verticillate. Anterior bract-cells and bracteoles 0.75–1.25 mm long, posterior bract-cells papillous to 0.75 mm long. Generally richly fertile. Oogonium 1.0 mm long, 0.5 mm wide, with 12 spiral cells. Coronula 0.075–0.15 mm long, 0.15–0.2 mm wide. Oospores 0.7 mm long, 0.45 mm wide, and black. Ripe oospores have been found throughout the year. Antheridia are 0.25–0.35 mm in diameter.

Two forms have been separated: 1. *Chara zeylanica* f. *elegans* A. Braun, which was found in a drain near Sanghar, 3.5.1998. Strongly encrusted. Spine-cells dense and up to 1.6 mm long in young internodes. On older internodes, spine-cells scattered and only up to 1.0 mm long. This form exhibits low fertility. 2. *Chara zeylanica* f. *curassavica* (A. Braun) H. et J. Groves, which is found in spring water in Loani, 12.10.1999., it has both totally and partly ecorticated branchlets, and is fertile at lowest branchlet nodes. Specimens with this distinguishing mark can be referred to as *Chara diaphana* Meyen (see also WOOD 1965).

CHOUDHARY (1969) has discussed the forms found in India. A revision of the *Chara zeylanica* complex is strongly needed.

Ecology and distribution: *Chara zeylanica* appears to be the most common species in Pakistan (Fig. 11). Normally in freshwater, but also found in brackish water (loc. 1). According to ZANEVELD (1940) this is not common, but is reported from India (DIXIT 1931). The species is common in India (PAL *et al.* 1962).

Chara globularis Thuill. (= *Chara fragilis* Desv.)

Localities (5): 1. Prov. Karakoram (Kashmir, India), Nagar village (altitude 2300 m), 10.9.1960, leg.: O. Polunin (BG); 2. Prov. Sindh: Hyderabad: River Indus at Chalgari pond (Mitari), 20.2.1998; 3. Prov. Sindh: Karachi, Hub dam, 11.3.1998, 29.11.1999; 4. Prov. Sindh: Thatta, Kinjhar lake, 24.2.1998; 5. Prov. Sindh: Thatta, Sonda pond, 24.2.1998.

References to Pakistan: FARIDI (1955), PAL *et al.* (1962).

General: *Chara globularis* is a monoecious, triplostichous, isostichous species. Spine-cells and stipulodes papillous.

Comments on studied plants: 8–15 cm high, with moderately encrusted axes to 0.5 mm in diameter and internodia of up to 3 cm in length. Cortex regularly triplostichous and isostichous. Spine-cells papillous and difficult to see in older internodes. Stipulodes papillous and in two rows. 6–8 branchlets in each whorl, to

24 mm long, and 0.5–1 times as long as the internodia, with 7–10 segments, end-segment of 1–2 cells and to 0.7 mm long. End-cells acute, to 0.2 mm long. Anterior bract-cells up to 0.75 mm long, bracteoles to twice the length of oogonia, and posterior bract-cells short, papillous. Plants richly fertile. Oogonia 0.85–1.0 mm long, 0.55 mm wide, with 12 spiral cells. Coronula up to 0.2 mm long, and to 0.25 mm wide. Oospores 0.65 mm long, and black. Ripe oospores in November–March. Antheridia 0.3–0.35 mm in diameter.

Specimens found in Karakoram at an altitude of 2300 m are so divergent that they are described here:

Plants to 25 cm high, with stem diameter to 0.7 mm. Internodes to 4 cm long. Slightly encrusted. Cortex triplostichous, isostichous. Spine-cells are very small to papillous. Stipulodes developed in upper row to 0.1 mm long, papillous in lower row. 7–8 branchlets in each whorl, to 15 mm long, 0.5–1.5 times the length of internodia. Number of segments are 1–3 of which 0–2 are ecorticated. Ecorticated part is up to 10 mm long. Anterior bracts and bracteoles are 1–3 times the length of oogonia, posterior bracts are papillous. The examined plants are monoecious and richly fertile, with some ripe oospores. Gametangia are the most common at the lowest branchlet nodium, independent of whether this is corticated or ecorticated, but are also often found on higher ecorticated nodia. Oogonium 0.75 mm long, 0.5 mm wide, with 11 spiral cells. Coronula is 0.1 mm high and 0.15 mm wide. Oospores black.

These specimens belong to the gymnophyllous taxa of *Chara globularis*/*Chara virgata*. GROVES and GROVES (1884) described a new variety, *C. fragilis* var. *sturrochii*, based on its lack of branchlet cortication from England. According to WOOD (1965) this taxon belongs to *Chara vulgaris*, because of diplostichous stem cortex. The specimens described here fit best *Chara leiopitys* Whelden, which is described from Argentina (WHELDEN 1946), but which has golden brown oospores. Other similar taxa are *Chara schroederi* Migula, which was described from Kenya (MIGULA 1914), and *Chara chrysospora* J. Groves et E. L. Stephens, which was described from South Africa. Both have brown oospores. The specimens described by us differ from the three other by having black oospores and smaller stipulodes in upper row. The length of the stipulodes in upper row indicate that all belong to *Chara virgata* rather than *C. globularis*. We agree with WOOD (1965) when he says: "It is peculiar that such similar forms as this (*chrysospora*) and f. *leiopitys* (S. America) occur in isolated continents, but it could be expected to occur occasionally as forms in a world-wide population of *C. globularis*." We are of the opinion that the gymnophyllous forms of *C. globularis* presumably belong to the same taxon. A revision of the described taxa is needed.

Ecology: Freshwater.

Distribution: *Chara globularis* is found scattered both in India (PAL *et al.* 1962), and in Pakistan (FARIDI 1955) (Fig. 12).

Chara connivens Salzmann ex A. Braun

Locality (1): Prov. Sindh: Thatta, Kinjhar lake, 21.12.1996, 24.2.1998, 5.8.1998, 13.3.1999.

References to Pakistan: None.

General: *Chara connivens* is a dioecious, triplostichous species.

Comments on studied plants: Up to 25 cm high with slightly lime encrusted axes to 0.5 mm in diameter and internodes up to 4.5 cm long. Cortex is regularly triplostichous and isostichous. Spine-cells papillous. Stipulodes papillous in both rows. Branchlets incurved and bract-cells are rudimentary. Oogonia up to 0.75 mm. Oospores black and found in March and August. Antheridia at the 2–4 lowest branchlet nodia up to 0.65 mm in diameter.

Ecology: Freshwater to 5–6 m depth.

Distribution: *Chara connivens* is new to Pakistan (Fig. 13), and only found in one locality in India (PAL *et al.* 1962).

Chara setosa Klein ex Willd. (= *C. brachypus* A. Braun)

Localities (4): 1. Prov. Sindh: Dadu, Kotri, Nain Baran, 20.1.1998; 2. Prov. Sindh: Dadu, Sehwan, Kai spring, 12.10.1999; 3. Prov. Sindh: Shikarpur, ponds in rice field, 21.9.1998, leg. M. A. Mahar; 4. Prov. Sindh: Thatta, Sujawal, 6.7.1999.

References to Pakistan: FARIDI (1955), PAL *et al.* (1962).

General: Separated from the other triplostichous species by having triplostichous cortex on the branchlets, and by having very short first segment on the branchlets. Monoecious.

Comments on studied plants: 8–20 cm with slightly lime encrusted axes up to 0.8 mm in diameter. Cortex triplostichous and isostichous to slightly tylacanthous. Spine-cells scattered, short to 0.1 mm long. Stipulodes in two rows with the upper to 0.5 mm long and the lower to 0.2 mm long. 8–9 branchlets in each whorl, up to 18 mm long, 0.5–1 times the length of the internodia, of 5–6 segments, the end-segments with two ecorticated cells, the end-cells short. Branchlets 2–3 corticated. Bract-cells short and papillous. Bracteoles up to half the length of mature oogonia. Plants richly fertile. Oogonia up to 0.1 mm long, 0.5 mm wide, and with 10 spiral cells. Ripe, black oospores found both in January and September. Antheridia up to 0.35 mm in diameter.

Ecology and distribution: In freshwater and scattered throughout both Pakistan (FARIDI 1955) (Fig. 13), and India (PAL *et al.* 1962). In Kai spring the species has been found in water to 35 °C.

Note: A closely related species, *Chara pseudobrachypus* J. Groves et Stephens, has diplostichous cortex on the branchlets. This species is reported from India (PAL *et al.* 1962). A study done by Dr K. Imahori (WOOD 1965) on this character concluded that *C. pseudobrachypus* normally had 2–3 corticated branchlet cortex. This means that *C. pseudobrachypus* can be regarded as synonymous with *Chara setosa*.

INFORMATION ON SOME OF THE LAKES WHERE CHAROPHYTES HAVE BEEN FOUND

Karohangro lake

This is the largest brackish water lake in Pakistan. The area covers 70 km², with a depth to 1–2 m. The lake has freshwater inflow from large draining areas, with high nutrition content which supports a rich plant growth along the margins of the lake (Table 1). *Typha domingensis* Pers. and *Phragmites australis* (Cav.) Trin. ex Steudel are dominating helophytes, while common submerged plants are *Hydrilla verticillata* Royle, *Najas minor* All., *N. marina* L., *Potamogeton pectinatus* L. and *Ipomoea aquatica* Forsk.

Chara zeylanica, *C. flaccida* and *Nitella hyalina* are found along the freshwater part, while *Lamprothamnium succinctum* is found in the more saline part of the lake.

Pateji lake

This is a large, shallow, 1.5 m deep, slightly brackish lake. The water is a mixture of freshwater from agriculture land and saline water from the Arabian Sea (Table 1). Commonly found are algae such as *Enteromorpha salina* Kützinger, *E. prolifera* (Müller) Agardh, *Rhizoclonium hieroglyphicum* (Agardh) Kützinger and *Lamprothamnium succinctum*. The last is found on mud bottom in areas with the highest salinity.

Bakar lake (Chotiari reservoir)

This is a large eutrophic freshwater lake (Table 1) with large reeds of *Phragmites australis*, *Typha domingensis* and *T. elephantina* Roxb. Submerged plants

Table 1. Some abiotic parameters of the lakes.

	pH	Conductivity $\mu\text{S/cm}$	Hardness as CaCO_3 , mg/l	Chloride mg/l
Karoghangro lake	8.2–8.9	3620–9290	500–1150	1182–3190
Pateji lake	7.9–8.3		753–9900	525–584
Bakar lake	8.0–9.0	517–577	128–170	301–387
Kinjhar lake	7.9–8.7	304–435	84–138	25–40

found are *Hydrilla verticillata*, *Myriophyllum verticillatum* L., *M. spicatum* L., *Najas minor*, *N. major*, *Potamogeton natans* L., *P. pectinatus*, *P. crispus* L., *Ranunculus aquatilis* L., *Nelumbium nelumbo* (L.) Druce and *N. lotus* L. Free floating plants include *Azolla pinnata* R. Br., *Lemna minor* L., *Spirodela polyrrhiza* (L.) Schleiden and *Salvinia rotundifolia* Willd.

Nitellopsis obtusa grows in depths between 1–3 m. *Chara zeylanica* grows in depths to 1.5–2 m on the margin of the lake and in surrounding ponds. The lake is situated in an area of sand dunes, and the bottom is sandy.

Kinjhar (Kalri) lake

A mesotrophic freshwater lake, 2–7.5 m deep. The colour of water is blue-green. The bottom sediments are calcareous or silty (Table 1), and the submerged vegetation is dominated by charophytes. Six species of charophytes are found: *Nitella hyalina*, *Nitellopsis obtusa*, *Chara flaccida*, *C. contraria*, *C. zeylanica*, *C. globularis* and *C. connivens*. *Nitellopsis obtusa*, *C. globularis* and *C. connivens* occur in deep water.

DISCUSSION

In total, 23 species of charophytes have been found in Pakistan so far. This article deals with 17 species found in the years 1996–1999 in different localities in Pakistan. The records given by FARIDI (1955) are mostly from North Pakistan, in an area around Lahore. These two works therefore cover most parts of the country, and provide an overview of the charophyte flora of Pakistan. Further investigations, especially in Baluchistan and the middle parts of the country, may yield other interesting findings. In this article we only concentrate on the 17 species found by us, as we have not seen specimens of the other 6 species found in Pakistan.

The charophyte flora of West and South Asia is little known, except for India, and partly for Saudi Arabia (KHOJA and HUSSAIN 1990, HUSSAIN *et al.* 1996). From Iran and Afghanistan there are only scattered information (BRAUN and NORDSTEDT 1882, VILHELM 1928, CORILLION 1957).

So far about 60 species have been reported from India. According to KHAN and SARMA (1979) the proportion *Nitella/Chara* decreases from East to West, from 2:1 in the Australian area to 1:1 in India. In Pakistan this proportion is further lowered. In Saudi Arabia only one undeterminable *Nitella* has been found (KHOJA and HUSSAIN 1990). The known charophyte flora of Pakistan is very similar to the nearby parts of India, except for the lower numbers of *Nitella* (ALLEN 1928, ANAND and LANGER 1988, 1991a, b, DIXIT 1931, 1942). In Gujarat province in India, the neighbouring province of Sindh, PATEL and JAWALE (1981) reported 18 taxa of *Nitella*. Six of the seven species of *Chara* found in Saudi Arabia (KHOJA and HUSSAIN 1990) are also found in Pakistan.

According to phytogeographical distribution of the Pakistani charophytes (including Kashmir (MUKERJI 1934)) can be grouped in the following categories:

- species only found in South Pakistan: *Chara connivens*, *C. corallina*, *C. gymnophylla*, *Nitella confervacea*, *N. dictyosperma*;
- species only found in the eastern parts of Pakistan: *Chara flaccida*, *C. globularis*, *C. wallichii*, *C. zeylanica*, *Lamprothamnium succinctum*, *Nitellopsis obtusa*;
- species only found in North Pakistan: *Chara braunii*;
- species distributed all over the country: *Chara canescens*, *C. contraria*, *C. setosa*, *C. vulgaris*, *Nitella hyalina*.

In Pakistan many water courses are influenced by human activities. Eutrophication is known to affect charophytes negatively (BLINDOW 1992). One should therefore take steps to protect the water quality of localities with species that are not common, *i.e.* *Chara connivens*, *C. corallina*, *C. wallichii*, *Nitella confervacea*, *Nitella dictyosperma* and *Nitellopsis obtusa*.

Charophytes research in Pakistan has received little attention, but we hope that funds in the future can be provided for a full field investigation of these algae.

* * *

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