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Systematic studies on *Udotea indica* A. Gepp & E. Gepp (Caulerpales, Bryopsidophyceae) populations collected in Pakistan

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&
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RÉSUMÉ

AFAQ-HUSAIN, S. & M. SHAMEEL (1996). Etude systématique de populations d'*Udotea indica* A. Gepp & E. Gepp (Caulerpales, Bryopsidophyceae) récoltées au Pakistan. *Candollea* 51: 7-17. En anglais, résumés français et anglais.

L'habitus, les structures végétatives et l'appareil reproducteur d'exemplaires d'*Udotea indica* A. Gepp & E. Gepp, en provenance de différentes populations de la région de Karachi (Pakistan) et de régions côtières avoisinantes, ont fait l'objet d'une étude poussée. Les individus récoltés ont montré de grandes différences dans l'habitus et les structures des appendices. Toutes les populations étudiées sont en définitive maintenues dans la même espèce.

ABSTRACT

AFAQ-HUSAIN, S. & M. SHAMEEL (1996). Systematic studies on *Udotea indica* A. Gepp & E. Gepp (Caulerpales, Bryopsidophyceae) populations collected in Pakistan. *Candollea* 51: 7-17. In English, French and English abstracts.

Habit, vegetative and reproductive structures were studied thoroughly in the plants of different populations of *Udotea indica* A. Gepp & E. Gepp from Karachi (Pakistan) and adjoining coastal areas of northern Arabian Sea. The plants were found very variable in habit and appendage structures. All the studied populations are finally retained in the same species.

KEY-WORDS: Algae — *Udotea indica* — *UDOTEACEAE* — Karachi — Pakistan — Morphology — Anatomy — Reproduction.

Introduction

The recent systematic treatment of the species of *Udotea* Lamouroux from tropical Western Atlantic by LITTLER & LITTLER (1990) has become the source to reinvestigate critically its populations from different localities along the coast of Karachi and adjoining areas of Balochistan. It is needed primarily to determine the taxonomic position of different populations i.e. whether they belong to a single taxonomic entity or not, and secondarily to ascertain its phylogenetic position. LITTLER & LITTLER (1990) have segregated 10 new species out of 17, which they have identified from tropical Western Atlantic, mainly on the characters of siphons and their lateral appendages, which are also used for establishing their phylogenetic relationships. The previous studies on *Udotea* from Karachi (Pakistan) were carried out inadequately being based on limited collections

(GEPP & GEPP, 1911; NIZAMUDDIN, 1963, 1969), reason for which the early workers missed a few characters, which might prove useful for a phylogenetic approach.

All the characters, studied by LITTLER & LITTLER (1990), have been investigated critically in the present work and as a result a few more characters were discovered, which were not reported in the previous works. The plants of *Udotea indica* are found to be highly variable within the populations under study, not only in habit but also in anatomical features. This variation is continuous and as such does not warrant the segregation of present populations into more than one species. Furthermore, the characters studied here do not support the segregation of this species into another genus as it has been done by FARGHALY (1980) and followed by SHAMEEL & al. (1989) and SHAMEEL & TANAKA (1992).

Material and methods

The plants of *U. indica* were collected randomly *in situ* from Manora, Buleji, Gadani and Sonmiani beaches (Fig. 24, 25) in the months of September–December 1984–1992. Fifty specimens were selected at random from each population. These collection spots are lying within a 100 km long shore line, where more or less the same environment prevails. Specimens were fixed in 4% formalin in seawater and some were mounted on herbarium sheets, which are kept in the Herbarium of PCSIR, Karachi (CLH) and Seaweed Herbarium, MAH Qadri Biological Research Centre, University of Karachi (KUH-SW). Whole plants were treated with a mixture of 5% hydrochloric acid and 1% aniline blue for 24 to 48 hours for the study of siphons, which were teased out from apical, middle and basal parts of the blades and from stipes separately. Surface and margin of the blades were studied from untreated plants. Free hand sectioning of untreated plants was carried out to obtain cross and longitudinal sections (C. S. & L. S.). Except few L. S. all sections were broken up into their constituent siphons due to their non-adherent consistency. Slides were prepared either in distilled water or a mixture of distilled water + acetic acid + glycerine (1:1:1, v/v). Some permanent slides were prepared in Karo (corn syrup) and drawings were made with the help of camera lucida.

Results

Udotea indica A. Gepp & E. Gepp in M. Weber, Siboga Exped. Monogr. 62: 121. 1911.
Syn.: *Decaisnella indica* (A. Gepp & E. Gepp) Farghaly 1980.

Type specimen: Karachi, Pakistan, leg. A. Gepp & E. Gepp (BM).

Type locality. — *U. indica* grows in small groups or patches on silt-covered rocks in sandy bottom pools and sandy flats of lower and mid-littoral areas on sheltered as well as exposed coasts. It occurs in association with *Bryopsis pennata* Lamour., *Caulerpa racemosa* (Forssk.) J. Ag., *Chaetomorpha spiralis* Okam., *Halimeda tuna* (Ellis & Soland.) Lamour. and *Polyphysa parvula* (Solms-Laub.) Schnet. & Bula-Meyer. The fronds of old plants become covered by several rhodophytic epiphytes e.g. *Antithamnion elegans* Berth., *Centroceras clavulatum* (C. Ag.) Mont., *Ceramium miniatum* Suhr ex J. Ag. and *Herposiphonia secunda* (C. Ag.) Ambron.

Specimens examined. — Manora, leg. M. Shameel, 10.11.1992, 21.12.1992; Buleji, leg. M. Shameel, 21.12.1992; Gadani, leg. S. Afaq-Husain, 16.9.1985; Sonmiani, leg. S. Afaq-Husain, 11.11.1984, 17.9.1985 (Fig. 25).

Distribution. — Arabian Sea: Pakistan (Karachi: Manora, Hawkes Bay, Buleji, Cape Monze; Lasbela: Gadani, Sonminai) and India (Okha Port, Okhamandal, Dwarka) (Fig. 24 and 25); Pacific Ocean: the Philippines (Batanes, Luzon: Ilocos Norte, Lyete: Biliran I.) (CORDERO, 1977; SILVA & al., 1987).

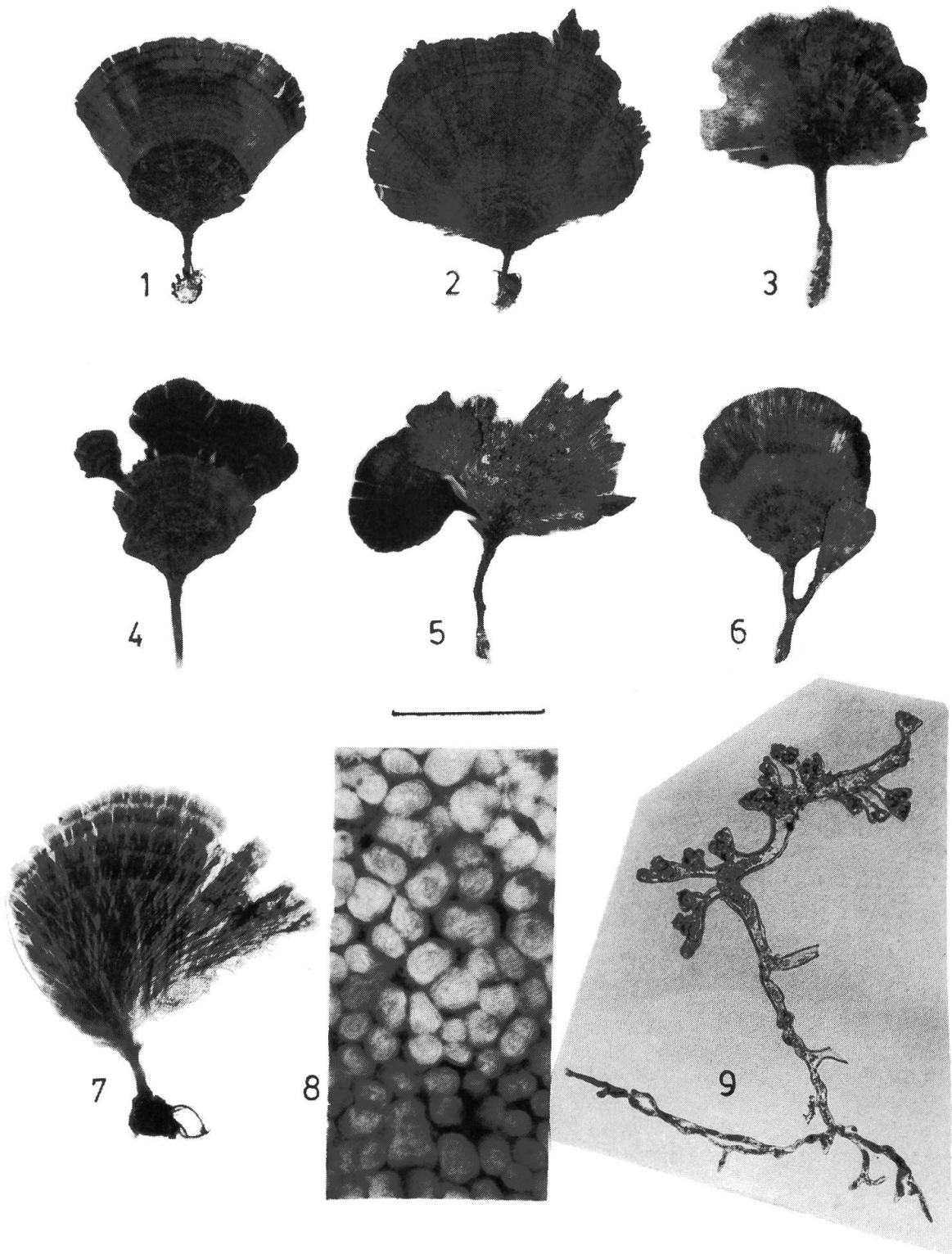


Fig. 1-9. — *Udotea indica* A. Gepp & E. Gepp
 1-3, plants showing range of habit; 4 and 5, plants bearing branch fronds on mother blade; 6, plant indicating branching of stipe from middle, each branch bearing a blade; 7, plant exhibiting conico-discoid holdfast and diagonal arrangement of tiers of siphons in slightly teased out blade; 8, surface view of the blade; 9, rhizoidal branch (below, without appendages) continued distally into main siphon (with appendages) of stipe; (scale for figs.: 1 = 20 mm; 2, = 24 mm; 3-5 = 19 mm; 6 = 15 mm; 7 = 10 mm; 8 = 75 μ m; 9 = 360 μ m).

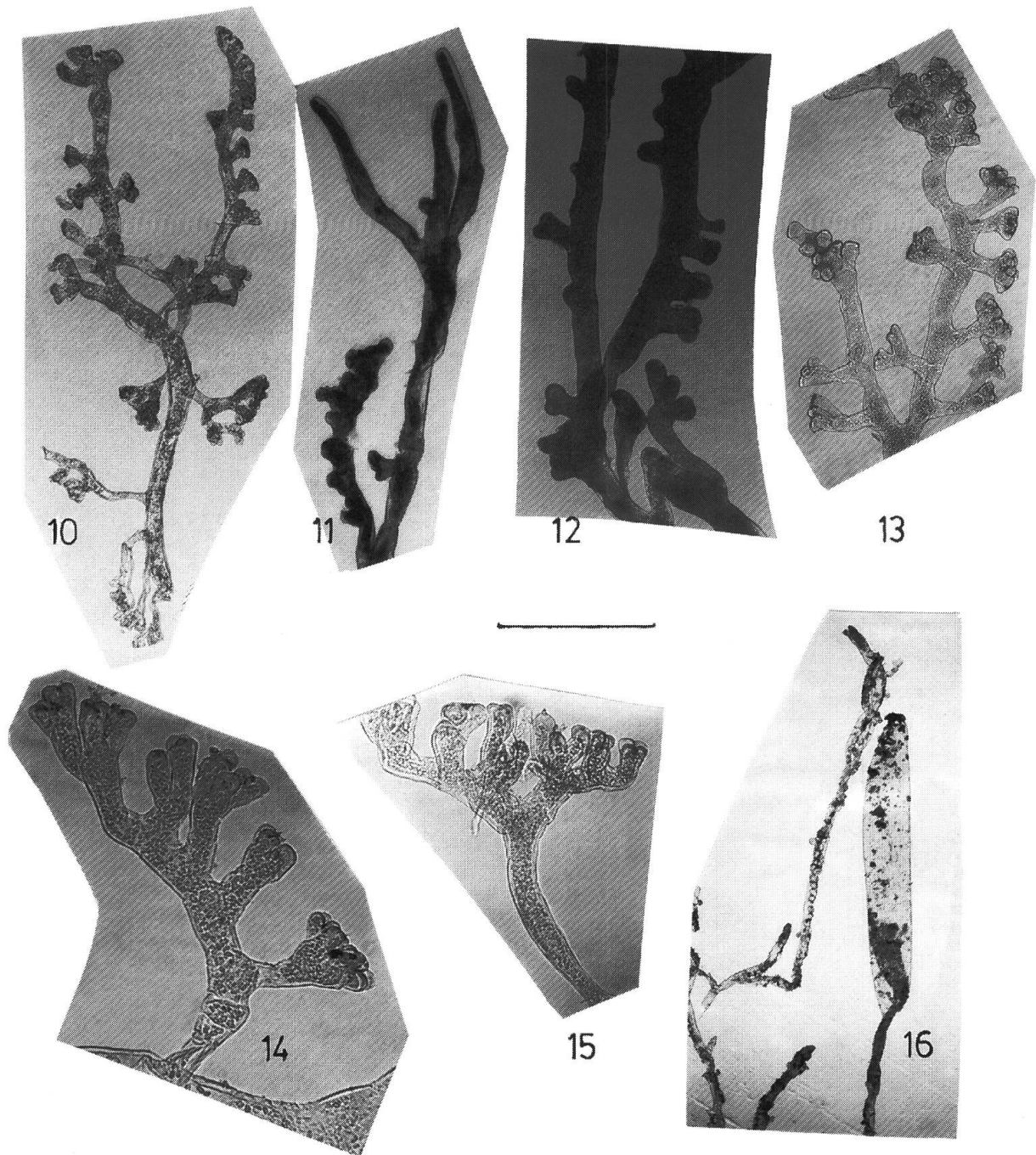


Fig. 10-16. — *Udotea indica* A. Gepp & E. Gepp

10, a siphon from distal part of the stipe ending in two branch siphons bearing simple to lobed papillae and branched to compound appendages proximally, branches also terminating in papillae; **11**, a blade siphon showing tapering terminal parts without appendages, a proximal branch bearing unilateral papillae; **12**, blade siphon (enlarged view) with simple papillae to lobed appendages with truncate or expanded heads; **13**, branch siphon of stipe bearing slightly biseriate but unilateral appendages, lobed to branched; **14**, a compound appendage of stipe siphon (enlarged view); **15**, a well branched appendage of stipe siphon (enlarged view); **16**, blade siphon with terminal reproductive organ (probably empty), with a darkly stained plug-like structure covering the opening at distal end; (scale for figs.: **10** = 412 μm ; **11** and **13** = 300 μm ; **12** = 216 μm ; **14** = 143 μm ; **15** = 150 μm ; **16** = 98 μm).

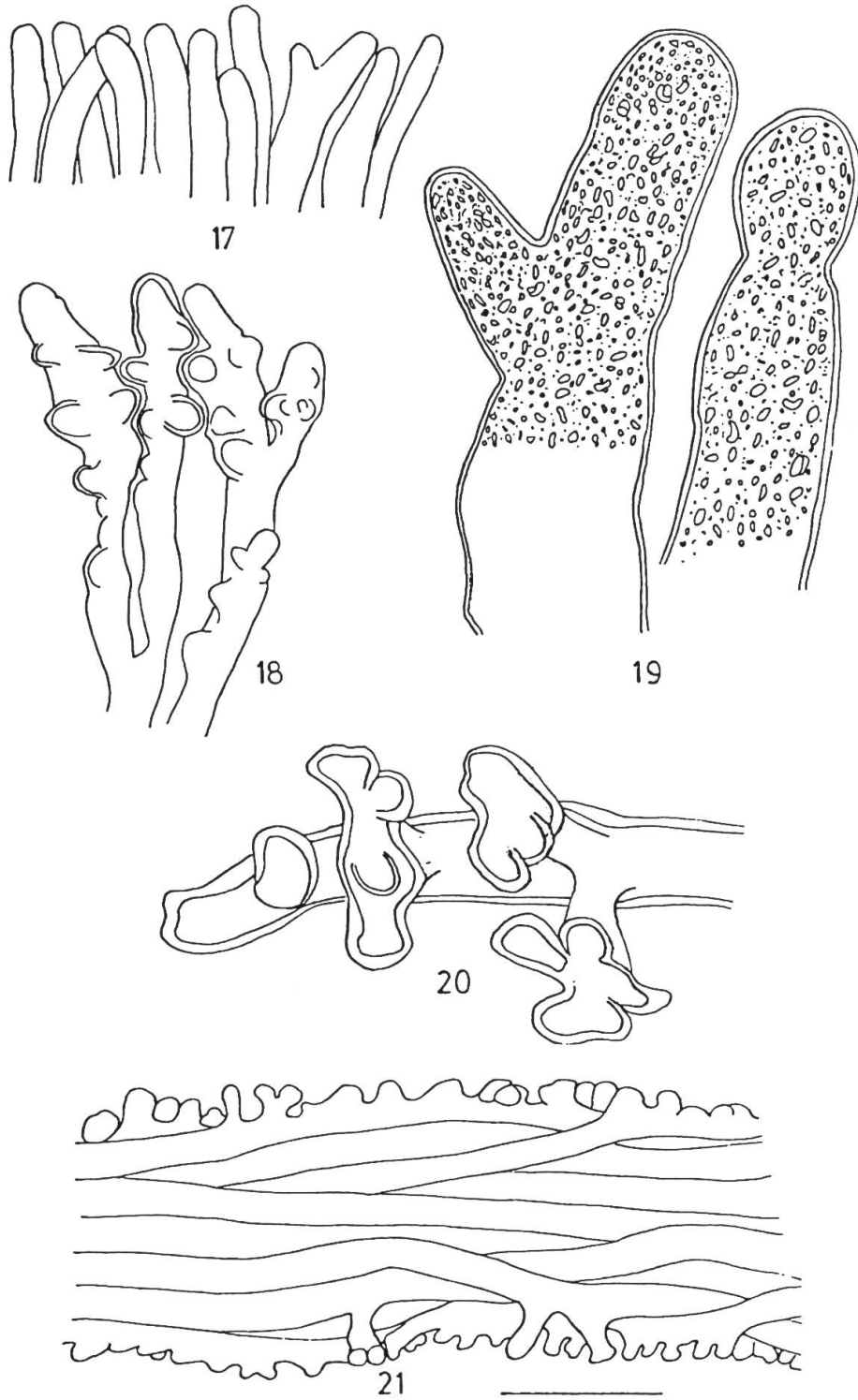


Fig. 17-21. — *Udotia indica* A. Gepp & E. Gepp

17, distal margin of the blade showing loose arrangement of siphons due to the absence of papillae; 18, distal margin of a blade exhibiting compact arrangement of siphons due to the presence of papillae fitted together; 19, enlarged view of apical parts of siphons, one showing subdichotomous branching and the other a constriction just below the tip; 20, enlarged view of apical part of a branch siphon of the blade exhibiting unilateral but divergently branched papillae, which appear bilateral in low magnification; 21, L. S. of distal part of a blade indicating longitudinal arrangement of siphons and papillate surfaces (scale for figs.: 17 and 18 = 145 μ m; 19 = 36 μ m; 20 = 68 μ m; 21 = 148 μ m).

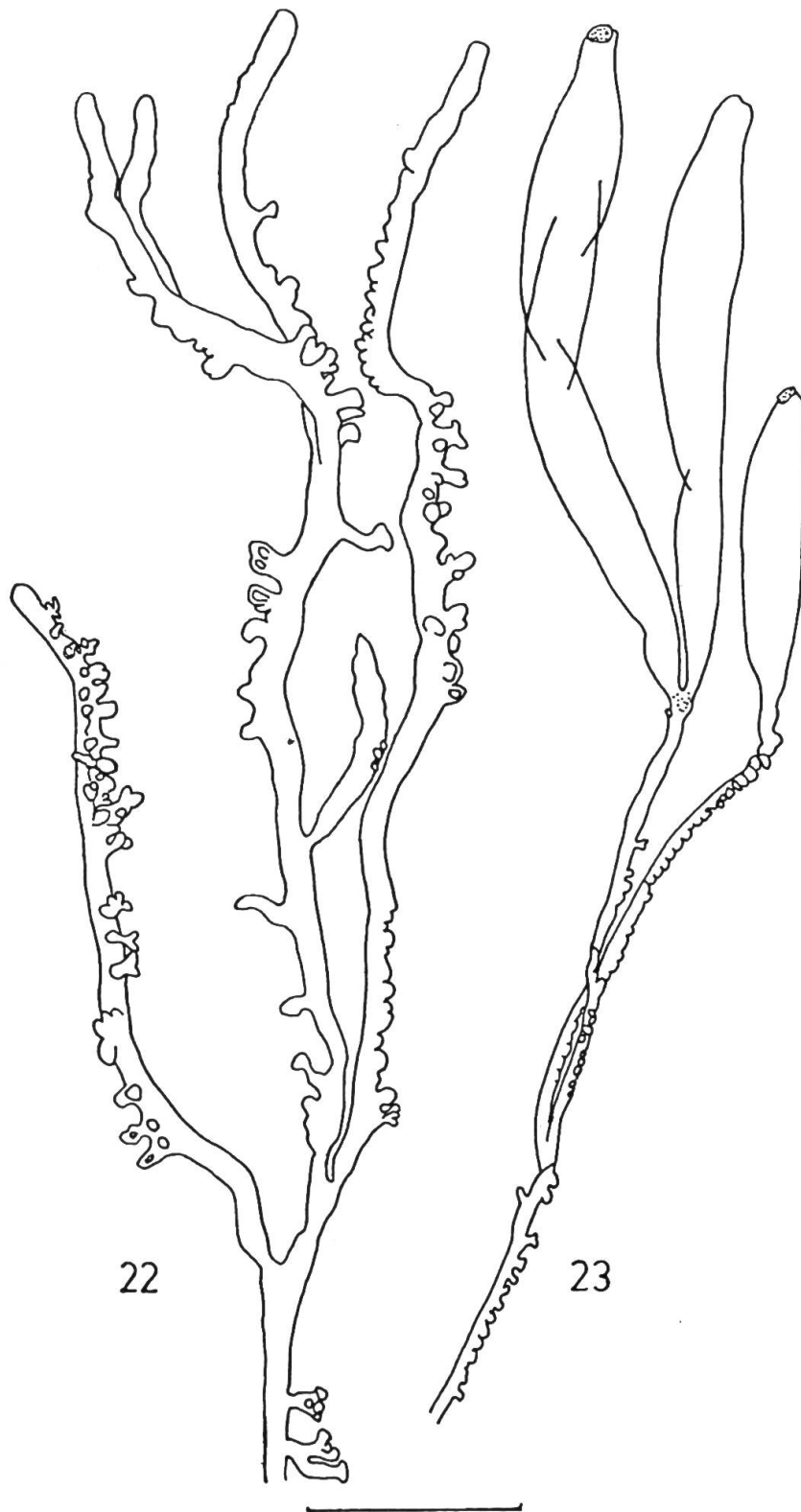


Fig. 22-23. — *Udotea indica* A. Gepp & E. Gepp
22, a vegetative blade siphon showing pattern of branching, types and arrangement of appendages and unequal constrictions in the basal parts of dichotomies; 23, blade siphon bearing terminal reproductive organs singly as well as in pair (scale for figs.: 22 = 333 μ m; 23 = 73 μ m).

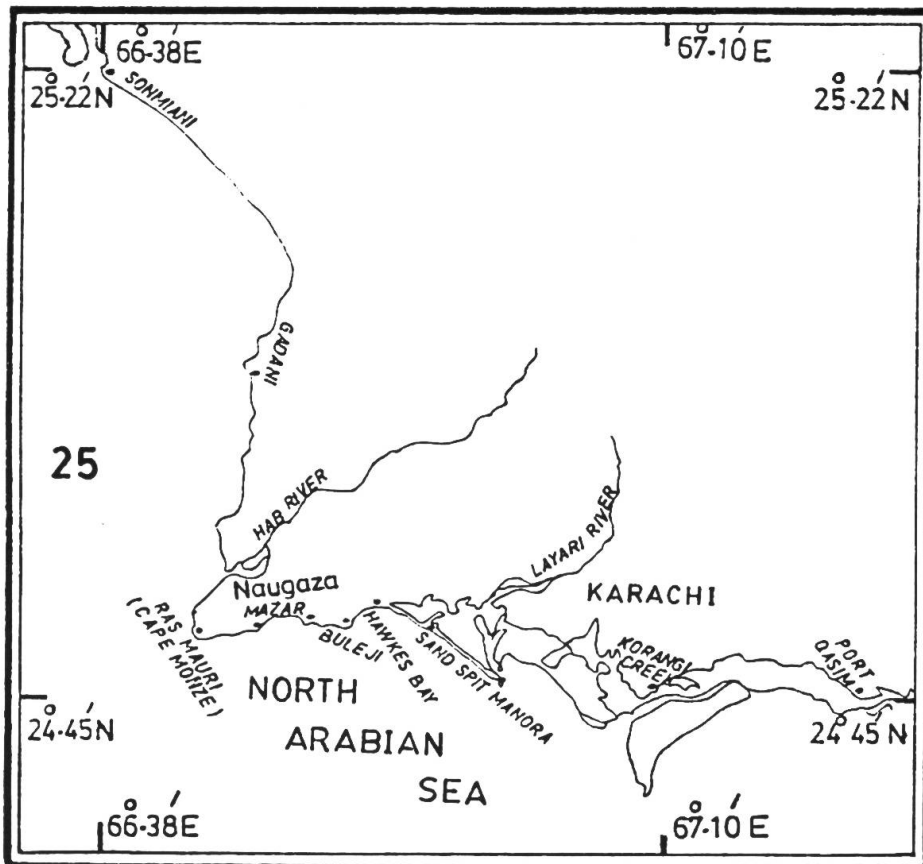
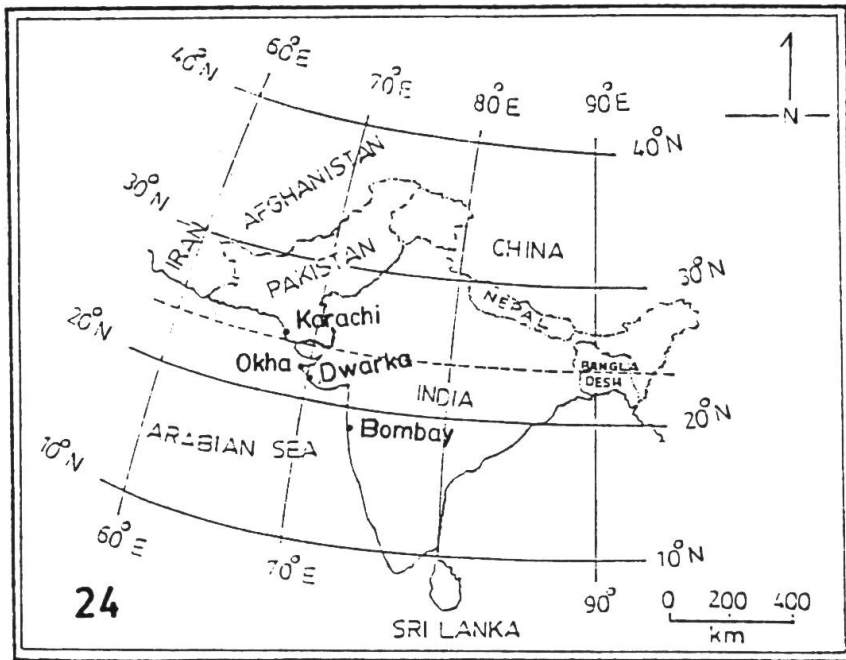


Fig. 24-25. — Geographical maps.
 24, map showing geographical positions of Pakistan and India and earlier sites of collection of *U. indica*; 25, map showing localities of collection and occurrence of *U. indica* on the coast of Pakistan.

Habit

The plants are upto 58 mm long, green in colour, slightly calcified, tough in consistency with rough surface. They grow as individuals or in groups of two to three from the same attaching mass. Each plant consists of an attaching system or holdfast, a stipe and a flat, fan-like blade, which is distinctly zonate (Fig. 1-6). The holdfast is made up of an entangled mass of rhizoidal siphons, which also grab sand particles inbetween them and the mass becomes hard to touch, elongated to bulbous or conicodiscoid in appearance (Fig. 7), upto 10 mm long and 4 mm broad or broader when the plants grow in groups. The stipe is cylindrical below, becoming oblong to compressed distally, 1.0-1.8 mm broad and 5-14 mm long. Sometimes a stipe gets branched into two, each bearing a blade (Fig. 6).

The blades are triangular with broadly rounded distal margin, half moon-shaped to orbicular in outline (Fig. 1-3), upto 45 mm long and 48 mm broad. They usually are more or less as long as broad, but their height may be longer or shorter than their breadth. The blade margin may be entire, lacerated, or lobed. The blades may bear proliferations or branched fronds at their distal margin, which slightly overlap each other laterally and are in same plane (Fig. 4 and 5). But sometimes a lobe is also seen arising proximally from the central axis of the blade.

Surface view of the thallus

The microscopic examination of the surface of blades reveals the presence of closely placed, roundish-oblong bodies, upto 43 μm long or broad, these are lobes or tips of appendages (Fig. 8). At the distal margin of the blade apical parts of the siphons are clearly seen, which are arranged closely more or less parallel and with obtuse tips. The blade appears two to three layered at margin and becomes multilayered proximally. The siphons may produce lobed projections or papillae just below the tips downward, which are closely fitted together forming a compact margin (Fig. 18), or they increase in length without producing projections so that the margin remains slightly loose consisting of finger-like projections (Fig. 17). In a slightly teased out frond the siphons appear radiating from base to apex in tiers or layers, and the siphons of one tier may be seen diagonally from that of the other (Fig. 7).

Anatomical description

In L. S. the blade is upto 310 μm thick consisting of (5-)-6(-7) siphons arranged longitudinally subparallel to slightly intermingled, not compact throughout but with interspaces inbetween them. The peripheral siphons bear projections or appendages directed outward, due to which both the sides appear papillate (Fig. 21).

The siphons do not stick to one another and are easily separable, coenocytic throughout, filled with many small discoid to oblong chloroplasts, upto 5 μm long or broad, easily visible under microscope. The main siphon and its branches are more or less of same breadth throughout except at apices, which may become narrow and taper to obtuse tips (Fig. 11 and 19). The tips may also appear broad due to formation of lobes or projections. The branching in the siphons is subdichotomous to lateral with a shallow constriction at the base, the parent siphon may also show a constriction above it (Fig. 22). Their walls are 2-8 μm thick and may be striated. The blade siphons are upto 60 μm broad and stipe siphons upto 75 μm . In the latter the constrictions may or may not be distinguishable but their walls usually are thicker and well striated (Fig. 19).

The siphons may be naked or beset with projections or outgrowths intermittently, closely to sparsely, sometimes only one, two or three projections are seen at a place, but usually many projections grow closely in single unilateral rows, which sometimes appear biserrate (Fig. 13 and 22). Their growth appears to occur on that surface of the siphon, which becomes exposed to the exterior. The outgrowths range from simple papillae to variously branched structures, known as appendages (Fig. 11 and 12). The papillae may be shorter or longer than breadth of the siphons, simple to lobed or slightly branched, with no differentiation of stalk (Fig. 18 and 20). The appendages are upto 320 μm long, consisting of a basal stalk-like structure and an unbranched to branched and lobed head. The stalk is upto 200 μm long, 20-30 μm broad, usually narrow above the base or in the middle (Fig. 14 and 15). The head is bi- to multilobed appearing truncate to swollen or expanded, or digitately branched sparingly to repeatedly into an umbellate structure (Fig. 15 and 20). The

stalks may also become branched forming compound appendages of various lengths (Fig. 10 and 14). All types of outgrowths terminate in broadly rounded or obtuse apices, which are fitted together so as to form the corticated surface of the thallus.

The blade siphons usually bear papillae, which are densely populated on peripheral branch siphons and may appear like rounded teeth of a saw (Fig. 23); however naked branch siphons were also observed (Fig. 11). The papillae may be lobed divergently in such a manner that they appear bilateral (Fig. 20). The main siphons of the blades also bear lobed to sparingly branched appendages usually less than 200 μm long, but longer were also found (Fig. 12). The stipe appendages usually are longer and digitately branched, but papillae are also found on distal parts of the peripheral branch siphons (Fig. 10 and 13). The siphons of stipe are continued below as attaching rhizoids, branching irregularly, becoming thin distally, without appendages (Fig. 9). The ultimate branches of the rhizoids are 7-20 μm broad, ending in obtuse to truncate or minute padlike structures.

Reproductive structures

A few plants have been found bearing oblong-elongate sack-like structures, hanging free in the form of a narrow frill at the distal margin of the blade or lying attached on its either surface easily visible in surface view. These are specialized terminal parts of siphons and appear to be fertile organs of the plants, upto 2.6 mm long and 0.3 mm broad, broadly obtuse at distal end when young but become narrow or papillate when mature (Fig. 16 and 23). A thickening of the wall has been observed at the base of young reproductive bodies and a darkly stained plug-like structure at the distal end of mature ones. The gametes or zooids have not been observed in them, they were either empty or contained contents similar to that found in vegetative siphons.

In the fertile plants a critical examination of different stages of the specialized terminal parts of the siphons reveals that the growth of the reproductive bodies is initiated at the tips of normal vegetative siphons, which become swollen and rich in cytoplasmic contents. They gradually increase in size becoming oblong-elongate structures, 5-7 times broader than mother siphon and initially containing cytoplasmic contents similar to that of mother siphon. A second reproductive body is seen arising beside the previous one from the same siphon (Fig. 23).

Discussion

The generic characters of the genus *Udotea* Lamouroux 1812 as defined by LITTLER & LITTLER (1990) are: "(1) an uncalcified basal, rhizoidal mass (= holdfast), (2) an upright corticated stalk (= stipe) and (3) a funnel- or fan-shaped terminal blade (= flabellum)". According to them the blades are composed of dichotomously branched siphons, which in some cases bear simple to variously compound lateral appendages, their stipes consist of central and longitudinal siphons surrounded by lateral appendages, which form a distinct cortical layer. All these characters are clearly exhibited by the specimens examined in the present work and their placement in the genus *Udotea* is beyond doubt.

Udotea indica was initially described from Karachi (Pakistan) by GEPP & GEPP (1911) and reinvestigated by NIZAMUDDIN (1963, 1969) for its reproductive bodies. Nevertheless, it could not be collected by ANAND (1940) from Karachi but has been reported from the neighbouring coast of Lasbela as well (SHAMEEL & al., 1989). This species is characterized by flabellate blade with simple or sparingly branched unilateral appendages, which are only present on the exposed and outer blade siphons. BØRGESSEN (1930, 1934) also identified this species from Okha Port, Okhamandal, Dwarka (India) on similar characters but the Indian plants were twice the size of the plants of Karachi (Pakistan). In present studies the plants were found to be highly variable in habit as well as internal structure. The shape of the blade is broadly to narrowly fan-shaped (making an angle of about 45° with the stipe) which gradually varies to half moon-shaped (making an angle of 180° with the stipe) on the one hand and to orbicular (side margins becoming roundish) on the other hand (Fig. 1-3). The margins may be entire, lacerated or lobed. The lobes usually are given

off from the distal margin but are occasionally seen attached near the central axis in the proximal part of the blade. The latter condition is also reported in *U. caribaea* Littler & Littler (LITTLER & LITTLER, 1990) but with larger lobes.

In the present species the marginal lobes sometimes get converted into branch fronds appearing like mother frond (consisting of a stipe-like structure and a fan-shaped blade, Fig. 4 and 5). Thus the tendency of producing lobes brings the present species close to *U. dixonii* Littler & Littler and *U. flabellum* (Ellis & Solander) Howe, which bear many such lobes. That is why *U. flabellum* growing in Krusadai Island (India) was initially misidentified by CHACKO & al. (1955) as *U. indica* but later on corrected by KRISHNAMURTHY & JOSHI (1970). The other tendency of producing branch fronds makes *U. indica* nearer to *U. occidentalis* A. Gepp & E. Gepp, which produces many such branch fronds from distal and basal surface. The branching of the stipe has also been observed from just above the holdfast to the middle of the stipe. This tendency makes this species quite different from others. However, branching of the stipe is also reported in *U. norrisii* Littler & Littler but its mode of branching is quite different from that of the present species.

The attachment system of the present populations of *U. indica* is also variously shaped from elongated to bulbous or discoid. The former character has been reported in *U. caribaea* and *U. spinulosa* Howe while the latter in *U. flabellum* Howe and *U. looensis* Littler & Littler etc. The present studies show that this variation in the plants under study is due to the variable nature of the substratum. The attachment system penetrates deep in soil or soft substratum forming elongated structures, on hard substratum it forms bulbous or discoid structures.

The type of cortication on the plants and the arrangement and structure of the appendages on the siphons are considered to be important characters from phylogenetic point of view (AGARDH, 1886; GEPP & GEPP, 1911; LITTLER & LITTLER, 1990). Ecortication is considered as a primitive character, which gave rise to partial cortication and then to complete cortication. *Udotea indica* has been placed in the group of partially corticated species along with *U. palmetta* Decaisne and *U. papillosa* A. Gepp & E. Gepp (GEPP & GEPP, 1911; FARGHALY, 1980). The microscopic examination of the surface of present plants reveal a complete cortication of both stipes and blades (Fig. 8). The stipe is strongly corticated in the sense that its siphons are not easily separable, their appendages are much branched and the tips interlock with those issuing from the neighbour siphons in such a manner that they hinder their separation. The blades are weakly corticated in the sense that their appendages are simple or lobed, the lobes simply acquire the space available in between the lobes issuing from the adjacent siphons, in such a manner that they do not hinder their separation.

The individual siphons of the present plants are partially corticated. The siphons of both stipes and blade bear lateral appendages in unilateral rows interrupted by short or long intervals, where the siphons are naked or without appendages. In fact the growth of the appendages takes place only on that surface of the siphon which is exposed to the exterior. Such condition is also exhibited by *U. palmetta* and *U. spinulosa*, which also bear unilateral appendages only on the exposed, outer blade siphons.

In the present studies the appendages were found to be highly variable in size and branching, ranging from small, simple papillae (may be smaller than the width of a siphon) to variously branched structures as long as four times the width of the siphon or more. The surface of the blade is entirely covered by simple or lobed papillae and that of stipe by branched appendages, but the latter were also found on the blade siphons and former on stipe siphons to some extent. The tips of the appendages are broadly rounded or obtuse and usually are bifid to multifid making the apices appear swollen, expanded or truncate. The blunt tips of the appendages are considered to be a derived character (LITTLER & LITTLER, 1990). Thus the present populations exhibit both primary (simple, papillose appendages) and derived (branched appendages with blunt tips) characters.

The reproductive organs were also observed in some plants collected from Sonmiani beach, which were different in shape and size from those reported by NIZAMUDDIN (1963). He found them to be 16 mm long and 2.5 mm broad with a thick constriction in the middle (NIZAMUDDIN, 1969), but in the present case they were only upto 2.6 mm long and 0.3 mm broad, without a constriction in the middle (Fig. 16 and 23). The present organs more or less resembled those of *U. avensis* A. Gepp & E. Gepp except that they were longer bearing long tapering ends (MEINESZ, 1980a,

b). In the present plants upto two reproductive bodies were seen arising terminally on a siphon, which probably showed that both the sister dichotomies of a siphon have a tendency to develop into reproductive organs.

In the present study, all the investigated populations exhibited more or less similar variations, which were found within each population and not between the populations. Since the ecological conditions are almost similar and all populations exhibit similar characters, there is nothing to correlate. Therefore, these populations were included in a single species. At the end it may be concluded that: 1) the populations under study should be retained in the single specific entity of *U. indica* and 2) no character warrants their placement into a separate genus, *Decaisnella* as has been done by FARGHALY (1980) and followed by others (SHAMEEL & al., 1989; SHAMEEL & TANAKA, 1992). The creation of a separate genus *Decaisnella* Farghaly was primarily invalid as it was not accompanied by a Latin diagnosis. Similarly the binomial *D. indica* (A. Gepp & E. Gepp) Farghaly was either not validly published. Furthermore, the characters on the basis of which *Decaisnella* was separated from *Udotea* by FARGHALY (1980) e.g. mono- or distromatic and foliaceous fronds with incomplete margin, without proliferation, simple papillate appendages, little calcification, filaments of the fronds trichotomous, were not found constantly in the investigated populations.

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