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STRUCTURE, DEVELOPMENT AND REPRODUCTION OF A NEW SPECIES *SCINAIA SAIFULLAHII* (BONNEMAISONIALES, RHODOPHYTA) FROM THE NORTH ARABIAN SEA

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Scinaia saifullahii Afaq-Husain *et* Shameel, a new taxon of red algae belonging to the group of cylindrical and unconstricted species of *Scinaia,* from the coast of Pakistan has been described. Its vegetative, anatomical and reproductive structures were studied critically. These plants may be distinguished from other species of *Scinaia* by their large size (up to 25 cm), generally large distance between successive furcations (up to 60 mm) and relatively large cystocarps (up to 300 μm diameter). Size and shape of urticles, hypodermal cells, carposporangia and carpospores together distinguish it from allied species.

Key words: Rhodophyta, Bonnemaisoniales, Galaxauraceae, Pakistan, *Scinaia.*

Introduction

The coast of Pakistan has a diverse algal flora [1], with algae belonging to the order Bonnemaisoniales very poorly studied along the coast of Karachi [2] and other coastal areas of the country [3,4]. Specially little known from Pakistani waters are species belonging to the family Galaxauraceae. During a survey of the marine algal flora of the Karachi and Lasbela coasts, several interesting red algae have been found [5-7]. A variety of forms attributed to the genus *Scinaia* Bivona-Bernardi grow on these coasts and may be grouped into four categories: (i) cylindrical-unconstricted forms, (ii) cylindrical-constricted forms, (iii) constricted into beaded and (iv) a flat form. These types may contain more than one species but at present it is very difficult to differentiate them because of the wide range of variations in different characters that overlap or appear similar even within the same group.

The present studies on a member of the cylindrical-unconstricted forms show that it differs from existing species of *Scinaia* to such an extent that it can be regarded as a new specific entity. These plants are found on either side of lower mark of the tidal zone, the larger ones grow subtidally and the smaller ones above the lowest tide mark. They were observed during November-February when the tide level fell to about zero during the day. Its habitat, vegetative, anatomical and reproductive structures have been investigated and are presented in detail.

Materials and Methods

The specimens were collected *in situ* as well as from the drifted at four study stations, namely Manora, Paradise Point, Naugaza Mazar and Cape Monze since 1985 to 1991 each year during the period November-February. These stations lie up to 30 km westward of Karachi Port (Pakistan) and comprise sandy to rocky shores. Specimens were fixed in 4% formalin-seawater solution on the spot and mounted on herbarium sheets which are kept in the Herbarium of PCSIR, Karachi (CLH) and the Seaweed Herbarium, MAH Qadri Biological Research Centre, University of Karachi (KUH-SW). About 40-50 specimens of different sizes from each station were studied. The largest plants were found at Naugaza Mazar and Cape Monze only.

The staining of different parts of the thalli was carried out in 1% aniline blue for 24-48h, either directly (for section cutting) or after treatment with 10% HCl for 24-48 h (for squashing to study the cells). The cross sections were prepared and stained as described earlier [5]. The temporary slides were made in distilled water or in a mixture of glycerine+acetic acid+distilled water (1:1:1, v/v) and permanent slides in Karo, a pancake syrup. Drawings were made with the help of a camera Lucida.

Observations. The following are the characters studied in detail of the new alga, *Scinaia saifullahii* Afaq-Husain *et* Shameel:

Morphological characters. Thalli are up to 25 cm long, brownish red to dark red, mucilaginous, cartilaginous (tough in consistency, not soft), cylindrical, 1-2 mm in diameter and not constricted. Holdfast discoid, 1-2 mm broad, giving rise up to 5 axes. Stipe harder than rest of the thallus, up to 5(-11) mm long, less than 1 mm broad at base, becoming up to 2 mm at distal end. Branching commonly dichotomous but trichotomies also observed, sometimes lateral branches also arise, up to 14 times branched, angle of branching usually broad. The

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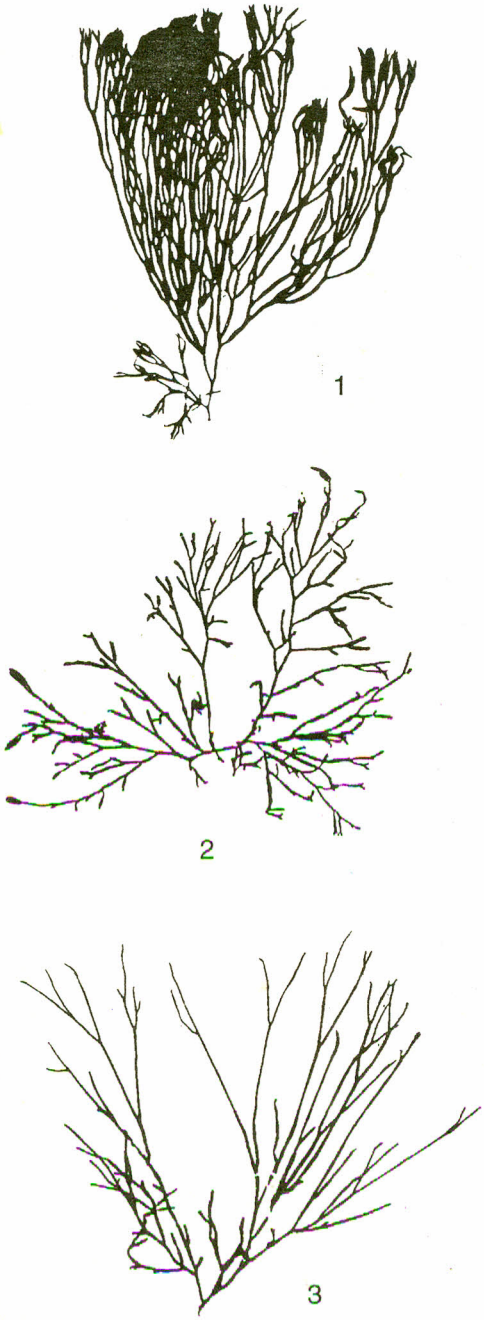
segments between 2 consecutive dichotomies vary in length from 3 to 60 mm in different plants as well as within the same plant, the shorter ones in the proximal region and the longest in the distal (Figs. 1-3). The apical segments when small appear spindle-like under a dissecting microscope, 1 mm broad, slightly tapering to obtuse at the tips which are recessed. The axial strand is not visible with the naked eye either in formalin-preserved or dried specimens.



Figs. 1-3. *Scinaia saifullahii* Afaq-Husain *et* Shameel sp. nov.
1. Holotype, a preparation on a herbarium sheet. 2 & 3. Plants showing habit, preparations on herbarium sheets.

Surface view of the thallus. When the surface of the thallus is examined microscopically 2 types of cells are differentiated; large colourless cells (the utricles) of 10-19 µm dia., round but appearing angular due to the presence of a second type of cells which are small, coloured and 5-12 µm in dia., surrounding the colourless cells (Figs. 4&5). Sometimes very small, 3-5 µm dia., dark coloured cells are also seen, 1-3 in one place in between the above cells (Fig. 5), their exact nature is not clear but these cells may be monosporangia.

Anatomical features. The thallus construction is typical of *Scinaia* [8,9]. The axial core is 200-300 µm in dia. and cortical region (peripheral zone of closely placed cells) 60-70 (-90) µm broad. The medullary filaments are made up of much elongated cells of different shapes and sizes, 2-9 (-16) µm in dia. (Fig. 8). The cortex is of the *S. forcellata* type [9,10] (Figs. 4 &5). The colourless utricles are oblong or oval, and may be slightly flat above becoming rectangular-like in T.S. (Figs. 6 & 7), (20-) (29-33) (-41) µm long x (10-) 15-20 (-24) µm broad, usually longer than broad but ones broader than long or as long as broad are also observed. Below the utricles the pigmented cells are usually globular-cuneate but oblong-elongate or conical are also present, 7-19 µm long x 7-14 µm broad (Figs. 6 & 7).

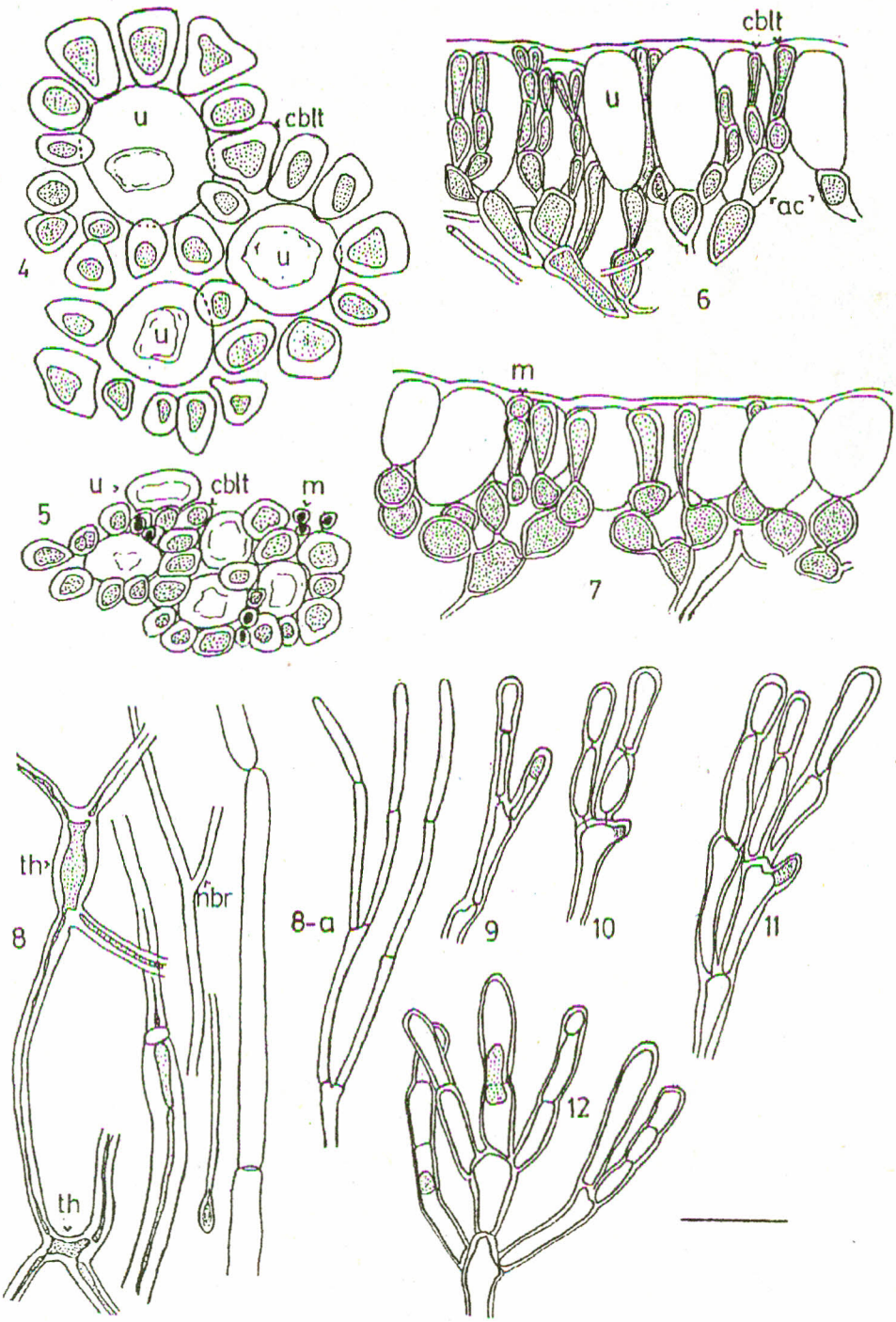
Growth of the thallus. The growth of the thallus is similar to multiaxial type [9, 11]. The growing points consist of a group of thin, cylindrical, sub-dichotomously divided filaments which are more or less 1 µm broad (Fig. 8-a) and whose apical cells divide by cross walls to produce daughter cells posteriorly. Each of the latter may give rise to one daughter branch from their distal ends which grow radially giving sub-branches repeatedly in a sub-dichotomous manner. In the distal region these branches and sub-branches become sub-trichotomous repeatedly so that the branch system becomes congested distally (Figs. 9-15).

Primarily all the cells contain pigments and are similar in appearance (Fig. 31) but soon differentiation starts into the outer colourless cells (or utricles) and the inner assimilatory cells which are two layered (Figs. 13, 15, 16 & 18). It is commonly observed that during development, one of the ultimate cells (probably the oldest) of the branch system starts turning first into an utricle and emerges above the other branches of the system (Figs. 11 & 14), but later on the smaller branches grow to the same level (Figs. 15 & 18).

The cells, which bear utricles, also give rise to narrow, 1-3 cell long branchlets, which grow along between the utricles (Figs. 6, 7, 16 & 18). The cells contain plastids and in surface view they appear rosette-like, surrounding the colourless utricles (Figs. 4 & 5). The basal cells of these branchlets are also rich in plastids and in turn may also give rise to a secondary utricle and produce secondary coloured branchlets

in a similar way to the parent branch. Sometimes from a young branch filament (Fig. 31), or a coloured branchlet (Fig. 16), a small and broad cell cuts off terminally which becomes large, round and densely filled with cytoplasm, 3-5 (-7) µm broad. Its function is not clear but it may be a monosporangium.

Reproductive structures. The plants are monoecious;

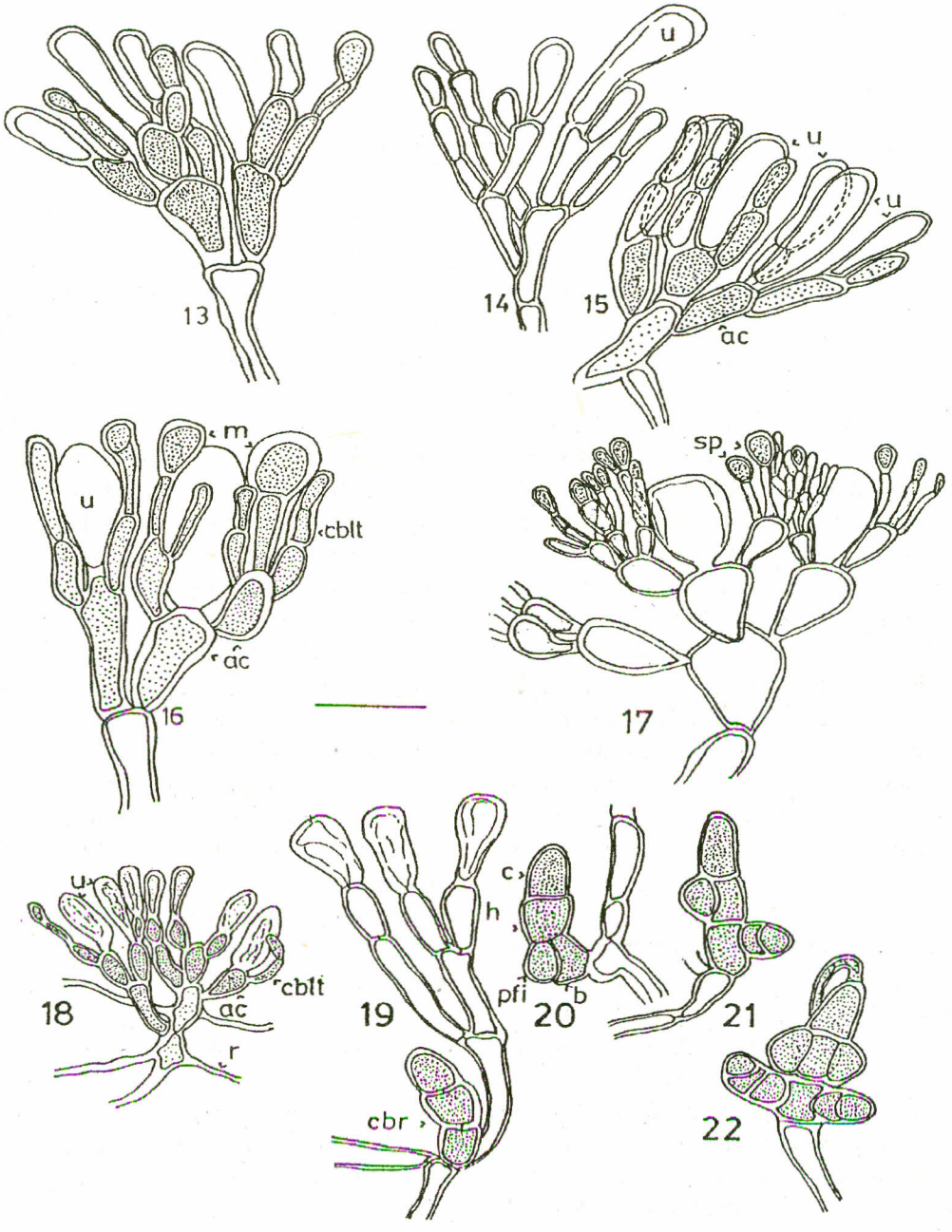


Figs. 4-12. *Scinaia saifullahii* sp. nov.

4 & 5. Surface view of the thallus showing colourless utricles surrounded by coloured cells. 6 & 7. Cross section of cortex from different plants showing arrangement, variation in size and shape of utricles, assimilatory cells, coloured branchlets and monosporangia-like bodies. 8, Different types of medullary filaments and cells. 8-a. A branch of a filament system arising from a growing point, with slender, elongated cells. 9-12. Young cortical filaments showing stages in development of cortical branch system. 9. A very young cortical branch with the initiation of a sub-dichotomy. 10 & 11. Showing initiation of a third branch. 12. Slightly older branch showing sub-trichotomous condition. (ac = assimilatory cells, cblt = coloured branchlets, m = monosporangium-like body, th = small and broad cell from which branch filaments arise, nbr = new branch, u = utricle).

spermatangia and carpogonia are found on the same plants.

Spermatangia. They are borne in sori-like patches on the surface of the thallus near its tip. The spermatangial branches arise in clusters between the utricles from the hypodermal cells. These cells may be unbranched and bear spermatangia on a long stalk-like cell or may be branched and consist of 2-3 smaller cells (Fig. 17). Usually 1, but sometime 2 spermatangia are borne terminally on a branchlet and are easily visible in surface view emerging above the utricle. The spermatangia are oblong, 3-5 µm long x 2-3 µm broad, each pro-



Figs. 13-22. *Scinaia saifullahii* sp. nov.

13-16. Different stages in the development of a cortical system. 13. A branch with differentiation of utricles and assimilatory cells. 14. A branch with 1 utricle projecting above the others. 15. A branch system in which all the utricles and coloured branchlets reach the same length. 16. Monosporangia-like cells on the branchlets. 17. A part of a cortical branch system bearing spermatangial branches with terminal spermatangia. 18. A young cortical branch system showing conversion of apical cells. 19. A young cortical branch bearing a young 3-celled carpogonial branch. 20. Carpogonial branch with first filament initial arising from the basal cell. 21. Carpogonial branch showing first filament arising from the basal cell and first daughter cell from the hypogynous cell (in Figs. 19-21 trichogyne not initiated). 22. Carpogonial branch with a young trichogyne showing two filaments (2-celled & 3-celled) from basal cell and first and second hypogynous daughter cells. (ac = assimilatory cells, b = basal cell, c = carpogonium, cblt = coloured branchlet, cbr = carpogonial branch, hypogynous cell, m = monosporangium-like body, pfi = pericarp filament initial, sp = sporangium, u = utricle.

ducing a single spermatium.

Carpogonia. The carpogonial branches are borne on the distal end of the 5th or 6th cell of young assimilatory branch systems. Their supporting cell usually bears 2 vegetative branches besides the carpogonial branch that is trichotomous (Figs. 19 & 23). The carpogonial branch is 3-celled (Figs. 19, 33 & 34), 18-25 µm long (without trichogyne). The carpogonium is broadly conical, 7.5-9.0 µm long and 3.0-5.4 µm broad at the base and becomes narrow distally (Figs. 22, 23, 35 & 36). The middle or hypogynous cell is smaller but usually slightly broader than the carpogonium, 4.5-6.6 µm long x 4.7-6.4 µm broad (Figs. 19 & 20). The 3rd or the basal cell is 5.4-9.4 µm long x 4.5-7.1 µm broad.

After formation of the 3 cells of the carpogonial branch, the basal cell starts dividing first by a vertical but slightly incurved wall to form the first initial of the pericarp filament which is about as broad as the mother cell (Fig. 20), then the second initial develops on the other side (Figs. 23, 35 & 36). By further divisions these initials form the pericarp filaments which develop around the middle cell of the carpogonial branch (Figs. 25, 26 & 32). After the initiation of the above filaments, the hypogynous cell also divides successively into 4 cells (Figs. 21-26, 35 & 36). First one cell is cut off on one side (Figs. 21 & 23), then the next cell on the other side of the hypogynous cell (Figs. 22 & 35). The third cell is cut off probably by either of the 2 daughter cells, so that all the 4 cells appear connected serially (Figs. 24 & 37). Moreover, in the young condition these cells are always unequal in size, one is larger (probably the mother cell, measured up to 18 µm in dia.) and one is smaller (measured up to 9 µm in dia.). During this period the pericarp filaments completely cover the middle cell product by repeated branching (Figs. 25, 26 & 32) and, finally form the sterile covering (the pericarp) of the cystocarp.

The trichogyne also starts developing after the formation of the first initial in the basal cell or even after the formation of the first daughter cell by the hypogynous cell. This stage is shown in the Figs. 20 & 21 in which the carpogonia branches do not bear a trichogyne but the branch bears either a filament initial only in the basal cell, or a 2-celled filament in the basal cell and a daughter cell from the hypogynous cell. Moreover, young trichogynes have been observed in the carpogonial branches, which are in a slightly more advanced stage of formation of filaments in the basal and middle cells (Figs. 22 & 23). The trichogynes are up to 70 µm long, 4-5 µm broad at the base, gradually taper distally and end in an obtuse apex, 1-2 µm broad; a constriction is always observed at the junction of the trichogyne and the carpogonium. It is also observed that the carpogonium remains emerged through the sterile covering for a long time without showing formation of gonimoblast initials (Figs. 25 & 32).

Cystocarp. Cystocarps are borne below the cortex, urn-shaped, 150-300 µm broad and 210-380 µm long with a neck which is 48-84 µm broad and opens to the exterior through an ostiole. The cystocarp encloses the gonimoblast which produces carpospores.

Gonimoblast. The gonimoblast consists of sub-dichotomously branched, closely placed filaments, the cells are up to 19 µm long x 6 µm broad. On maturation, 1-4 distal cells of the gonimoblast filaments increase in size and form carposporangia. They mature and discharge successively from the apex downward; 1-2 mature carposporangia are seen at a time (Figs. 27, 28 & 33); these are oval, oblong or more or less rectangular in outline, 8-17 µm long x 6-8 µm broad, each produces a single carpospore. The carpospores are round, oval or oblong, 7-14 µm long x 6-7 µm broad (Fig. 30). A second carposporangium may be seen arising within the previously discharged one (Fig. 29).

General characters. Plants up to 25 cm high, cartilaginous, up to 14 times dichotomously branched at wide angles; segments between successive dichotomies up to 60 mm long, unconstricted, cylindrical, up to 2 mm broad, with blunt apices. Utricles oblong-obovate, up to 41 µm long x 24 µm broad, surrounded by narrow coloured branchlets appearing like a rosette in surface view; hypodermal cells up to 19 µm long x 14 µm broad. Plants monoecious; spermatangia borne in small sori, 1-2 on each mother cell, oblong, up to 5 µm long x 3 µm broad; carpogonial branches 3-celled, up to 25 µm long (without trichogyne); carpogonium conical, distal up to 9 µm long x 5 µm broad; hypogynous cell produces 3 daughter cells in the form of one 1-celled and one 2-celled branches. Cystocarp urn-shaped, up to 300 µm broad; up to 4 distal cells of the gonimoblast filaments are converted into carposporangia, up to 17 µm long x 8 µm broad; carpospores roundish, oval or oblong 7-14 µm long x 6-7 µm broad. Secondary carposporangia develop within the old empty ones.

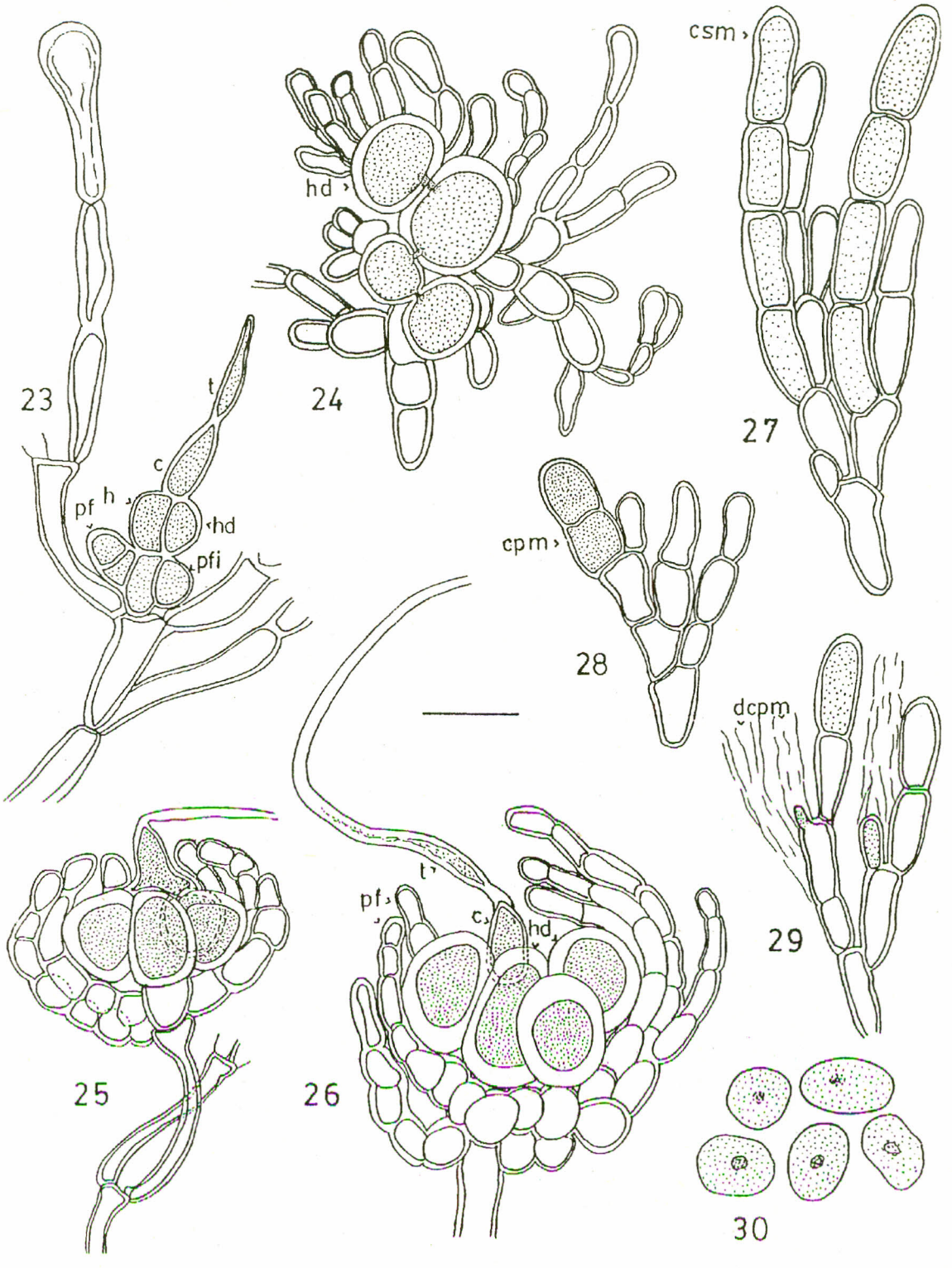
Holotype. H.Sc. 11 PCSIR (*Leg.* S. Afaq Husain 23-12-1988) Paradise Point, Karachi, Pakistan (Fig. 1).

Isotypes. H.Sc. 12, 13, PCSIR (*Leg.* S. Afaq-Husain 23-12 1988) Paradise Point, Karachi (CLH).

Other specimens examined. Manora (*Leg.* S. Afaq-Husain 11-11-1989, M. Shameel 27-1-1990, 16-2-1991); Naugaza Mazar (*Leg.* S. Afaq-Husain 26-11-1988, M. Shameel 19-12-1990); Cape Monze (*Leg.* S. Afaq-Husain 7-1-1985, 5-2-1985, M. Shameel 21-11-1991).

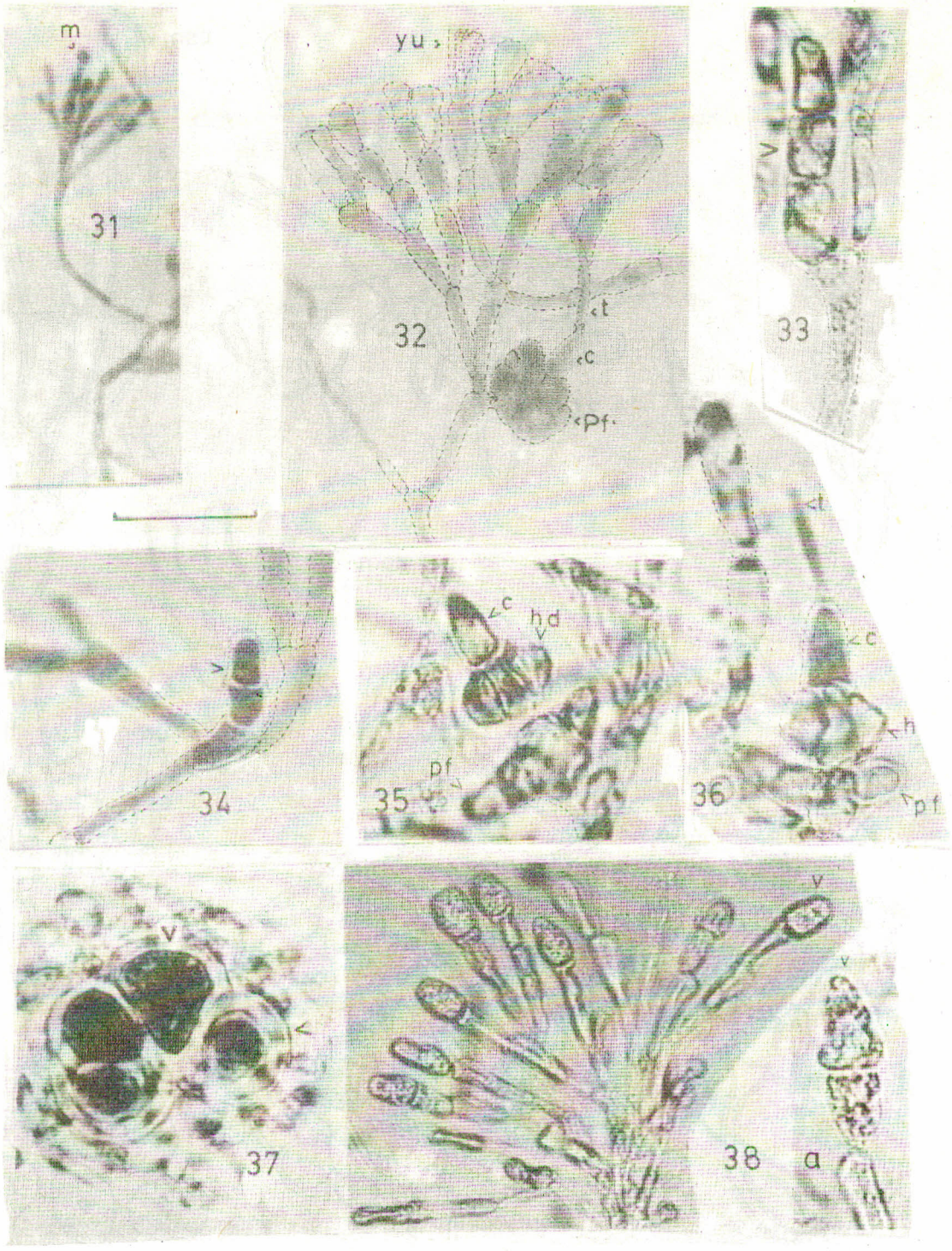
Habitat. This species grows on rocks in the lower part of littoral zone or below the tidal level.

The new species, *Scinaia saifullahii,* has been named after Prof. Dr. S.M. Saifullah, who has published several contributions on the mangrove ecosystem as well as on marine



Figs. 23-30. *Scinaia saifullahii* sp. nov.

23. Carpogonial branch with young trichogyne, showing first 2-celled filament, second initial from basal cell and first hypogynous daughter cell. 24. Four cells of hypogynous product (spread out by gentle tapping of coverslip) showing cytoplasmic connections serially arranged. 25 & 26. Mature carpogonial branches from different plants showing a long trichogyne, a carpogonium, a 4-celled hypogynous product and pericarp filaments developing around the hypogynous cell product. 27-28. Branches of the gonimoblast from different plants bearing 1-4 carposporangia varying distally in shape and size. 29. Secondary carposporangia developing within the discharged one. 30. Carpospores showing variation in shape and sizes. (c = carpogonium, cpm = carposporangium, dcpm = discharged carposporangium, h = hypogynous cell, hd = hypogynous daughter cell, pf = pericarp filament, pfi = pericarp filament initial, t = trichogyne).



Figs. 31-38. *Scinaia saifullahii* sp. nov.

31. A young cortical branch system with undifferentiated cells and a monosporangia-like body emerging terminally. 32. A young cortical branch system showing conversion of terminal cells into young utricles and the lower cells into assimilatory cells and a carpogonial branch with pericarp filaments completely covering the middle cell product and the carpogonium clearly visible above it. 33 & 34. Young, 3-celled carpogonial branch (arrow) from different plants (trichogyne not initiated). 35. Carpogonial branch showing one daughter cell on each side of hypogynous cell, and one 2-celled and one 1-celled filament arising on either side of the basal cell. 36. Carposporangial branch with a young trichogyne, hypogynous cell with 3 daughter cells in the middle (one cell slightly visible on the back) and one pericarp filament arising on each side of basal cell. 37. The hypogynous cell and its 3 daughter cells connected in series (cytoplasmic connections visible). 38. Gonimoblast branches bearing one terminal carposporangium (arrow) and 'a' showing two (enlarged view). (c = carpogonium, h = hypogynous cell, hd = hypogynous daughter cell, m = monosporangium-like body, pf = pericarp filament, t = trichogyne, yu = young utricle).

planktonic and benthic algae of Pakistan.

Discussion

The present plants of *Scinaia* are characterised by *S. forcellata* type of cortex [9], in which large colourless utricles are surrounded by smaller coloured or colourless cells. Among species which bear such a type of cortex, *S. australis* (Setchell) Huisman, *S. fascicularis* (Brgesen) Huisman and *S. snyderae* (Setchell) Huisman are similar in appearance to the present species; all these species are large in size with the cylindrical narrow fronds bearing large segments between 2 successive furcations. However, the present species differs from the above three in being larger in size, up to 25 cm and bears larger segments between successive dichotomies, varying up to 60 mm (Table 1). *Scinaia australis* and *S. snyderae* previously belonged to the genus *Pseudoscinaia,*

Table 1. Comparative Features of *Scinaia saifullahii* With Three Other Species of *Scinaia*.

Features	*S. saifullahii*	*S. australis*	*S. fascicularis*	*S. snyderae*
Plant height	25 cm	17 cm	15 cm	20 cm
Consistency	cartilaginous	soft	cartilaginous	--
Diameter of frond	1.5-2 mm	(0.3-) 1-1.5 (-2) mm	2 mm throughout	1-2 (-2.5) mm
Length of segments between successive dichotomies	3-60 mm sister segments of a dichotomy equal or unequal	4-35 mm sister segments equal	(10-) 15-20 (-30) mm	--
Branching	14 times dichotomous, rarely trichotomous	10-11 times dichotomous	8-10 times dichotomous	9-13 times dichotomous
Branch apices	slightly tapering to obtuse or blunt apices	distincly pointed	--	--
Utricle size and shape	(20-)29-33(-41) x (10-) 15-20 (-24) µm oblong, not conical below	20-47 x 18-37 µm (ovoid-oblong or conical, in figure)	26-36 x 12 µm (elongated pear-shaped, broad above, narrow below, in figure)	20-26 x 12-20 µm (ovoid, oblong, to broader than long or as long as broad, in figure)
Size of hypodermal cells	7-19 x 7-14 µm	10-35 x 10- 25 µm	8-10 µm diam.	--
Sexuality	monoecious	monoecious	monoecious	--
Spermatangia	3-5 x 2-3 µm borne 1-2 terminally on unbranched stalk-like or branched filaments	3 µm dia. borne 1-4 terminally on branched filaments	5 x 3 µm borne 1-2 terminally on stalk-like filaments	unknown
Carpogonial branch	3-celled, 18-25 µm long	3-celled	3-celled, 17-19 µm long	3-celled
Carpogonium	7-9 x 3-5 µm	--	8-9 x 5-6 µm	--
Hypogynous daughter cells	3 cells, in the form of one 1-celled + one 2-celled branches	3(-4) cells in the form of one 1-celled + one 2-celled (-3-celled branches)	3 cells, in the form of one 1-celled + one 2-celled branches	3 cells, in the form of one 1-celled + one 2-celled branches
Size of cystocarps (excluding neck)	150-300 µm	275 µm	195-255 µm	130-170 µm on resoaking
Carposporangia	8-17 x 6-8 µm in linear group of 1-4	10-14 x 7-10 µm	(up to 36 x 16 µm, in linear group of 4-6, in figure)	--
Carpspores	7-14 x 6-7 µm round, oval to oblong	--	9-19 x 5-15 µm oval to elongate	--

which was erected by Setchell on the basis that "gonimoblasts projecting into and also lining the walls of the sporiferous cavity" [12]. However, Huisman showed that the development of the gonimoblasts in the type species *P. snyderae* as well as in *P. australis* is identical to the genus *Scinaia,* therefore *Pseudoscinaia* was made synonymous to *Scinaia* and the 2 species were transferred to the latter genus by him [10].

Scinaia snyderae was described from California (USA) and has not been collected since its original description [13], as such its full description is not available and therefore cannot be compared. However, Huisman re-examined the pressed material of its holotype and gave a brief description on the basis of which it can be concluded that *S. snyderae* is a bit thicker than the present species [10], varying up to 2.5 mm, and its utricles and cystocarps are much smaller (Table 1). In the present species the utricles are about twice as long as in *S. snyderae.* Moreover, spermatangia are unknown in the latter species but are well defined in the present species.

Scinaia australis was described from Australia and is not reported from elsewhere [10]. It differs from the present species in being soft, with low number of branches and in having much smaller segments between successive dichotomies (Table 1). Moreover, the branch apices are distinctly pointed in the former species but obtuse or blunt in the latter. In *S. australis* the utricles are much broader and the hypodermal cells twice as large as in *S. saifullahii* but the cystocarps tend to be larger in the latter species than in the former. Moreover, spermatangia occur in small sori in the new species and in extensive sori in the Australian species, the spermatangial mother cells bear 2-4 spermatangia in the latter and 1-2 in the former.

Scinaia fascicularis was described and reported from India only which adjoins the coast of Pakistan and its occurence in the area of study is not out of the question. This species is the smallest among the 4 species under discussion; its less number of branches and much smaller segments together make it quite different from *S. saifullahii* (Table 1). The cortex of the present species is quite different from that of *S. fascicularis* as shown in Fig. 1, p. 165 by Desikachary and Singh [14]. The utricles are shown to be pear -shaped and much narrower (up to 12 µm broad in distal parts, however described as 16-18 µm broad in surface view), but these are broader, up to 24 µm and not pearshaped in *S. saifullahii.* Moreover, the proximal coloured (assimilatory) cells are shown to be broader than the utricles; Desikachary and Singh wrote "the inner cells (proximal coloured cells) of these anticlinal filaments are large and rounded and the outer cells are gradually smaller" [14]. Such a type of cortex in which the coloured cells are broader than the utricles, was not found either by Huisman [10, 15] or the present authors. The coloured cells do not surround the colourless utricles completely in *S. fascicularis* [14]: (Fig. 2, p. 165) as is found in the present species (Figs. 4 & 5 and other species [10, 15].

The appearance and mode of development of the spermatangia, the carpogonial branch and the hypogynous daughter cells are identical in *S. fascicularis and S. saifullahii,* but the formation of a small cell in the filament, on which the carpogonial branch develops is clearly shown in the former species but is lacking in the latter. The present species also differs from the former in the formation of carposporangia, which are much broader (up to 16 µm) and are produced in terminal series of 6 or more [14]: Fig. 4, p. 165), but in the present species up to 4 distal cells are converted into sporangia, and these are only up to 8 µm broad. Cystocarps also tend to be broader in *S. saifullahii* than in *S. fascicularis* (Table 1).

Thus *S. saifullahii* can be separated from the other species by its greater length and longest segments lying between successive dichotomies coupled with other characters such as shape and size of utricles and hypodermal cells and blunt branch apices. Moreover, *S. autralis, S. fascicularis* and *S. snyderae* are endemic to their type areas and thus separated by geography; the type locality of *S. saifullahii* falls in the vicinity of the type locality of *S. fascicularis,* which also suggests the possibility that the 2 species may be close to each other but quite distant from the Australian and American species. It is, therefore, proposed to give the present group of plants a separate specific status.

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