

OCCURRENCE OF THE GENUS *PADINA* (DICTYOPHYCEAE, PHAEOPHYCOTA) IN THE COASTAL WATERS OF KARACHI

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Abstract

Six fan-shaped, striated species of *Padina* Adanson were collected from northernmost part of the Arabian Sea and taxonomically investigated. This the first detailed taxonomic study of the algal genus from the coast of Pakistan, based on a large survey (1989-1996) of different coastal areas of Karachi. This study revealed two new records from Pakistan et al., *P. fraseri* (Greville) Greville and *P. vickersiae* Hoyt and two new species i.e. *P. afaqhusainii* Aisha et Shameel and *P. nizamuddinii* Aisha et Shameel. *Padina pavonica* (L.) Thivy and *P. vickersiae* were found to exhibit an unusual phenomenon, syntagmatic *in situ* germination, i.e. all the species dividing and merging into one outgrowth.

Introduction

Occurrence of the brown algal genus, *Padina* Adanson at the coast of Karachi was first reported by Anand (1940). It is an important member of the family Dictyotaceae (order Dictyotales, class Dictyophyceae, phylum Phaeophycota; *fide* Shameel, 2008) and develops a community at shallow rocky pools with sandy bottom from mid to lower littoral zones. Gradually its various species were found to grow at Karachi (Salim, 1965; Zahid *et al.*, 1983; Begum & Khatoon, 1988; Shaikh & Shameel, 1995), Lasbela (Shameel, 1987; Shameel & Afaq-Husain, 1987; Shameel *et al.*, 1989), Makran (Shameel *et al.*, 1996, 2000; Shameel, 2000) and other coastal areas of Pakistan (Shameel & Tanaka, 1992). Most of these investigations were simple ecological surveys, and no composite taxonomic study of this genus was ever carried out from any area of Pakistan. Therefore, the present investigation was undertaken, based on a large taxonomic survey.

Materials and Methods

Surveys were conducted of different coastal areas of Karachi (Pakistan) during 1989-1996. Algal thalli were detached from the rocks at mid and lower littoral zones and preserved in 4 % formaldehyde. Different parts of thalli were cut into thin slices with the help of shaving blade by free hand section cutting technique. Sections were stained in 1 % aniline blue for 5-10 minutes, one or two drops of 1M hydrochloric acid were added for 30 seconds and washed with seawater. The sections were then mounted in a solution of 75 % glycerin with aniline blue (75 mL Gly + 20 mL aniline blue + 5 mL distilled water). Finally the slides were sealed with the sealing material (Cutex) and observed under microscope (Nikon, Japan).

Results and Discussion

Padina Adanson 1763:13, *nom. cons.*

Thalli attached with a discoid, matted, rhizoidal, filamentous holdfast, single frond also common in some species; fronds yellowish brown, dark brown or olive green; stipe usually short, compressed to cylindrical, rarely flattened; calcification uncommon, few thalli have

calcification in small quantity; fronds vary from spherical, reniform or kidney-shaped, strap like or oval; laceration usually found in old or mature parts, young stage of thallus forms expanded, fan-shaped structure; margin enrolled and smooth; phaeophycotean hairs frequent on one surface of thallus, disappear in mature part in some species; in younger parts hairs present with reproductive organs either sexual or asexual, arranged in concentric zones, usually found on single surface of thallus, but rarely occur on both surfaces. Represented by six species at Karachi Coast, which are distinguished as follows:

1. + Single holdfast bears more than five fronds -----2
 - Single holdfast bears less than five fronds -----3
2. +Thallus throughout three layered thick -----2.*P. fraseri*
 - Thallus throughout not three layered thick -----4
3. + Tetrasporangia club-shaped----- 1.*P. afaqhusainii*
 - Tetrasporangia spherical /oval-shaped -----5
4. + Fronds club-shaped-----5.*P tetrastromatica*
 - Fronds kidney-shaped----- 4.*P. pavonica*
5. + Reproductive organs found on single surfaces -----3.*P nizamuddinii*
 - Reproductive organs found on both surfaces-----6.*P vickersiae*

1. *Padina afaqhusainii* Aisha et Shameel, *sp. Nov.* Figs.1, 2a-s

Diagnosis: *Supremus erant duos layered creber procul marginal secui quod six layers cells summitto secui eram three layered near marginal prodigium basal secui tamen medullary vel medius secui comprised quattuor ut six layers cells stipes - vultus tetrasporangia erant instituo utriusque superficies thallus inter sporangia singulus layer phaeophycotean saeta erant tendo quod indusium est absentis.*

Morphological characters: Thalli up to 16 cm high, attached by branched rhizoidal filaments, brown to dark brown in colour; stipe long, flattened, non-calcified, 8-10 x 2-3 mm; usually a single frond develops from a single holdfast but sometime 2-4 fronds are also formed.

Cytological features: Thallus varies in thickness in different parts, upper marginal portion two layered in thickness, lower or basal part consists of three, four to six layers of cells which is a very common character in the species of *Padina*. Peripheral cells in upper part squarish to rectangular in shape, transversely arranged, 23-34 x 11-23 μ m, lower epidermis with rectangular cells which are radially arranged, rarely squarish, 23-34 x 11-23(-34) μ m; cortical part contains two to four layers of squarish to rectangular, uniformly arranged cells, 46-68 x 34-68 μ m; peripheral region at the basal part of thallus produces undivided rhizoidal filaments; few phaeophycotean hairs present, in older part usually absent.

Reproductive structures: Thalli were without sexual reproductive organs, asexual reproductive organs *i.e.* concentric layers of tetrasporangia present on both the surfaces without indusia. Sporangia club to oval in shape, 34- 57 x (23-)-34-57 μ m. Phaeophycotean hairs present in between two layers of reproductive organs in younger stage of sporangia, absent in growing or mature sporangia.

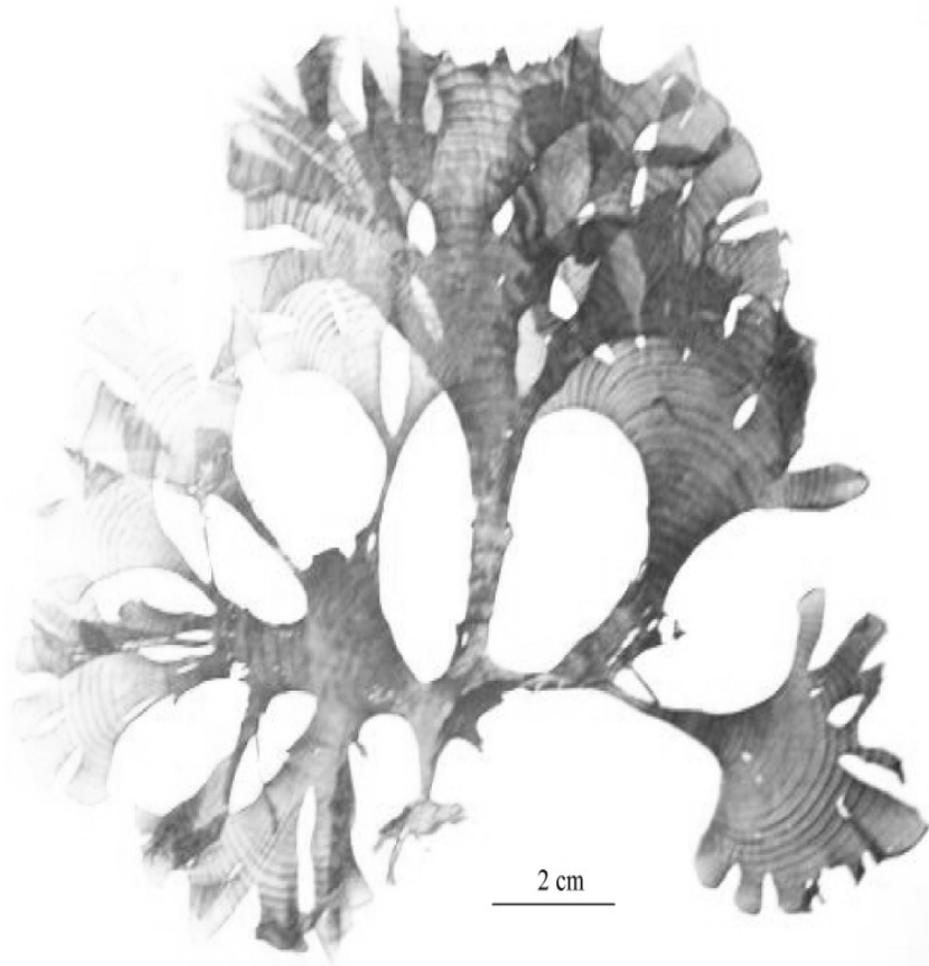


Fig. 1. *Padina afaqhusainii* Aisha et Shameel: Type Specimen.

Growth: The presence of *Vaughaniella* stage shows that growth is initially from a single apical cell, which divides and re-divides to develop a plurilocular sporangium like structure, that further divides longitudinally to produce a group of marginal cells which grow and form a fan-shaped structure.

Type locality: Manora, Karachi, Pakistan.

Etymology: Named after Dr. Syed Afaq-Husain for his devotion and contributions in the field of Phycology.

Habitat ecology: Grows massively on rocks, in the sandy bottom of shallow pools, in association with *Cystoseira indica* (Thivy et Doshi) Mairh and some *Udotea indica* A. Gepp et E. Gepp., also found in channels present in between the rocky pools at Manora Coast.

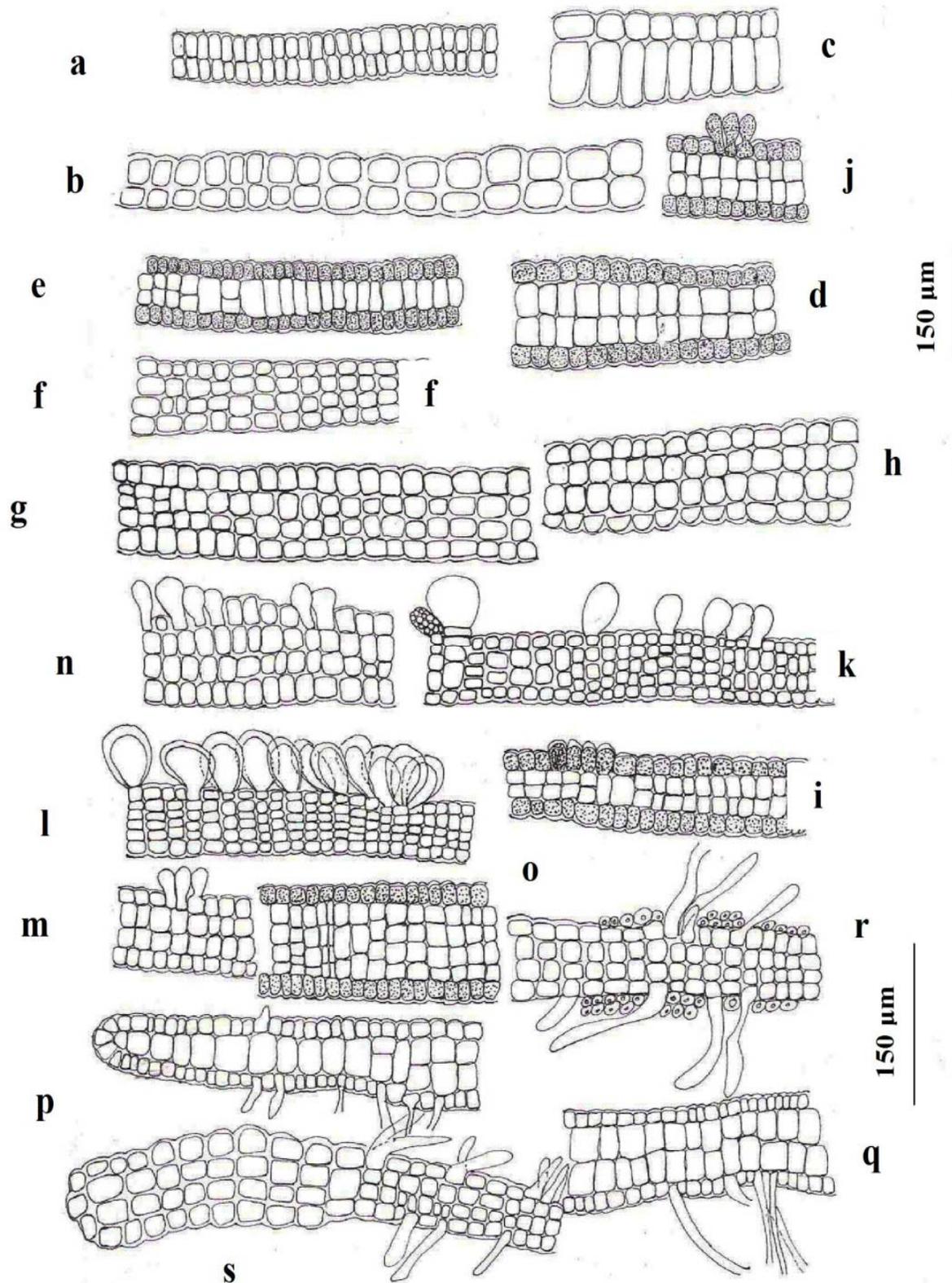


Fig. 2. *Padina afaqhusainii* Aisha et Shameel: **a-c.** Transverse sections of thalli near margin, **d-h.** transverse sections of middle part of young thalli, **i & j.** transverse sections of thallus middle part with oogonia, **k-n.** transverse sections of thallus middle part with undivided and developing tetrasporangia, **o.** transverse section of thallus of lower part showing transverse division, **p.** transverse section of thallus upper part near margin and growth division along with single apical cell, **q-s.** transverse sections of thalli with devlping rhizoids.

Local distribution: Manora (*Leg.* Aisha 12-12-1989, 29-12-1990, 28-01-1991); Buleji (*Leg.* Aisha 14-11-1993).

Remarks: The specimens were two layered thick at marginal part and six layered in the lower part. It was three layered near marginal portion of the basal part, but medullary or middle parts comprised of four to six layers of cells. Club-shaped tetrasporangia were found on both surfaces of the thallus, in between sporangia single layer of phaeophycotean hairs were present without indusium. All the known species of *Padina* always have more layers of cells in lower portion as compared to the middle part but the specimens of Karachi Coast have much more layers of cells in the middle part than the lower portion, this character made it a different species from all other described species. It resembles with the other newly described species *P. nizamuddinii* (see later) in anatomy of the thallus, but differs in the structure of tetrasporangia and occurrence of sporangia. A major feature of *P. afaqhusainii* is the absence of hair bands, this is also a distinctive character in *P. glabra* Gaillard which is uncommon in the genus.

2. *Padina fraseri* (Greville) Greville 1830:1504; Figs. 3,4a-l & 5i-p

Zonaria fraseri Greville 1829:423; *Padina pavonia* Lamouroux var. *fraseri* (Greville) Dickie 1874:191.

References: Greville, 1830:15; Agardh, 1848:114, 1882:120; Kützing, 1849:565, 1859:30; Lucas, 1936:88; Lindauer, *et al.*, 1961:195; Taylor, 1966:356; Womersley, 1967:222, 1987:217; Silva *et al.*, 1987:78, 1996:604; Nizamudin & Begum, 2006:224.

Morphological characters: Thallus erect up to 10 cm high, attached by a matted fibrous holdfast, bearing 2-6 or more fronds; stipe flattened, 1-3 x 2-4 mm; calcification rare on upper surface, common on the fibrous holdfast; fronds circular to semi-circular; in young parts laceration very little, common in mature fronds; reproductive organs and phaeophycotean hairs present in concentric zones; margin smooth to slightly undulate.

Cytological features: Thallus composed of three layers except enrolled margin with two layers of cells; cells mostly iso-diametric, rectangular or squarish; upper peripheral cells rectangular, radially arranged, with discoid dense phaeoplasts, 23-34(-46) x 11-23 μm ; cells of lower epidermis rectangular, radially arranged in marginal part, but squarish in older parts, 34-46 x 11-23 μm ; cells of cortical or middle layers squarish, iso-diametric; phaeophycotean hairs grow in concentric zones; unseptate rhizoidal filaments present in lower part of thallus, double walled cells present in between these filaments.

Reproductive structures: Tetrasporangia or gametangia spherical, oval or rarely club-shaped, 57-80 x 46-91(-114) μm ; asexual reproductive organs present in groups between layers of hairs, on one surface of thallus, indusia present; sexual reproductive organs not seen.



Fig. 3. *Padina fraseri* (Greville) Greville: Herbarium specimen.

Growth: Initially growth takes place through single apical cell but later on it forms a group of marginal cells which take part in further growth.

Type locality: Novan New Hollandian (probably near Fremantle, Western Australia).

Habitat ecology: Grows on muddy rocks and in rocky shallow pools forming almost pure colonies. When water is little high and temperature is low they grow luxuriantly.

Local distribution: Buleji (*Leg.* Aisha 20-9-, 1-12- & 29-12-1990, 14-11-1993).

Geographical distribution: Andaman Islands, Australia, India, Indonesia, Mauritius, Myanmar, New Zealand, Pakistan, Polynesia and The Philippines.

Remarks: This is the first record of this species at the coast of Pakistan. The specimens gathered are characterised by three layered internal structure from base to apex, except enrolled marginal part, middle portion having concentric zone of reproductive organs in

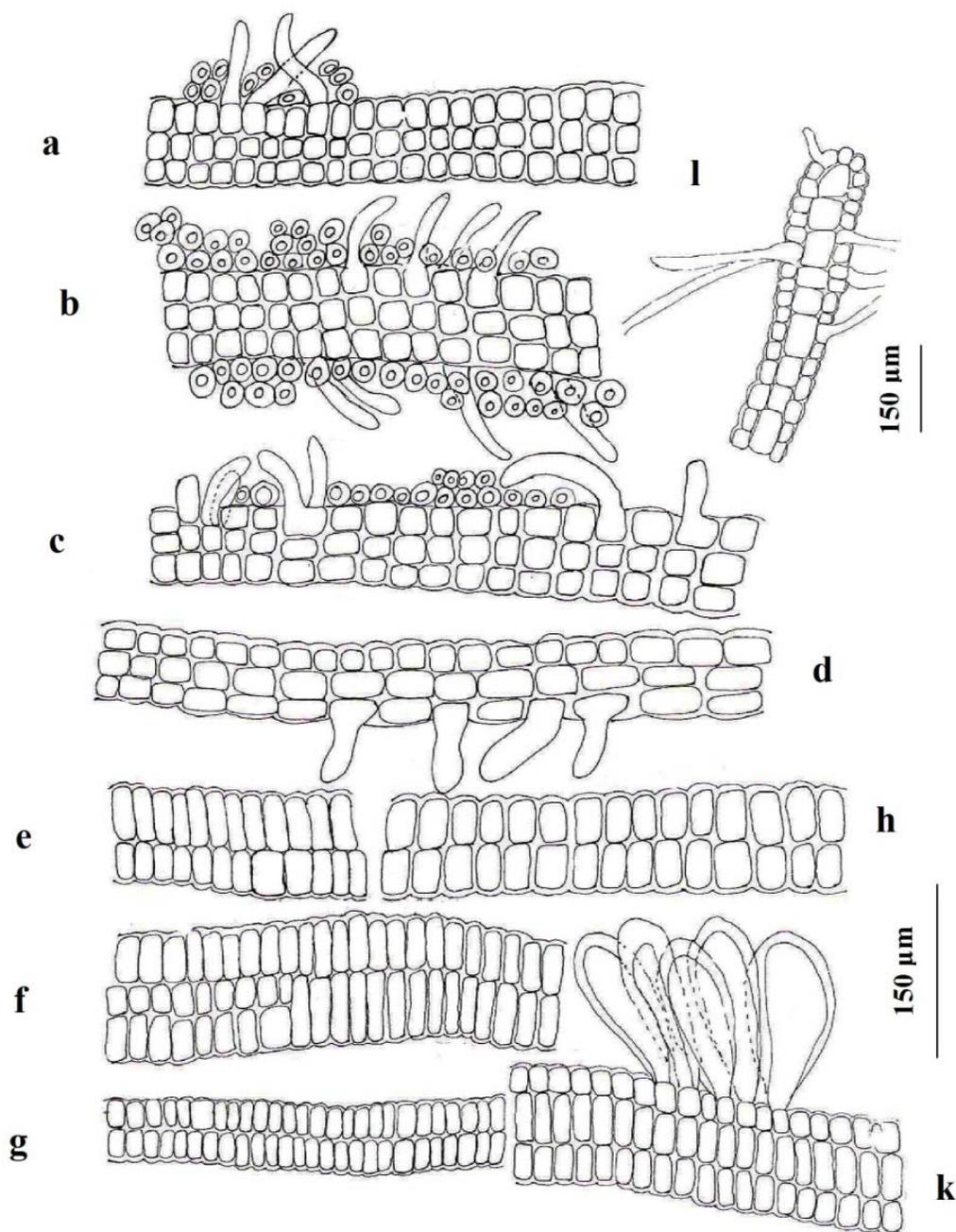


Fig. 4. *Padina fraseri* (Greville) Greville: **a-d.** Transverse sections of thallus lower part with developing rhizoids, **e-h.** transverse sections of thallus middle part with undivided tetrasporangia, **k.** transverse section of thallus middle part near margin, **i.** transverse section of lower part showing single apical cell and developing rhizoids.

between two layers of phaeophycotean hairs. These features of Karachi specimens resemble with the descriptions given by Taylor (1966) and Womersley (1987). They differ from New Zealand specimens (Lindauer *et al.*, 1961) in showing more than three layers in their lower part, due to this character Womersley (1987) suggested that it should belong to *P. gymnospora* (Kützinger) Sonder. Our specimens are characterised by having three layered cell structure, calcified lower part and presence of indusia, therefore, identified as *P. fraseri*.

Kraft (2009) expressed doubt about the occurrence of *P. fraseri* outside of temperate Australia. However, there are records from the Indo-Pacific (Womersley, 1987; Silva *et al.*, 1996). He suggested that tristromatic species from those regions previously identified as *P. fraseri* or *P. gymnospora* were actually more apt to represent *P. boergesenii* Allender *et* Kraft. A key feature of basically cold-water *P. fraseri* is the larger height of cells in the central layer (Farrant & King, 1989).

3. *Padina nizamuddinii* Aisha *et* Shameel, *sp. nov.* Figs. 6, 7a-z² & 8w-z

Diagnosis: *Medius secui per magis layers cells ut foedus ut summus quod summitto secui thallus character est tantum instituo vetus medius vel subolesco secui thallus, quod iunior medius secui same numerus layers ut tendo summitto secui.*

Morphological characters: Thalli up to 15 cm high, olive green to yellowish brown in colour, attached by fibrous, leathery, somewhat discoid holdfast; stipe compressed, almost flat, 10 X 1-3 mm, calcification absent; fronds expanded, lacerated; club to kidney-shaped; frond usually single but in perennials 1-4 fronds are formed, when young it forms single circular thallus, later on it becomes apically lobed due to wave action or develops by a group of marginal cells; margin smooth and enrolled.

Cytological features: Thallus internally composed of 2-4(-5) layers of cells, but in the middle part it forms 4-7 layers of cells, it may be found in those thalli which develop lobes in apical part, or all specimens may be perennial because upper middle *i.e.* younger part has 3-4 layers of cells; marginal enrolled portion has two layers of cells, upper layer contains squarish cells, lower layer with rectangular and radially arranged cells; upper peripheral cells squarish 23-34 X 23 μm; cortical cells also squarish, but some are rectangular, regularly transversely arranged, 34-57 X 23-68 μm; cells in lower epidermis usually rectangular and radially arranged, sometimes squarish and transversely arranged, 11-23 X 23 μm; upper and lower peripheral cells in the basal part of thallus produce non-septate rhizoidal filaments, very few double walled rounded cells found in between these rhizoidal filaments; phaeophycotean hairs and reproductive organs are formed in concentric zones on thallus.

Type locality: Hawkesbay, Karachi, Pakistan.

Etymology: Named after Prof. Dr. Mohammed Nizamuddin, the renowned phycologist and world authority on brown algae.

Habitat ecology: Grows on rocky ledges, muddy rocks and on rocks submerged in shallow waters, forming their own communities. Only *Codium* spp. grows with them.

Local distribution: Manora (*Leg.* Aisha 11-11-1989); Hawkesbay (*Leg.* Aisha 14-11-1989); Buleji (*Leg.* Aisha 20-9-1990, 29-12-1990); Nathiagali (*Leg.* Aisha 24-10-1990).

Remarks: The specimens have anatomically quite distinct features such as middle part with more layers of cells as compared to upper and lower parts of thallus. This character is only found in old middle or mature part of thallus, whereas younger middle part has same number of layers as in the lower part. This species has oval-shaped tetrasporangia,

alternating with single layer of phaeophycotean hairs, indusium absent; these features resemble with *P. tenuis* Bory, but it totally differs in its internal structure of thallus. On the basis of its peculiar arrangement of cells in middle part of the thallus this species becomes distinct from all other known species of *Padina*. Apparently it resembles a widespread species of *P. gymnospora* (Kützinger) Sonder as treated by Abbott, Hare & Huisman (in Abbott & Huisman, 2004; Kraft, 2009), but differs from it in its above mentioned arrangement of cells.

4. *Padina pavonica* (L.) Thivy in Taylor 1960: 234 Figs. 9, 10a-k

Fucus pavonicus L. 1753:1162; *F. pavonius* L. 1759:1345, *Padina pavonia* (L.) Lamouroux 1816:304, *Zonaria pavonia* (L.) C. Agardh 1820:125.

References: Agardh, 1848:113; Taylor, 1960:234; Duraiatnam, 1961:36; Misra, 1966:154; 1967:233; Krishnamurthy & Joshi, 1970:11; Islam, 1976:40; Nizamuddin 1981:25; Zahid *et al.*, 1981:210; 1983:156; Shameel, 1987:513; 2000:51; Shameel & Afaq-Husain, 1987:295; Silva *et al.*, 1987:78; 1996:605; Begum & Khatoon, 1988:297; Shameel & Tanaka, 1992:38; Shameel *et al.*, 1996:227; 2000:84, Nizamuddin & Begum, 2006:227.

Morphological characters: Thallus up to 15 cm high, forming clumps of yellowish brown colour; attached by an expanded, discoid, flexuous holdfast, fronds 2-8 or more; stipe short, cylindrical, 3-4 mm long as well as broad, stupose, non-calcified; fronds expanded, fan-shaped, in older part become kidney-shaped, with no laceration in younger part, mature part frequently lacerated; attenuated forming convex apex; reproductive organs and phaeophycotean hairs present in concentric regions; margin smooth, enrolled.

Cytological features: Thallus composed of 2-6 layers; cells of upper epidermis squarish to barrel-shaped, 11-23 μm broad, having dense phaeoplasts; while in lower peripheral part cells squarish to rectangular in shape, arranged radially, 23-46 x 23-34 μm ; cortical region consists of 1-4 layers of iso-diametric cells, large, squarish, rarely rectangular, arranged in regular transverse rows, with less amount of phaeoplasts, 23-46 x 23-34; at the basal portion peripheral cells give rise to small unseptate rhizoidal filaments, in between these filaments many double walled cells present.

Reproductive structures: The reproductive organs are borne only on single surface of thallus. Which may be oogonia or tetrasporangia as their shapes are very similar. Tetrasporangia are differentiated by the presence of partition walls. The reproductive organs forming 1-2 layers which alternate with sterile filaments *i.e.* phaeophycotean hairs. Tetrasporangia oval-shaped, (23-)57-80 X 57-68(-80) μm . Sexual reproductive organs were not observed. Reproductive organs are borne only one/single surface of the thallus.

Growth: Growth usually takes place by a group of marginal cells, but it initially grows by a single apical cell, sporangia starts to grow on mother thallus before liberation. In this condition it forms plurilocular like structure which is known as *Vaughaniella* stage. Our specimens which bore *Vaughaniella* stage, seemed to be perennial individuals as environmental conditions were not favourable for their liberation and growth.

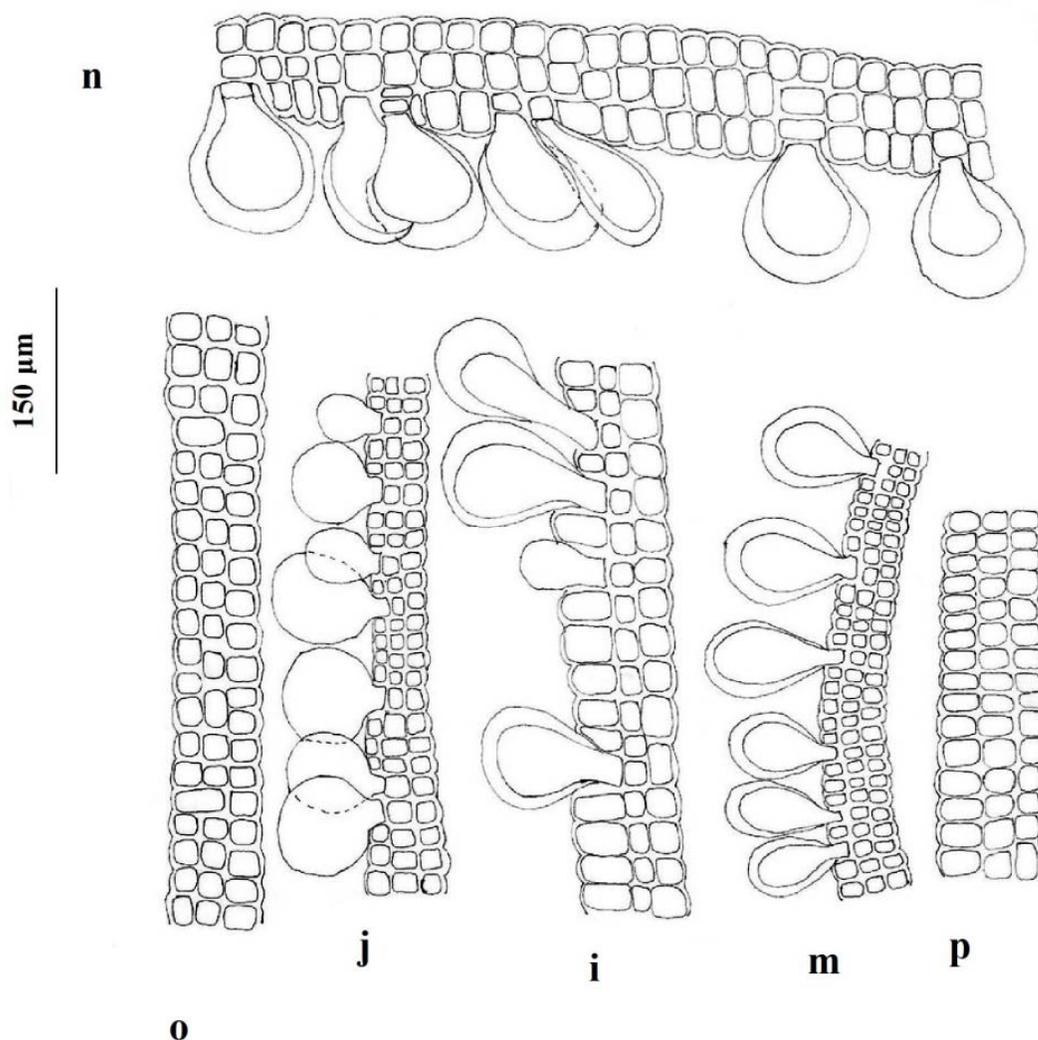


Fig. 5. *Padina Fraseri* (Gerville) Greville: **i, & m, n**. Transverse section of thallus middle part with undivided tetrasporangia, **o & p**. transverse sections of thallus middle part near margin.

Type locality: Mari Europae australis.

Habitat ecology: Grows during summer to spring seasons on muddy pools having rocky base or in rocky pools where water movement is very slow.

Local distribution: Manora (*Leg. Aisha 11-11-1989, Leg. Nizamuddin 10-11-1992*); Buleji (*Leg. Aisha 2-10-1989*); Nathiagali (*Leg Aisha 16-10-1989*).

Geographical distribution: Andaman Islands, Australia, Bangladesh, Djibouti, India, Indonesia, Kenya, Laccadive Islands, Madagascar, Maldives, Mauritius, Myanmar, Oman, Pakistan, Réunion, Rodriguez Island, Seychelles, Somalia, Sri Lanka, Tanzania, The Philippines and Yemen.

Remarks: Thallus is characterised by convex apex, fibrous holdfast, non-calcified basal portion, 1-2 layers of reproductive organs alternating with phaeophycotean hairs and

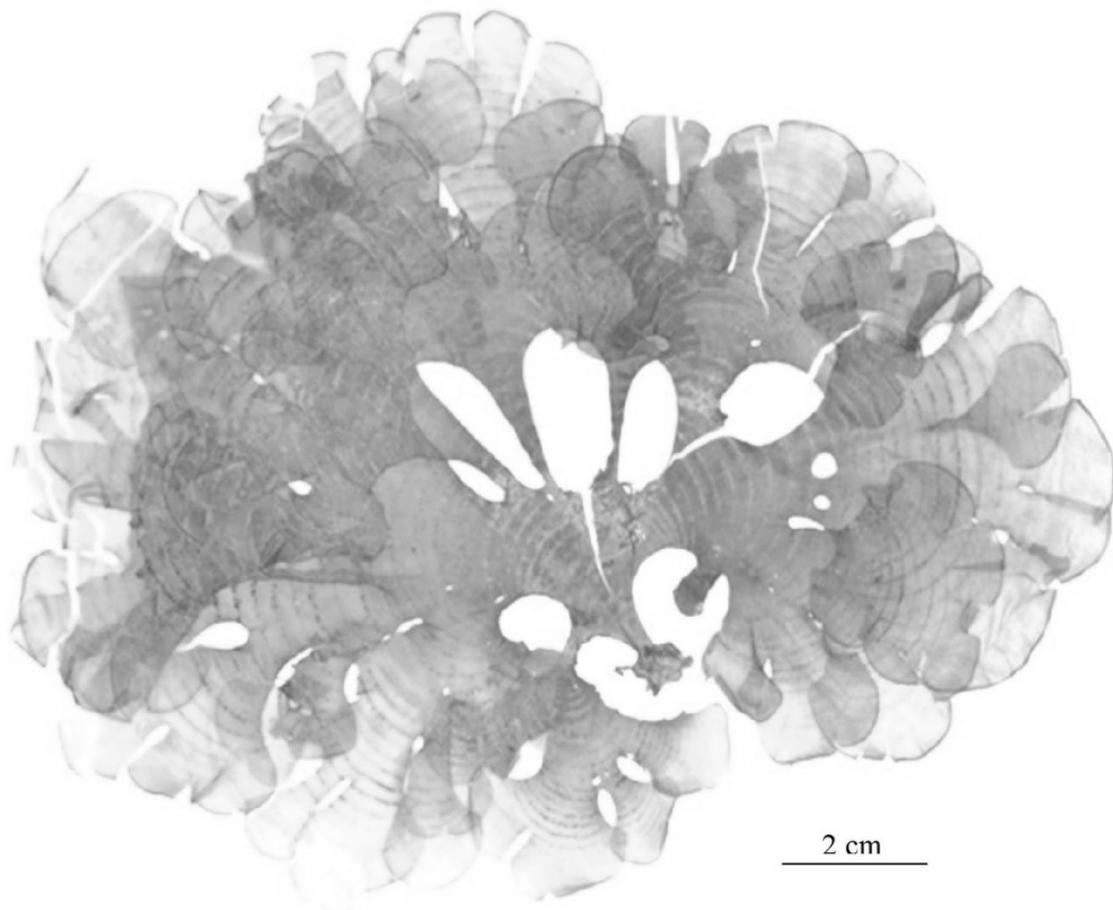


Fig.6. *Padina nizamuddinii* Aisha et Shmeel: Type specimen

internally thallus composed of 1-4 layers of cortical cells, while all cells are isodiametric in size. Our specimens agree with the description given by Misra (1966) in thallus morphology number and arrangement of internal cells and absence of calcification, but differ in shape of cells and thallus height. The specimens of Libya described by Nizamuddin (1981) are similar in morphological appearance, number and arrangement of internal cells, but differ in having calcification. They match with the specimens of Sri Lanka (Durairatnam 1961). Specimens collected from the coast of Karachi, show variations in number of cortical layers, shape of cells and arrangement of reproductive organs in different ecological conditions. Sometimes instead of two layers of reproductive organs only one layer alternates with phaeophycotean hairs. Our specimens showed an unusual phenomenon, syntagmatic *in situ* germination (Fig. 10 h-j) *i.e.* all the spores dividing and merging into one single outgrowth.

The name of species has some contradictions: Misra (1966, 1967) and Silva *et al.* (1987, 1996) adopted *Padina pavonica* (L.) Thivy, whereas Durairatnam (1961), Nizamuddin (1981), Zahid *et al.* (1983), Shameel (1987), Begum & Khatoon (1988) and Shameel & Tanaka (1992) considered *P. pavonia* (L.) Lamouroux as a correct name. *Fucus pavonicus* L. has priority over *F. pavonius* and may be considered as basionym, therefore its correct name should be *P. pavonicus* (L.) Thivy. Furthermore, the intended basionym of *P. pavonia i.e.* *Fucus pavonius* is an illegitimate substitute for *F. pavonicus* (Silva *et al.*, 1996). Therefore the latter epithet may not be considered as an orthographic variant.

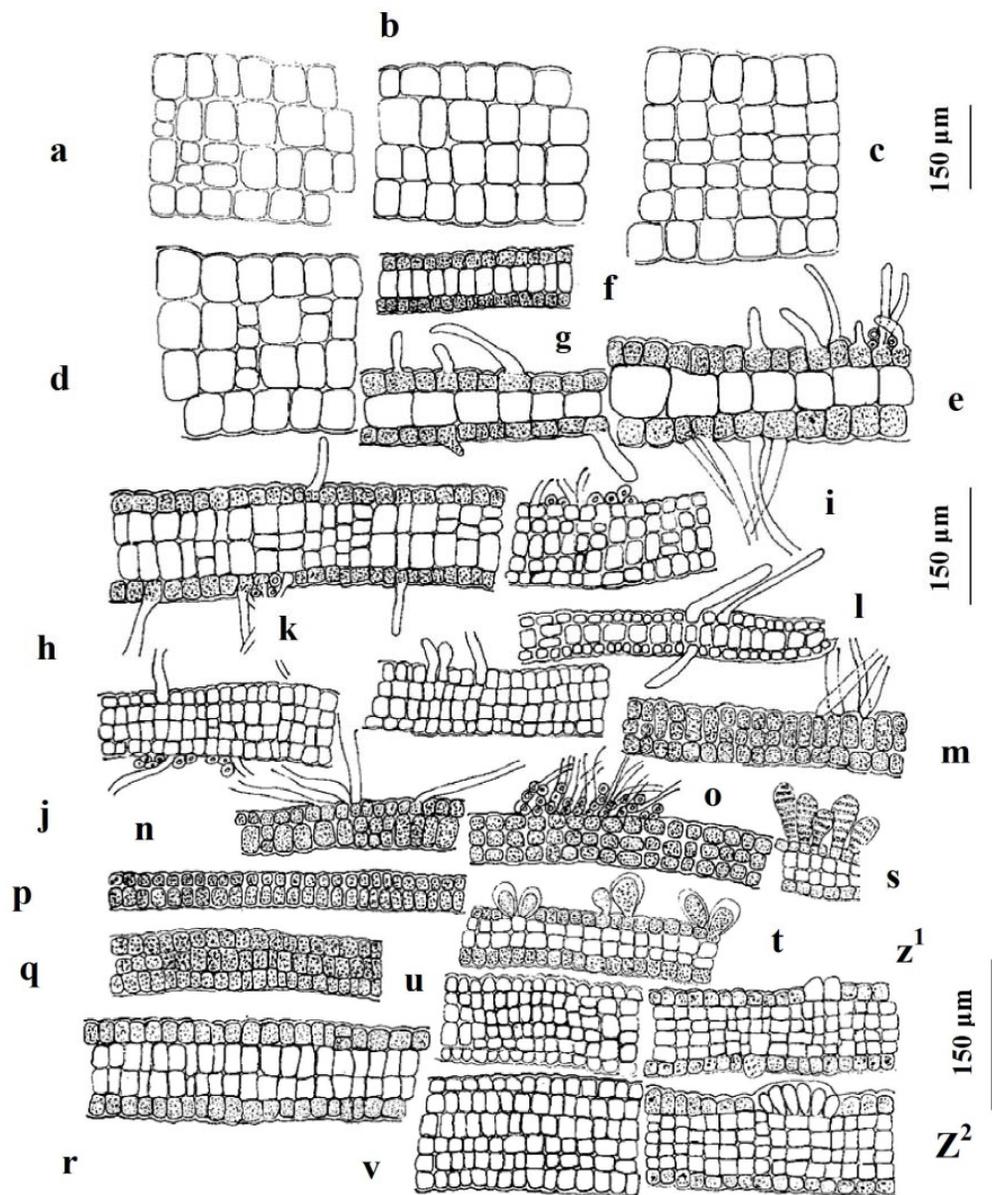


Fig. 7. *Padina nizamuddinii* Aisha et Shameel: **a-d.** Transverse sections of thallus lower part with developing rhizoids, **e & f.** transverse sections of young thallus lower part showing transverse division along with single apical cell, **g & h.** transverse sections of thallus middle part near margin with tuft of hairs, **i-l.** transverse sections of thallus middle part near margin, **m-p.** transverse sections of thallus middle part showing growth zones, **q-s.** transverse sections of thallus middle part with phaeophycotian hairs, **t-v.** transverse sections of thallus older part along with margin, **y&z¹.** transverse sections of male thallus middle part with sori of antheridia, **z².** transverse section of thallus middle part with oogonia.

5. *Padina tetrastromatica* Hauck 1887:43 ;Figs.11, 12 a-s

References: Hauck, 1887:43; Weber-van Bosse, 1913:150; Børgesen, 1930:172; 1935:35; 1936:77; 1937:315; 1939:80; Anand, 1940:5; Duraiatnam, 1961:36; Salim, 1965:195; Misra, 1966:158; 1967:233; Krishnamurthy & Joshi, 1970:11; Islam, 1976:41; Jaasund, 1976:45; Lawson & John, 1982:149; Shameel & Afaq-Husain, 1987:295; Silva *et al.*, 1987:79; 1996:607; Begum & Khatoon, 1988:298; Shameel *et al.*, 1989:179; 2000:84; Shameel & Tanaka, 1992:39; Shaikh & Shameel, 1995:22; Shameel, 2000:51; Nizamuddin & Begum, 2006:231.

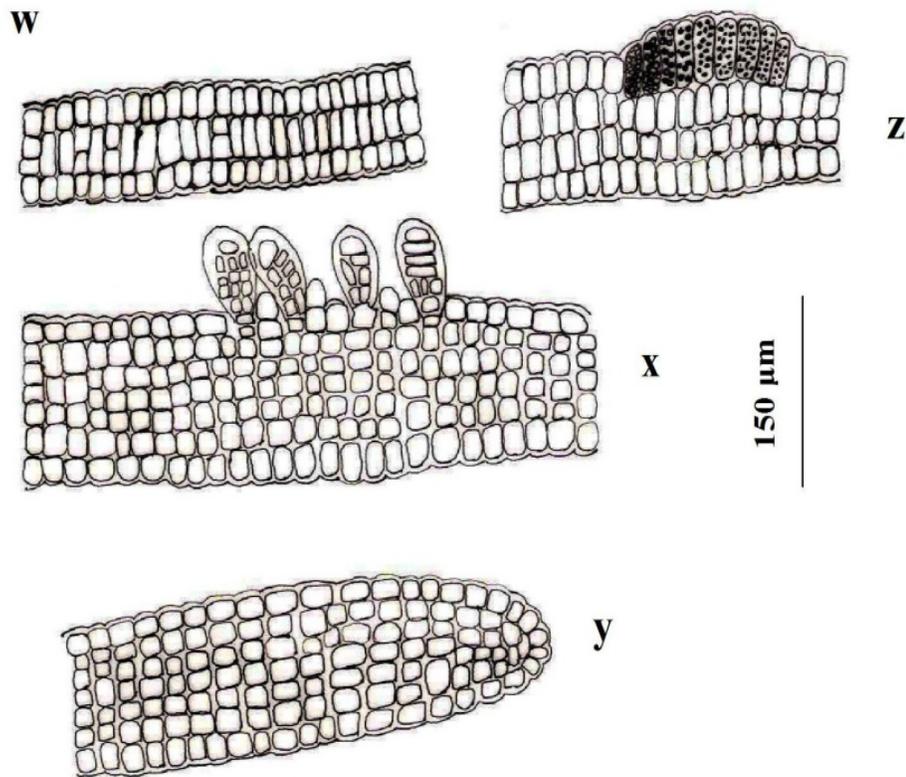


Fig. 8. *Padina nizamuddinii* Aisha et Shameel: **w.** Transverse section of thallus older part along with margin, **x.** transverse section of thallus middle part with developing tetrasporangia, **y-z.** transverse sections of male thallus middle part with sori of antheridia.

Morphological characters: Thallus up to 14 cm high, attached with the help of a leathery, fibrous disc-shaped holdfast; dark brown to yellowish brown in colour, 2-6 fronds arise from a single holdfast; stipe short, flattened, 4-5x 3-5 mm, non-calcified; fronds in young as well as in mature stages much lacerated, each lobe usually club-shaped, laceration so deep that each lobe of mature thallus appears like an independent individual; margin smooth and enrolled.

Cytological features: Thallus 2-4 layered thick, two layered structure found in marginal part of thallus, most of the thalli have three layered structure but four layered in basal part; peripheral layers *i.e.* upper and lower both have not much difference in their cell structure, except squarish cells found in the upper peripheral layer only, cells 11-23 x 11-23 µm; cortical region usually has a single layer but in lower part two layered, cells mostly squarish, rarely rectangular, 23-57 x 23-46(-57) µm; in lower portion rhizoidal filaments develop from peripheral layer, which are without cellular partition; between rhizoidal filaments double walled, circular, empty cells, compactly arranged.

Reproductive structures: The specimens bore only asexual reproductive organs, whereas sexual reproductive organs were not recorded. Asexual reproductive bodies *i.e.* tetrasporangia spherical or semi-spherical, 57-80 x 46-57 µm, indusium absent; phaeophycotean hairs present singly in between the row of tetrasporangia; older part of thallus forms 1-2 mm broad bands due to massive growth of tetrasporangia.

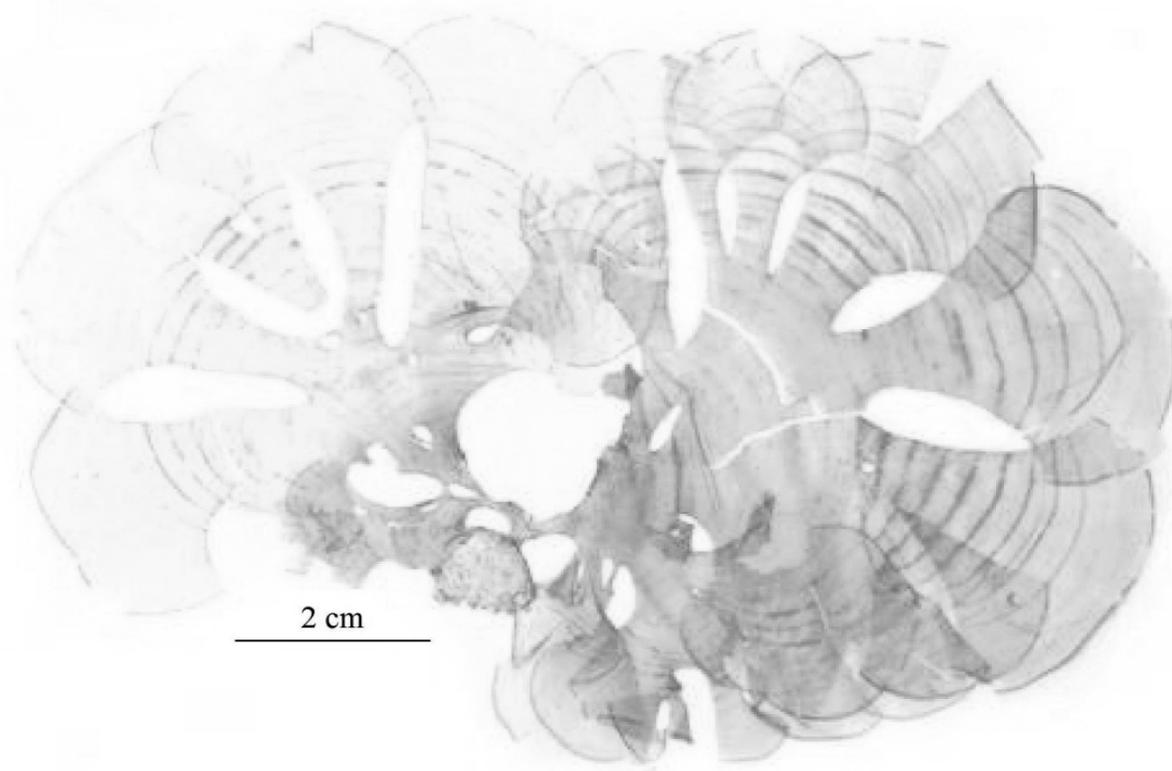


Fig. 9. *Padina pavonica* (L.) Thivy: Herbarium specimen.

Growth: Thallus shows *Vaughaniella* stages in older part of the thallus, therefore the growth takes place in the similar fashion as described in the previous species.

Type locality: Meith, Somalia.

Habitat ecology: Grows in shallow pools with rocky bottom or on sheltered portion of rocky pools and always remains submerged in water, with the association of *Dictyota dichotoma* (Hudson) Lamouroux, *Cystoseira indica* (Thivy et Doshi) Mairh, *Sargassum swartzii* C. Agardh and *Sargassum virgatum* C. Agardh. Thalli found at Buleji Coast usually had epiphytic and epizooic organisms, due to which their growth was affected, it appeared as if they were growing in an unfavourable condition.

Local distribution: Buleji (*Leg.* Aisha 2-10-1989, 4-10-1994); Nathiagali (*Leg.* Aisha 16-10-1996).

Geographical distribution: Andaman Islands, Australia, Bangladesh, Diego Garcia Atoll, India, Indonesia, Iran, Kenya, Kuwait, Laccadive Islands, Malaysia, New Zealand, Nicobar Islands, Pakistan, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania, The Philippines and Yemen.

Remarks: Specimens of Karachi Coast are characterised by 2-4 layers of thickness in the thallus, but major part of thallus is made up of three layered structure, in between reproductive organs single layer of phaeophycotean hairs are present, non-calcified fronds, laceration is most frequent. All these distinguishing features are similar with other

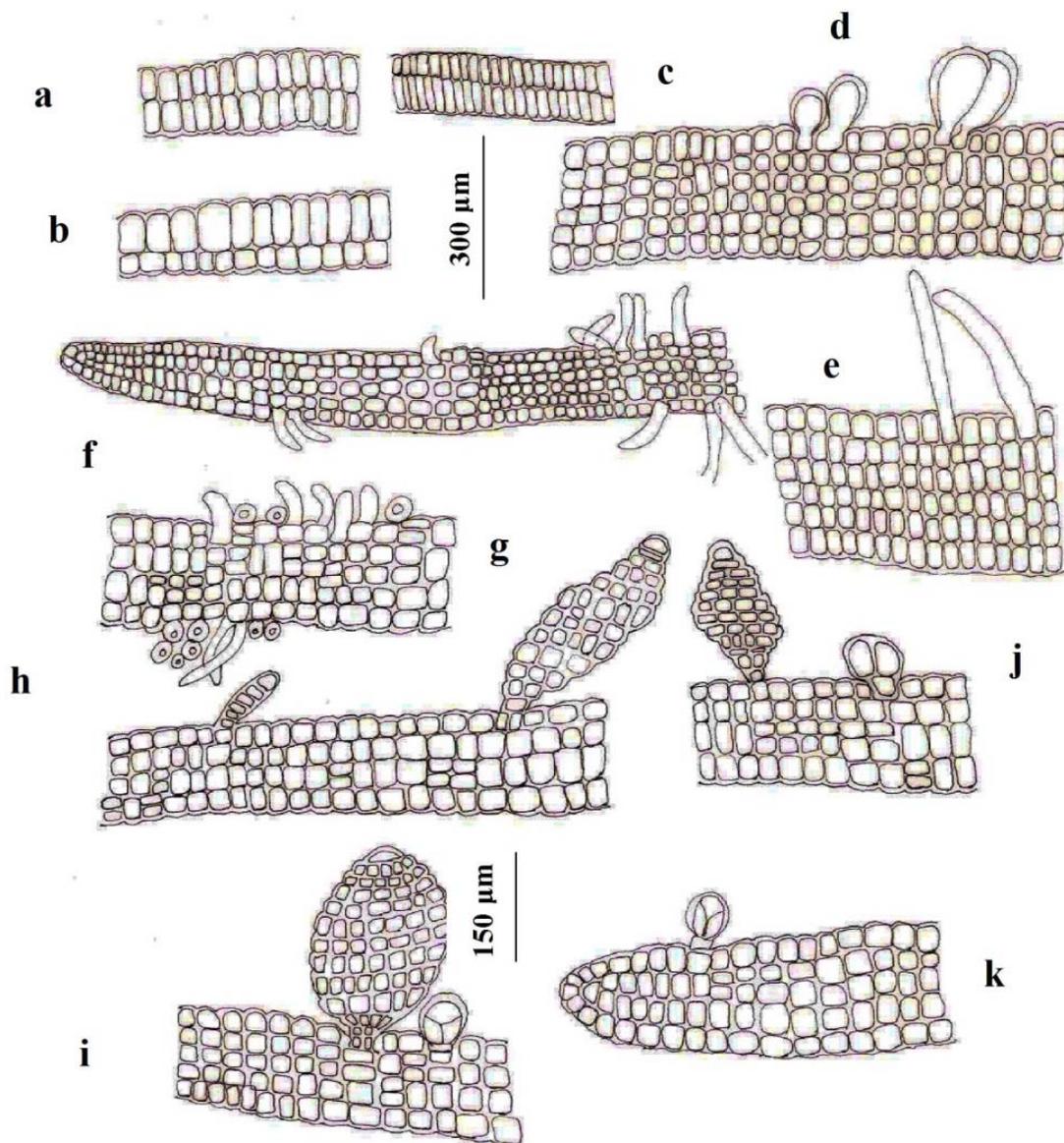


Fig. 10. *Padina pavonica* (L.) Thivy: **a-c.** Transverse sections of thallus upper part, **d.** transverse section of thallus middle part with divided and undivided tetrasporangia, **e-g.** transverse sections of thallus middle part near margin alongwith developing rhizoids, **h-j.** transverse sections of thallus middle part with developing and undivided tetrasporangia, **k.** transverse section of thallus middle part near margin with developing and undivided tetrasporangia.

described Indian specimens of Børgesen (1930, 1936), Duraiatnam (1961), Misra (1966) and also Pakistani specimens (Shaikh & Shameel, 1995) in internal structure of thallus, arrangement of reproductive organs, but differ only in the absence of calcification. Our specimens differ from type material in having three layered structure instead of four layered but other characters such as arrangement of reproductive structure are similar. All the specimens collected from the Indian and Pakistani coasts were placed under *P. tetrastromatica* Hauck. However, *P. tetrastromatica* is described on the basis of their four layered structure, so Indian and Pakistani specimens may be placed under different species rather than in *P. tetrastromatica*. These specimens showed anatomical similarity with *P. tenuis* Bory but differ in the arrangement of reproductive organs and shape of

lobes. Wynne (1998) argued that *P. tetrastromatica* is a synonym of the earlier *P. antillarum* (Kützinger) Piccone. But his illustrations of *P. antillarum* are quite different from those of the present specimens. Therefore, in the present treatment Karachi populations are treated as *P. tetrastromatica* rather than *P. antillarum*.

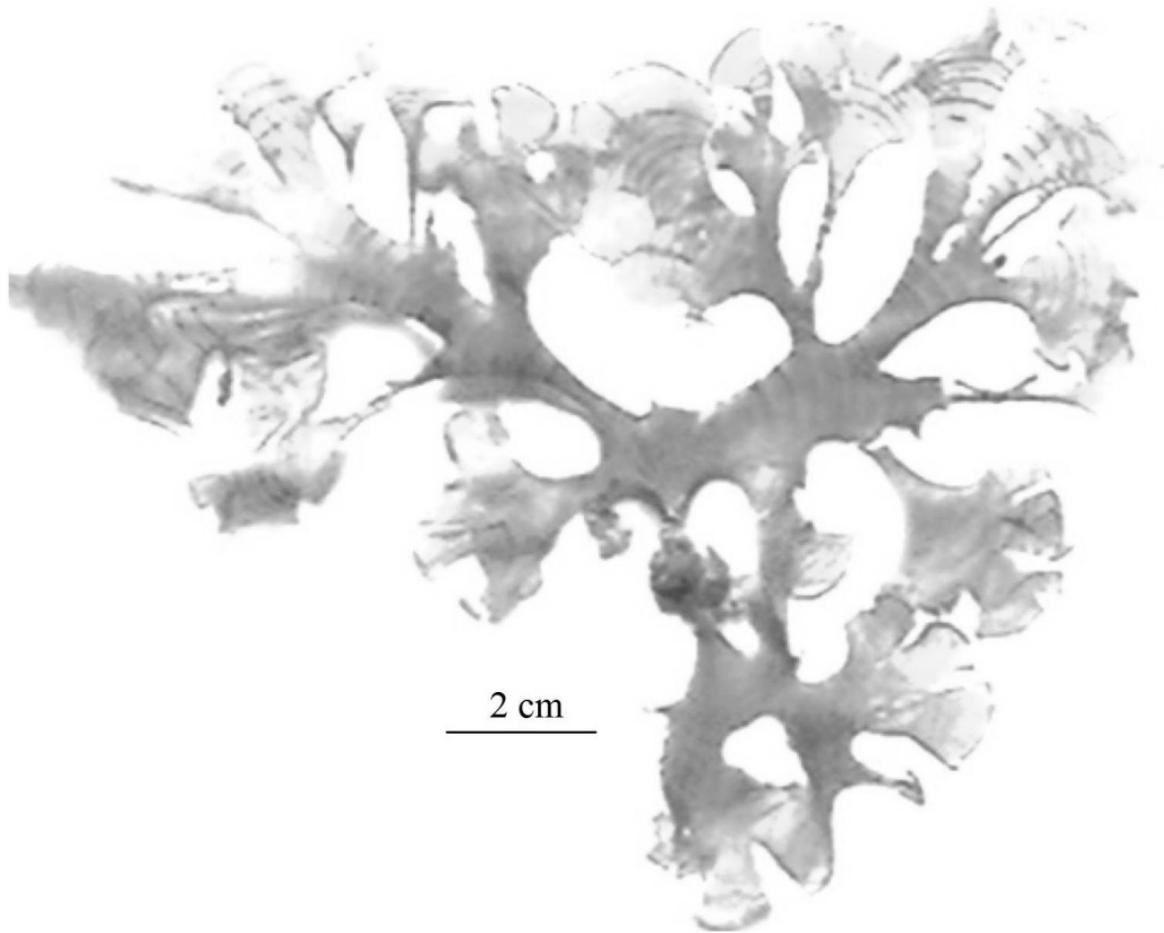


Fig. 11. *Padina tetrastromatica* Hauck: Herbarium specimen.

6. *Padina vickersiae* Hoyt in Howe 1920:595; Figs.13,14 a-l

Synonym: *Padina variegata* Vickers 1905:58.

References: Hoyt in Howe, 1920:595; Hoyt, 1920:456; Taylor, 1942:56; 1960:236; Earle, 1969:172; Islam, 1976:41; Silva *et al.*, 1996:605, Nizamuddin & Begum, 2006:232.

Morphological characters: Thallus up to 15 cm high, attached by discoid fibrous holdfast; from single holdfast 1-4, olive green, yellowish brown or dark brown fronds develop; fronds expanded, fan-shaped, lacerated, parts strap to club-shaped; margins enrolled, smooth; calcification absent; stipe short, compressed, flattened, 2-5 x 1-3 mm.

Cytological features: Thallus anatomically consists of 6-7 layers; marginal part two layered thick, but later part has four to seven layers of cells *i.e.* medullary portion, basal

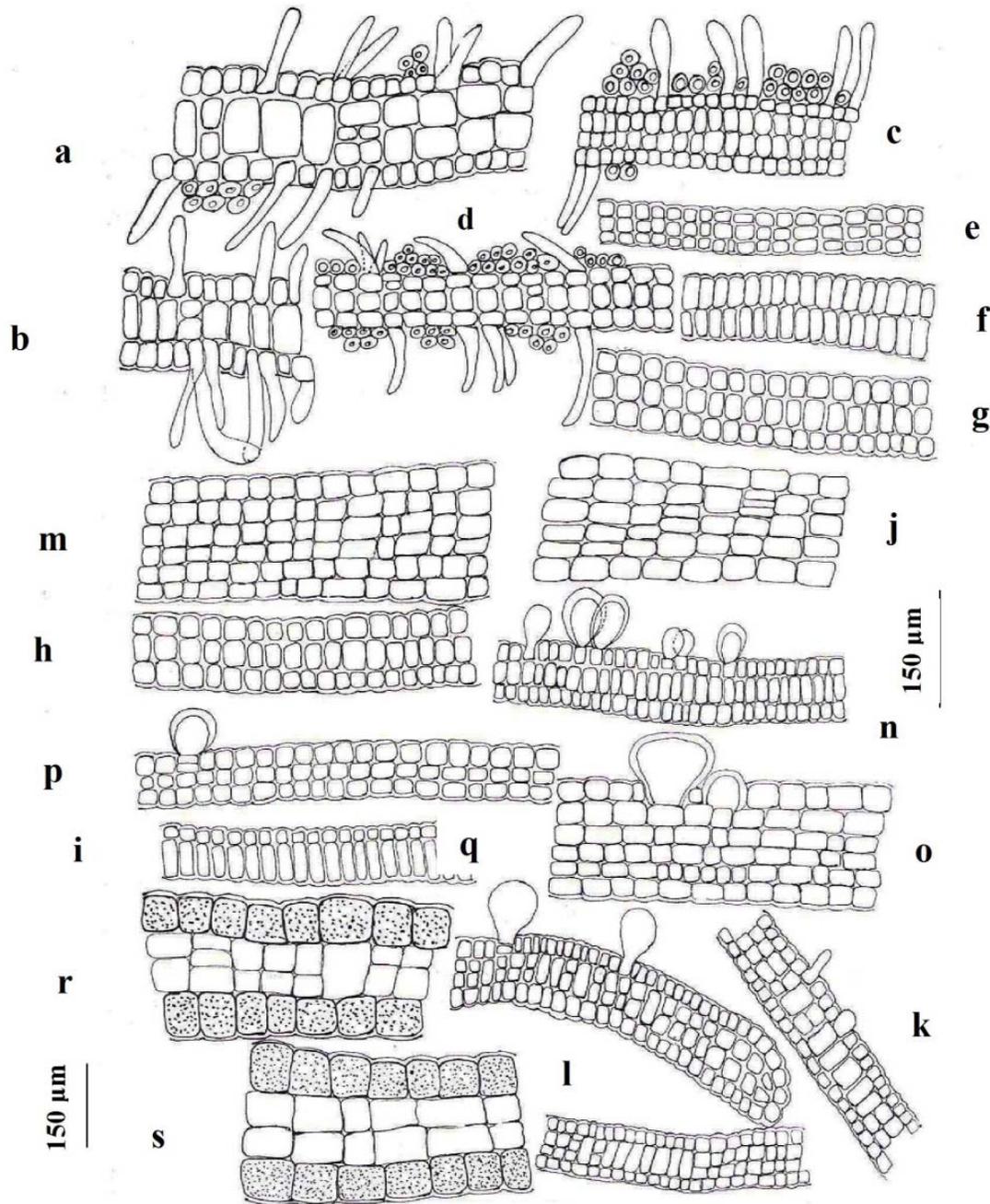


Fig. 12. *Padina tetrastromatica* Hauck: **a-d.** Transverse sections of thallus lower part with developing rhizoids, **e-l.** transverse sections of thallus middle part near margin, **m.** transverse section of thallus lower part, **n-q.** transverse sections near margin with undivided tetrasporangia, **r & s.** transverse sections of thallus middle part showing peripheral cells with dense phaeoplasts.

part is also six to seven layered in thickness; both peripheral layers have small squarish cells with dense phaeoplasts, 23-34 μm long as well as broad; in middle part three to four layers of cells, rectangular to squarish in shape, with few phaeoplasts, 23-46 x 23-34 μm ; at lower portion of thallus unseptate rhizoidal filaments, in between these filaments small, rounded, double walled, cell-like structures compactly present.

Reproductive structures: Among sexual reproductive organs only male organs were observed in the collected specimens, whereas oogonia were not recorded. Asexual

reproductive organs *i.e.* tetrasporangia without indusium, present on both surfaces of thallus, but in some found only on upper surface, spherical to oval in shape, aggregated in groups of 3-4 sporangia, arranged in concentric zones. In between two rows of reproductive organs there is a single layer of phaeophycotean hairs, which almost disappear in the mature part where *Vaughaniella* stage is found to be developing, (-46)57-68 x 46-57 μm .



Fig. 13. *Padina vickersiae* Hoyt: Herbarium specimen.

Growth: The species grows vegetatively by means of a group of marginal cells, but initially it takes place by a single apical cell, that grows on mother individual. This apical cell divides longitudinally to form a group of marginal cells, which repeatedly divide to form expanded fan-shaped thallus. The plurilocular, sporangia-like structure grow on mother thalli (*Vaughaniella* stage).

Type locality: Beaufort, North Carolina, U.S.A.

Habitat ecology: It was found growing on shallow pools of rocks and also in channels in association with *Cystoseira indica* (Thivy et Doshi) Mairh, *Caulerpa taxifolia* (Vahl.) C. Agardh, *Halimeda tuna* (Ellis et Solander) Lamouroux and *Sargassum wightii* Greville.

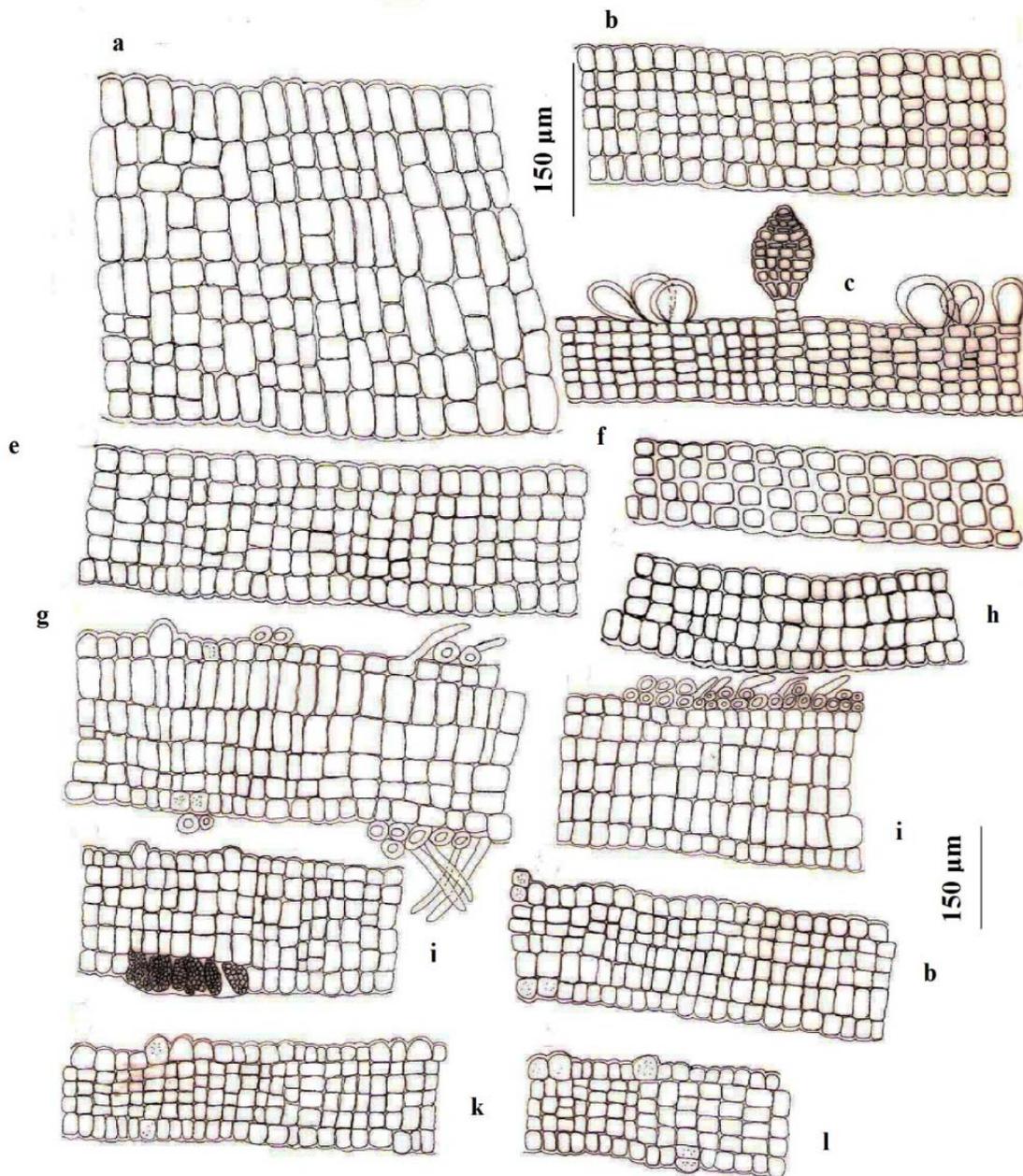


Fig. 14. *Padina vickersiae* Hoyt: **a-d.** Transverse sections of thallus lower part, **e-f.** transverse sections of thallus lower part with developing rhizoids, **g-h.** transverse sections of thallus middle part, **i.** transverse section of thallus middle part near margin with developing and undivided tetrasporangia, **j.** transverse section of thallus middle part with sporangia, **k-l.** transverse sections of thallus middle part with growth zones.

Local distribution: Manora (*Leg.* Nizamuddin 10-4-1992); Buleji (*Leg.* Aisha 16-9- & 2-10-1989); Nathiagali (*Leg.* Aisha 24-1-1990).

Geographical distribution: Australia, Bangladesh and U.S.A.

Remarks: This is the first record of this species from Pakistan. The specimens gathered from Karachi Coast have 6-7 layers of thickness in the middle and lower parts of thallus. They have more than six layered thickness throughout except the marginal part, two

layers of reproductive organs have single layer of phaeophycotean hairs, present in younger part but disappear in the mature part. They are found only on single surface. The specimens anatomically resemble *P. gymnospora* (Kützinger) Sonder, *P. vickersiae* Hoyt in Howe and *P. crassa* Yamada. They are more closely related to *P. vickersiae*, but differ in the arrangement of reproductive organs and phaeophycotean hairs from other two species. Due to 6-7 layered thickness throughout the thallus except margins and arrangement of reproductive organs these specimens are identified as *P. vickersiae*, as they differ in arrangement and occurrence of reproductive organs from other species of *Padina*.

This species is now regarded as a synonym of *P. gymnospora* (Allender & Kraft, 1983; Silva *et al.*, 1996; Kraft 2009), but Abbott, Hare & Huisman (*in* Abbott & Huisman, 2004) raised some technical difficulties in doing so. Therefore, our specimens are considered as *P. vickersiae* rather than *P. gymnospora*. The Karachi specimens of this species also showed syntagmatic spore germination (Fig. 14c).

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