STUDIES ON SOME INDIAN MEMBERS OF THE RHODYMENIALES

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FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN BOTANY

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CERTIFICATE

This is to certify that the thesis titled **"Studies on some Indian members of the Rhodymeniales"** submitted to the Bharathidasan University, Tiruchirappalli in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy in Botany,** embodies the results of the bonafide research work carried out by **Shri. S. Kalimuthu ,** under my guidance and supervision during the period 1996-1999 in the Department of Botany, A.V.V.M. Sri Pushpam College (Autonomous), Poondi – 613 503, Thanjavur District.

I also certify that no part of this thesis has been submitted anywhere else for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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DECLARATION

I do hereby declare that this work has been originally carried out by me in the Department of Botany, A.V.V.M. Sri Pushpam College (Autonomous), Poondi, affiliated to Bharathidasan University, Tiruchirappalli and this work has not been submitted elsewhere for any other degree.

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Dedicated

to my

Beloved Wife

and

Children

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CONTENTS

Introduction

INTRODUCTION

The order Rhodymeniales is a well-defined group when compared with some of the other orders of the class, Rhodophyceae. This order consists of rather naturally distinctive groups (Kylin, 1956; Sparling, 1957). Rhodymeniales currently includes three families viz. Champiaceae, Lomentariaceae and Rhodymeniaceae (Silva *et al.*, 1996).

Schmitz (1889) introduced the order Rhodymeninae with six families: Sphaerococcaceae, Rhodymeniaceae, Delesseriaceae, Bonnemaisoniaceae, Rhodomelaceae and Ceramiaceae. Later the Delesseriaceae, Rhodomelaceae and Ceramiaceae were transferred to Ceramiales by Oltmanns (1904). Sjoestedt (1926) erected a new order Sphaerococcales for the Sphaerococcaceae and Kylin (1928) placed Bonnemaisoniaceae in Nemalionales.

The order Rhodymeniales is characterised by the procarp bearing one or two auxiliary-cell branches composed of two cells (except for *Epymenia obtusa* which bears three-celled ones), which are initiated directly from the supporting cell before fertilisation. However, these cell branches become distinctive generally only after fertilisation. The algal thallus is flattened or slightly flattened, cylindrical or hollow, and shows multiaxial growth with meristems located at the apex or margin. Tetrasporangia occur either terminally or intercalarily in the cortical layer and are divided cruciately or tetrahedrally (except *Coeloseira* which bears polysporangia). Spermatangia originate from superficial cortical cells. Cystocarps are surrounded by a pericarp with ostiole. The life cycle is generally of triphasic haplodiplontic type i.e. *Polysiphonia*-type.

Bliding (1928) divided Rhodymeniales into two families: Rhodymeniaceae and Champiaceae. Champiaceae has filamentous cells in the medulla, tetrahedrally divided tetrasporangia and three to four-celled carpogonial branch forming a large fusion cell in cystocarp formation whereas Rhodymeniaceae lacks inner filamentous cells in the medulla, cruciately or tetrahedrally divided tetrasporangia and three-celled carpogonial branch not forming a large fusion cell in cystocarp formation.

Schmitz (1889) divided the family Rhodymeniaceae into two subfamilies viz. Gloiocladioideae and Rhodymenieae and Kylin (1931) divided it into three: Fauchioideae, Rhodymenioideae and Hymenocladioideae. Fauchioideae was separated from the others by the presence of a net-work of cells in pericarp and Hymenocladioideae, by the occurrence of

intercalary and tetrahedrally divided tetrasporangia. The Gloiocladioideae Schmitz was equivalent to the Fauchioideae Kylin. Sparling (1957) preferred to divide the family Rhodymeniaceae into two, Rhodymenioideae and Hymenocladioideae, because the character adopted for the separation of Fanchioideae was not significant and he suggested for including it in Rhodymenioideae.

The family Champiaceae was divided by Kylin (1931) into two subfamilies, Lomentarioideae and Champioideae. Lomentarioideae was distinguished by a three-celled carpogonial branch, almost all cells of the gonimoblast converting into carposporangia and terminal formation of tetrasporangia. Champioideae was characterised by the four-celled carpogonial branch, conversion of superficial cells of gonimoblast into carposporangia and the intercalary formation of tetrasporangia.

Guiry (1974) proposed a new family, Palmariaceae based on *Palmaria palmata* (L.) O. Kuntze (=*Rhodymenia palmata* (L.) Grev.) including the genera *Halosaccion* and *Leptosarca*. The family was characterised by the occurrence of stalk cell in the formation of tetrasporangia and the absence of female gametophyte.

Morphological and anatomical studies on members of Rhodymeniales

Studies on the vegetative structure and reproductive organs of the members belonging to Champiaceae were made by Nageli (1847), Berthold (1882), Debray (1886-1890), Bigelow (1887), Hauptfleisch (1892), Davis (1892, 1896), Hassenkamp (1902), Okamura (1902, 1907, 1910, 1916, 1921, 1927, 1930a, b, 1933, 1934, 1935), Boergesen (1915-1920), Kylin (1923, 1931), Bliding (1928), Rosenvinge (1931), Svedelius (1937), Hollenberg (1940) Lee and Kurogi (1973) and Lee (1978), while similar studies on the members of Rhodymeniaceae were made by Kuckuck (1912), Boergesen (1920), Okamura (1907-1935), Sjoestedt (1926), Kylin (1930), Sparling (1957) and Lee (1978).

Detailed studies dealing with the developmental anatomy of reproductive organs had been made only on the following genera; *Fauchea* (Sjoestedt, 1926; Kylin, 1930; Sparling, 1957), *Faucheolax* (Sparling, 1957), *Gloioderma* (Sparling, 1957), *Gloiocolax* (Sparling, 1957), *Chrysymenia* (Bliding, 1928; Lee, 1978), *Erythrymenia* (Sparling, 1957), *Botryocladia* (Bliding, 1928), *Rhodymenia* (Sjoestedt, 1926; Kylin, 1930; Sparling, 1957; Tokida and Masaki, 1959; Lee, 1978), *Rhodymeniolax* (Sparling, 1957), *Epymenia* (Sparling, 1957), *Gymenocladia* (Sparling, 1957), *Halosaccion* (Lee, 1978), *Minium* (Moe, 1979), *Asteromenia* (Huisman and Millar, 1986) and *Cordylecladia* (Brodie and Guiry, 1988) of Rhodymeniaceae, *Lomentaria* (Hauptfleisch, 1892; Kylin, 1923; Bliding, 1928; Svedelius, 1937; Lee, 1978);

Binghamia (Lee and Kurogi, 1973), *Champia* (Hauptfleisch, 1892; Davis, 1896; Bliding, 1928; Lee, 1978), *Chylocladia* (Hauptfleisch, 1892; Hassenkamp, 1902; Kylin, 1923; Bliding, 1928), *Gastroclonium* (Hauptfleisch, 1892; Bliding, 1928), *Coeloseira* (Hollenberg, 1940) and *Champiocolax* (Bula-Meyer, 1985) of Champiaceae.

According to Levring *et al.* (1969); the order Rhodymeniales (Rhodophyta) has two families, 35 genera and about 185 species. Rhodymeniales members occur in all tropical and temperate waters. Krishnamurthy and Joshi (1970) have listed 16 Indian species of Rhodymeniales together with their distribution. Desikachary *et al.* (1998) have listed the following 20 species, collected from various parts of the Indian coats.

Family: **Champiaceae**

1. *Champia compressa* Harvey - Tuticorin, Hare Island
2. *C. compressa* Harvey var. *scindia* Boergesen - Tuticorin
3. *C. indica* Boergesen - Dwarka, Okha, Dona reef
4. *C. globulifera* Boergesen - Pamban
5. *C. parvula* (*C. Agardh*) Harvey - Okha, Dona reef, Tuticorin, Hare Island, Pamban, Krusadai Island
6. *C. somalensis* Hauck - Dwarka
7. *C. zonata* (J. Agardh) J. Agardh - Coast of Hindustan
8. *Gastroclonium iyengarii* K. Srinivasan - Okha, Dona reef

Family: Rhodymeniaceae

1. *Botryocladia botryoides* (Wulfen) J. Feldmann - Pearl Banks of Gulf of Mannar
2. *B. leptopoda* (J. Agardh) Kylin - Cape Comorin, Krusadai Island, Dwarka, Dona reef
3. *B. skottsbergii* (Boergesen) Levring - Laccadives, Krusadai Island, Nicobars-Kamorta Island
4. *Ceratodictyon spongiosum* Zanardini - Krusadai Island
5. *Coelarthrum muelleri* (Sonder) Boergesen - Okha, Dwarka, Dona reef

6. *C. opuntia* (Endlicher) Boergesen	- Tuticorin, Dhanuskodi, Krusadai Island, Tiruchendur, Gulf of Mannar
7. *Gelidiopsis variabilis* (Grev.) Schmitz	- Pudumadam, Tuticorin, Cape Comorin, Karwar, Bombay, Lakshdweep
8. *G. intricata* (J. Agardh) Vickers	- Andaman-Nicobar Islands
9. *G. repens* (Kuetzing) Schmitz	- Tuticorin
10. *Halichrysis thivyae* (Dawson) Eiseman and Moe	- Cast ashore after a storm on the northern shore of Krusadai Island
11. *Rhodymenia dissecta* Boergesen	- Tuticorin, Pamban, Tiruchendur, Idinthakarai, Cape Comorin, Dwarka
12. *R. sonderi* P. Silva.	- Bombay-Kolaba, Goa, Dona Paula.

Only very few studies have been made on Indian Rhodymeniales that too limited on their distribution and description. Hence in the present investigation, detailed studies have been carried out on the morphology, anatomy and reproductive structures of nine species viz. *Champia compressa, C. globulifera, C. indica, C. parvula* and *Gastroclonium iyengarii* of Champiaceae and *Botryocladia leptopoda, Coelarthrum opuntia, Gelidiopsis variabilis* and *Rhodymenia sonderi* of Rhodymeniaceae collected from the Gulf of Mannar region of Tamil Nadu State and Okhamandal coast of Gujarat State (Fig. 1). Other species could not be collected during my study period.

In addition, studies have also been made on the seasonal growth and phenology of *Champia globulifera* collected from Mandapam of the Gulf of Mannar region for a period of one year from April 1997 to March 1998 and correlated with the data collected on environmental and hydrological parameters such as temperature, salinity, dissolved oxygen and nutrients.

Champia globulifera occurs commonly in the Mandapam area. It grows attached to the rocks in the intertidal region which get exposed during lowest tides. This species was selected for seasonal studies because of its availability in the nearshore areas and the site is suitable for studying the environmental parameters.

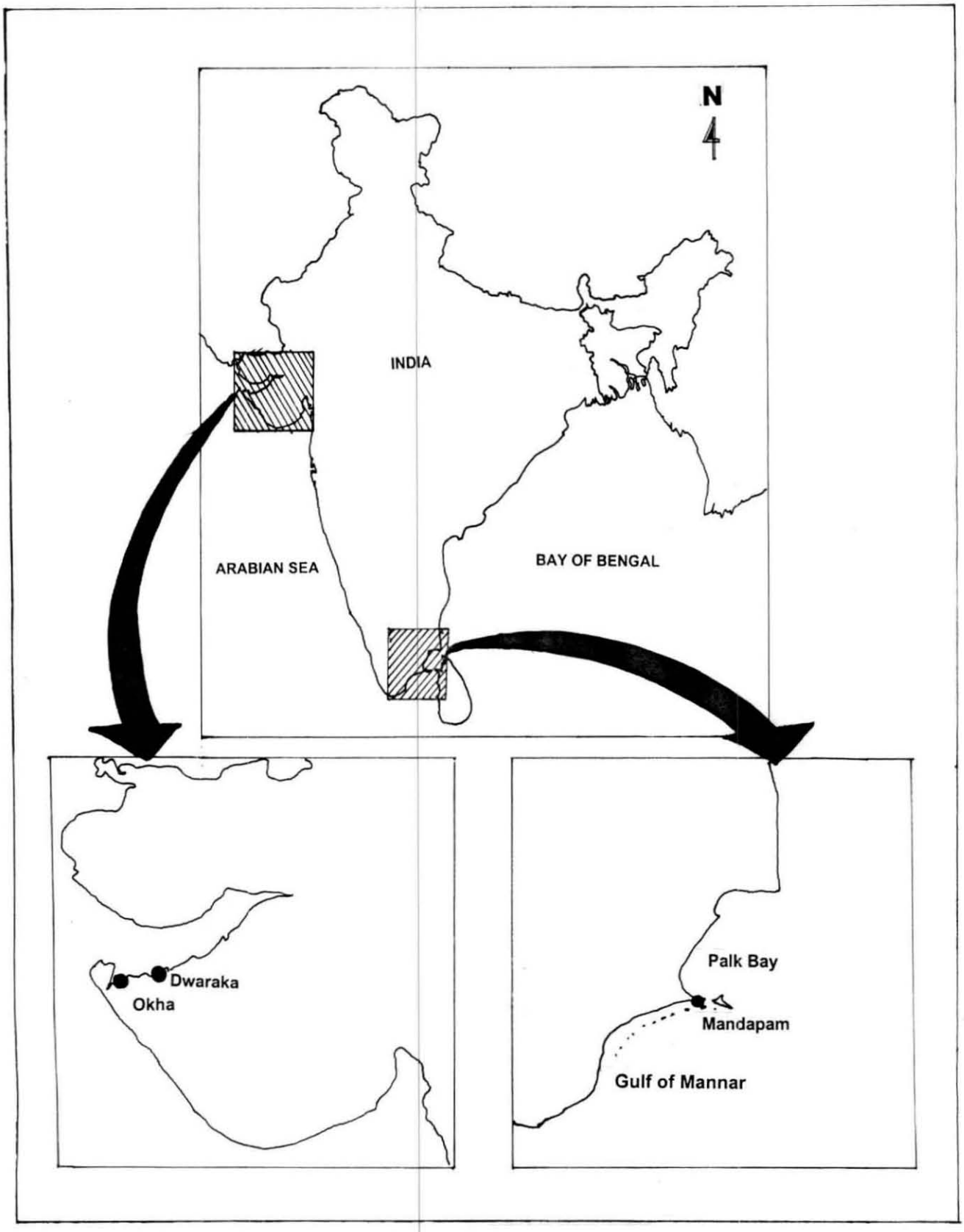


Fig. 1. Map showing the study areas

Review of Literature

Geographical Distribution of taxa of Rhodymeniales

Womersley (1950) listed the marine algae of Kangaroo Island in Australia, including the Rhodymeniales. Huisman (1993) reported a new record of *Coelarthrum boergesenii* from Rottnet Island in Western Australia. Huisman *et al.* (1993) recorded a new genus *Semnocarpa* from southern and western Australia.

Laing (1926) prepared a reference list of New Zealand marine algae including the Rhodymeniales.

Rhodymeniales from Japan were reported by many authors. Yamada (1923, 1932, 1934, 1935) reported the marine algae of Mutsu Bay, Urup and Kuriles in Japan. Tokida (1932, 1954) reported the marine algae from Robben Island and Saghalien. Marine red algae of Oshoro Bay, Hokkaido and it's adjascent waters were listed by Inagahi (1934). Segawa (1935) studied the marine algae of Susahi Province, Idsu and its vicinity. Kawabata (1936) listed the marine algae from Shikotan Island. Takamatsu (1938) gave an account of marine algae from the Sauriku coast, north eastern Honshu, Japan. Takamatsu (1939) reported the marine algae from the coast of Japan Sea in north-eastern Honshu. Nagai (1941) listed the marine algae of the Kurile Islands. Yamada and Tanaka (1944) reported the marine algae in the vicinity of the Akkesi Marine Biological Station. A list of marine algae from the coast of Iwate was prepared by Kawashima (1955). Funahashi (1967) enumerated the marine algae in the vicinity of Noto Marine Laboratory. Lee (1978) made an extensive study of the Rhodymeniales from Hokkaido Bay.

Cordero Jr. (1980) reported *Rhodymenia* sp. from Philippines.

A list of marine plants in the vicinity of the Institut Oceanographique de Nha Trang, Vietnam was given by Dawson (1954) which included Rhodymeniales.

Rhodymeniales of China were reported by Howe (1924) and Tseng and Li (1935).

Rhodymeniales occurring at Vladivostok and its vicinity was reported by Funahashi (1966).

Anand (1943) reported *Botryocladia leptopoda, Coelarthrum muelleri, C. opuntia, Champia plumosa, C. compressa, C. compressa* var. *scindia, C. parvula, C. salicornioides, C.*

globulifera and *C. somalensis* from Karachi, Pakistan. Shameel (1987) and Shameel *et al.* (1989) reported *Botryocladia leptopoda, Coelarthrum muelleri, Champia compressa, C.parvula, C. globulifera* and *C. plumosa* from the coast of Lasbela, Pakistan.

Boergesen (1944) reported eight species of Rhodymeniales from Mauritius. Boergesen (1950, 1951, 1952, 1953) reported another five species, *Botryocladia skottsbergii, Champia parvula, C. indica, Coelothrix indica* and *Erythrocolon podagricum* from Mauritius.

Jaasund (1976, 1977) reported the Rhodymeniales from Tanzania and described eight species.

Papenfuss (1940) prepared notes on South African marine algae including Rhodymeniales. Norris (1989, 1991) reported *Botryocladia* sp., *Halichrysis coalescens* and *Microphyllum borneense* from South Africa. John (1980) reported a new species of *Botryocladia* from Ghana (Tropical West Africa).

Coppejans (1980) reported *Lomentaria orcadensis* from the coastal area of Boulonnais (Pas-de-Calais), France. Maiz *et al.* (1987) reported the occurrence of *Chrysemenia wrightii* a Japanese member of Rhodymeniales in the Etangde Than (mediterranean coast of France).

Hooker (1833) prepared an account of British flora. Guiry (1977) studied the marine algae of the British Isles and described the habitat, distribution, synonymy, structure, development of thallus and reproductive structure and phenology of *Rhodymenia pseudopalmata* var. *pseudopalmata, R. pseudopalmata* var. *ellisiae* and *R. delicatula*. Hiscock and Maggs (1984) recorded *Rhodymenia holmesii* from South-West Britain.

Cullinane (1978) gave a preliminary account of the distribution of *Cordylecladia erecta* in Ireland and the British Isles. Guiry and Cullinane (1979) recorded *Gastroclonium reflexum* and *Rhodymenia pseudopalmata* var. *ellisiae* from the Wexford Coast, Ireland.

Marine algae from Canary Islands were reported by Boergesen (1929), Ballesteros *et al.* (1992) and Gonzales-Ruiz *et al.* (1995). *Lomentaria subdichotoma* and *Rhodymenia ardissonei* were recorded by Ballesteros *et al.* (1992).

The marine algae of Denmark, includig Rhodymeniales were listed by Rosenvinge (1931).

The marine algae collected during the Norwegian Scientific expedition to Tristan da Cunha were reported by Baardseth (1941).

Norris and Ballantine (1995) reported two new species of *Chrysemenia* from the tropical western Atlantic.

Boergesen (1915-1920) reported the marine algae of the Danish West Indies.

Rivera and Edding (1986) described the morphology of *Gastroclonium parum* from Chile. Santelices *et al.* (1989) recorded *Gastrocloninum cylindricum* and *G. trichodes* from Chile.

Diaz-Piferrer *et al.* (1964) and Ballantine and Wynne (1986) reported *Coelathrix irregularis* and *Halichrysis peltata* from Puerto Rico. A new species *Botryocladia ganesanii* was described by Aponte-Diaz (1988) from the Caribbean coast of Puerto Rico.

Ganesan (1981) reported on the marine algal flora of Venezuela. Lemus (1984) recorded the genus *Rhodymenia* for the first time from Venezuela.

Dawson (1963) listed the Rhodymeniales of Pacific Mexico. Leon-Tejera and Gonzalez-Gonzalo (1994) reported the Rhodymeniales from Oaxaca coast, Mexico.

Taylor (1939) listed the algae including members of Rhodymeniales from Uruguay, Argentina, the Falkland Islands and the Strait of Magellan during "Hassler", Albatross and Shnitt Expeditions.

Setchell and Gardner (1903, 1924, 1930) reported the Rhodymeniales from North-western America. Taylor (1937, 1945, 1960) listed the marine algae, including Rhodymeniales from the North America, Galapagos Islands and eastern tropical and subtropical coasts of America. Dawson (1945, 1949, 1950, 1960) reported the Rhodymeniales from Pacific coast, Channel Islands in Southern California and eastern tropical and subtropical coasts of America. Kylin (1925) reported the red algae in the vicinity of the Biological Station at Friday Harbour, Washington. Hollenberg (1940) reported the Rhodymeniales from southern California. Smith (1944) reported the Rhodymeniales of the Monterey Peninsula, California. Doty (1947) reported the marine algae of Oregon. Lindstorm and Scagel (1979) reported *Gastroclonium coulteri* from southeast Alaska. Searles (1984) reported a new species *Gloioderma rubrisporum* from North Carolina. Breda and Foster (1985) studied the composition, abundance and phenology of *Botryocladia pseudodichotoma* and *Rhodymenia californica* var. *californica* associated with two central California kelp forests. Phillips *et al.* (1988) reported

Rhodymenia californica, *R. pacifica* and *Botryocladia pseudodichotoma* from the kelp forests of California.

The red algae including Rhodymeniales of Iceland was reported by Jonsson (1901). The presence of Rhodymeniales in East Greenland was reported by Lund (1959).

Kjellman (1983) reported the Rhodymeniales of the Arctic. Moe (1986) recorded a new genus and species *Hymenocladiopsis crustigea* from the Antarctic Peninsula. Lu Baoren *et al.* (1986) reported *Leptosomia simplex, Rhodymenia antarctica* and *R. palmatiformis* from the Davis Station, Antarctica.

Silva *et al.* (1996) have prepared a catalogue of the benthic marine algae including Rhodymeniales of the Indian Ocean.

Studies on structure, reproduction, cytology, ecology, productivity and culture of Rhodymeniales

Grubb (1925) reported the male reproductive organs of Rhodymeniales. Svedelius (1937) observed apomeiotic tetrad division in *Lomentaria rosea*. Dawson (1941) reviewed the genus *Rhodymenia* with descriptions of new species. Papenfuss (1946) reported the structure and reproduction of *Trichogloea requienii*. Sparling (1957) studied the structure and reproduction of 13 species of Rhodymeniaceae.

Lee (1969) reported on the male organs of Rhodymeniales. Lee and Kurogi (1968 a, b) reported on the antheridium formation in *Halosaccion saccatum*, *H. firmum* and *Rhodymenia intricata*. Lee and Kurogi (1972) made ecological observation of the members of the Rhodymeniales in Hokkaido. Lee and Kurogi (1973) studied the development and structure of vegetative and reproductive organs of *Binghamia californica*. Lee (1978) studied the structure and development of reproductive organs in *Halosaccion yendoi*, *H. firmum*, *Rhodymenia intricata*, *R. pertusa* and *Chrysemenia wightii* of Rhodymeniaceae, *Lomentaria hakodatensis*, *L. catenata* and *Champia parvula* of Champiaceae. Huve and Huve (1976) studied *Halichrysis depressa*.

Thursby and Steele (1984) reprted on the indeterminate growth of pericarps in three members of Rhodymeniales. Kajimura (1986) studied the morphology of *Gloioderma japonicum*. Ballantine (1989) studied the reproduction of *Botryocladia pyriformis* and *B. wynne*.

Brodie and Guiry (1988) described the life history and reproduction of *Cordylecladia erecta*. The life history of *Gloioderma iyoensis* was reported by Migita and Lima (1990).

Heine (1983) studied the seasonal productivity of *Botryocladia pseudodichotoma* and *Rhodymenia californica* var. *californica*.

Sparling (1961) gave a report on the culture of some species of *Halosaccion*, *Rhodymenia* and *Fauchea*.

Studies on Indian Rhodymeniales are very few. Boergesen (1924, 1931, 1933, 1937, 1938) described the ecology, distribution and anatomy of *Coelarthrum opuntia, C. muelleri, Botryocladia leptopoda, B.skottsbergii* and *Rhodymenia dissecta of Rhodymeniaceae and Champia globulifera, C. indica and C. compressa* var. *scindia* of Champiaceae.

Devanesan and Chacko (1941) reported about the commensalism in sponges, symbiotic association of the sponge *Adocia dendyi* with the alga *Ceratodictyon spongiosum*. The reproductive development of this red alga was investigated and the genus *Ceratodictyon* was classified under Rhodymeniales by Price and Kraft (1991). This alga was isolated from an alga-sponge (*Sigmadocia symbiotica*) and unialgal culture was done in simple inorganic medium in the absense of sponge. A very good growth of the alga was obtained. However the plant died when introduced in nature (Price et. al. 1984).

Srinivasan (1960, 1969) reported a new species *Gastroclonium iyengarii* from Okha and described the anatomy of vegetative and tetrasporic plants. Later Balakrishnan (1975) reported cystocarpic plants of *G. iyengarii* collected from Porbandar and Veraval.

Dawson (1963) described a new species, *Maripelta thivyae* which was collected by Thivy from the shores of Krusadai Island, after a storm. Eiseman and Moe (1981) renamed it as *Halichrysis thivyae* because of numerous coaslecent blades and polychromatic medulla.

Umamaheswara Rao (1968, 1969) reported *Champia compressa, C. globulifera, C. parvula, Botryocladia leptopoda, Coelarthrum opuntia* and *Gelidiopsis variabilis* from Gulf of Mannar area.

Krishnamurthy and Joshi (1970) prepared a checklist of Indian marine algae. They enumeraed 21 species under Rhodymeniales, of which five belonged to Sri Lanka and Pakistan. Umamaheswara Rao and Sreeramulu (1970) reported *Gelidiopsis variabilis* from Visakhapatnam coast.

Gopalakrishnan (1970) reported *Champia globulifera* from Gulf of Kutch.

Anon (1978) reported the marine algal resources of Tamilnadu based on the survey of coastline from Athankarai to Rameswaram in Palk Bay and the coastline from Rameswaram to Melamidalam including 20 islands in the Gulf of Mannar. Seven species of Rhodymeniales viz. *Botryocladia leptopoda*, *Coelarthrum opuntia*, *Rhodymenia sonderi*, *R.dissecta*, *Rhodymenia* sp., *Champia compressa* and *C. parvula* were among the red algae growing in this area. Among them, *Botryocladia leptopoda*, *Coelarthrum opuntia* and *Champia parvula* were found to occur in huge quantities.

Chauhan and Mairh (1978) reported the growth of *Champia compressa* from Saurashtra coast. Kaliaperumal and Umamaheswara Rao (1982) studied the seasonal growth and reproduction of *Gelidiopsis variabilis* for a period of 2½ years and reported that only tetrasporic and vegetative plants were found in the populations. Untawale *et al.* (1983) noted the occurrence of *Champia compressa* in Goa coast. Kaliaperumal and Pandian (1984) reported the occurrence of *Botryocladia leptopoda* at Idinthakarai and Kovalam, *Coelarthrum opuntia* at Tuticorin area, Manapad and Kovalam and *Champia parvula* at Tuticorin area and Manapad.

Agadi (1985) reported *Champia* sp. from Kumba, Karnataka coast. Sohba and Nair (1985) recorded *Botryocladia leptopoda* from Kanyakumari (Tamil Nadu), Thangasseri and Thirumullavaram (Kerala). Balasundaram (1985) recorded *Rhodymenia dissecta* on intertidal rocks at Tiruchendur, Tamilnadu occassionally. Subba Rao *et al.* (1985) carried out a survey of the marine algal resources of the Andhra Pradesh and recorded the occurrence of *Champia parvula* from Bhimulipatnam to Itchapuram. Kaliaperumal *et al.* (1989) have recorded *Champia parvula* from Kiltan, Bingaram, Androth, Kavaratti and Suheli islands of Lakshadweep during the seaweed resources survey in all the islands of Lakshadweep. Maya and Nair (1992) collected *Champia compressa* from the rock pools of Kovalam, Kerala coast. Anilkumar and Panikkar (1993) have described *Champia compressa* and *C. parvula* collected from the Kerala coast.

Kaliaperumal *et al* (1998) reported about the seaweed resources and their distribution in the deep waters extending from Dhanuskodi to Kanyakumari in Tamilnadu. The deep water seaweed resources survey was conducted at a depth ranging from 5 to 22 m. A total of 100 algae including five species of Rhodymeniales were recorded. *Botryocladia leptopoda* and *Coelarthrum opuntia* were reported from the Dhanuskodi-Kilakkarai sector. *Botryocladia leptopoda* occurred in harvestable quantity of 862.5 tonnes from 417.5 sq.km. area while all

the other species were in negligible quantities. *Champia compressa* was recorded from Nallatannitivu-Vembar sector, *Gastroclonium iyengarii* was collected from Kattapadu-Tiruchendur sector whereas *Champia compressa* and *C. parvula* were recorded from the Alantalai-Manapad sector.

Materials and Methods

MATERIALS AND METHODS

Extensive collection of members of the order Rhodymeniales (Rhodophyta) occurring along the east and west coasts of India was made during 1996-98. Among the sixteen Indian species listed by Krishnamurthy and Joshi (1970), only nine species only could be collected during the study period. *Champia globulifera* was collected from Pamban coast, *C.parvula* was collected from Krusadai Island and *C. compressa* and *C. indica* were collected from Shivrajnagar and Dwaraka in Gujarat. *Gastroclonium iyengarii* was collected from Port Okha. *Botryocladia leptopoda* was collected from off Manoli Island in Mandapam area and Kanyakumari. *Coelarthrum opuntia* was collected off Manoli Island in Mandapam area and Manapad. *Rhodymenia sonderi* was collected from Manapad and Kanyakumari. The ninth species *Gelidiopsis variabilis* was collected from Pudumadam.

The seaweeds were collected from the intertidal region and shallow waters upto 6.0 m depth. Seaweed materials of each collection were cleaned and transported to the laboratory in polythene bags containing seawater for preparing herbarium and for preservation in 5% seawater formalin for microtomy.

Preparation of herbarium

Fresh seaweeds collected from the sea were washed well with filtered seawater. A clean tray was filled with filtered seawater with a wooden plank immersed in it. A white paper was spread over the immersed wooden plank. Cleaned specimen was placed on the paper oriented in the same manner as in nature and then the plank was gently raised above the water level. After draining the water, the white paper with the specimen was transferred to a folded blotting paper without disturbing the arrangement of the specimen on the paper. Blotting papers were changed every 24 h to facilitate quick moisture absorption. The specimens got attached firmly to the white paper and got dried completely within a week. The herbarium specimens were then labelled, giving the genus and species names, locality, date of collection and other details.

Preservation

The specimens were repeatedly washed with filtered seawater to remove the sand particles and epiphytes. They were then fixed in 5% seawater-formalin for preservation.

Microtomy

The seawater-formalin preserved specimens were carefully examined before processing for microtomy. The external morphology of the thallus was studied by examining through a stereoscopic microscope. Photographs of the vegetative and reproductive parts were taken. Microphotographs of the reproductive structures were also taken. Parts of the specimens with important stages were cut into small bits (1.0 to 1.5 cm long) for sectioning with microtome.

Dehydration and infiltration

Tertiary Butyl Alcohol method (Johansen, 1940) was used.

The selected bits of the thallus were transferred to 50% alcohol and after 30 minutes through Tertiary Butyl Alcohol (TBA series).

The Tertiary Butyl Alcohol series were prepared as per the combinations given below:

	Approximate total percentage of alcohol				
	50	***70***	***85***	***95***	***100***
Distilled water	50	30	15	---	---
95% Ethyl alcohol	40	50	50	45	---
Tertiary Butyl Alcohol	10	20	35	55	75
100% Ethyl alcohol	---	---	---	---	25

In 50% solution, two changes were given to the materials at two h intervals. In 70% solution two changes were given to the materials at two h intervals and then kept over-night. This was followed by changes to 85%, 95% and 100% at one h intervals. After the 100% solution, the material was transferred to pure Tertiary Butyl Alcohol. Two changes were given with this at two h intervals and then kept in the same fluid overnight.

Infiltration

The dehydrated materials were passed twice through equal proportion of pure Tertiary Butyl Alcohol and liquid paraffin at two h intervals. Then the material along with a small

amount of Tertiary Butyl Alcohol and liquid paraffin was poured over the just solidified top of the molten paraffin wax (56-58°C melting point)* and kept in an oven, maintained at 58°C. Paraffin blocks with the materials arranged in a convenient way for taking vertical and transverse sections were prepared after giving two changes of fresh molten wax at six h intervals**.

* BDH paraffin wax was boiled and cooled atleast four or five times and kept in an oven at 58°C.

** A thick paper boat was designed and smeared with glycerine. Materials with molten paraffin wax were poured on the boat and the materials were arranged and lifted a little by using hot needles. After solidification the paraffin wax block was stored.

Sectioning

Serial microtome sections of 6-10 μm thick were taken using a Rotary microtome. Clean slides wee smeared with Haupt's adhesive* and ribbons with sections of material were floated on four or five drops of 4% formalin on the slides. The ribbons were stretched on a 35°C hot plate. Then the formalin was drained off the slides and were left to dry for a couple of days.

* Haupt's adhesive: To make it, 1 g plain knox gelatin was dissolved in 100 ml distilled water at a temperature of 30°C. When completely dissolved 2 g phenol crystals and 15 ml glycerin were added. Then stirred well and filtered.

Staining

The prepared slides with paraffin ribbons were brought down through xylol-alcohol series in Coplin jars, in the sequence given below.

Xylol I Xylol II	30 minutes in each
Xylol : Absolute alcohol	
3:1 2:2 1:3	5-10 minutes in each
Absolute Alcohol	

95% 90% 85% 70% 60% 50% 30%	5-10 minutes in each

The slides were washed thoroughly in distilled water, transferred to Iron alum (4%)* for 40 min., again washed thoroughly in running water followed by changes in distilled water and passed through

30% alcohol 50% alcohol	5 - 10 minutes in each

* - Iron-alum: 4.0 g Ferric ammonium sulphate dissolved in 100 ml of distilled water.

and stained in Ehrlich's Haematoxylin** for 30 min.

** - Ehrlich's Haematoxylin:

Distilled water	100 ml
Absolute alcohol	100 ml
Glycerine	100 ml
Glacial acetic acid	10 ml
Haematoxylin crystals	2 g
Aluminium ammonium sulphate	in excess

Destain in 50% alcohol,

pass through

60% alcohol 70% alcohol 80% alcohol 90% alcohol	5-10 minutes in each

Counterstain with Erythrosin stain* - 15 min.

Destain in 90% alcohol,

pass through

Absolute alcohol	5-10 minutes
Absolute alcohol : Xylol series	

3:1	
2:2	
1:3	5-10 minutes in each
Xylol I	
Xylol II	

* - Erythrosin stain: 1 g of Erythrosin dissolved in 100 ml of 90% alcohol.

Mounting

The slides from xylol II were taken out and mounted using the DPX mountant and cover glasses. The excess of DPX mountant was removed and the slides were carefully indexed.

Description of the Specimens

Herbarium specimens, fixed materials and microtome sections were thoroughly examined to study the morphological and anatomical features of nine different species of Indian Rhodymeniales.

The herbarium specimens were used to note down, height of the thallus, basal attachment (simple or clustered), branching and other morphological characters.

The fixed materials were used for studying the structure of vegetative and reproductive structures and to take measurements of the breadth and width of these structures using ocular micrometer.

Microtome sections were used to study the cellular structure of the thallus, development of gametangial and tetrasporangial sori and cystocarps and also for measuring the size of cells, spores and reproductive structures.

Ecological studies on *Champia globulifera*

The growth and phenology of *Champia globulifera* occurring at Mandapam were studied for a period of one year from April 1997 to March 1998. Monthly samples were collected at random from the rocks, cleaned well and brought to the laboratory in plastic buckets with sea water. Hundred plants were measured to calculate the mean height and standard deviation in height of the population.

Surface seawater samples were collected every month. Atmospheric temperature and surface seawater temperature were measured in the field itself using a standard centigrade thermometer. Salinity was estimated using a Salinometer (Model E.2). Dissolved oxygen was estimated by the modified Winkler's method (Strickland and Parsons, 1972). The seawater was analysed for phosphate, nitrate, nitrite and silicate contents following the standard methods of Strickland and Parsons (1972).

Results and Discussion

RESULTS AND DISCUSSION

Results of the studies on the morphology, anatomy and structure of reproductive organs of 9 members of Rhodymeniales collected from the Gulf of Mannar area of Tamil Nadu State and Okhamandal Coast of Gujarat State are presented in this chapter.

RHODYMENIALES

Plants show various shapes from filiform to fleshy membranous thalli, sometimes hollow, corticated, with a modified multiaxial type of structure, commonly appearing parenchymatous; asexual reproduction is by tetraspores in sporangial sori or scattered over the plant just below the surface; sexual reproduction is by spermatangia borne on surface cells in more or less restricted areas and by carpogonia in procarps sunken in the cortex; auxiliary cells are established by segmentation indirectly from the cell supporting the carpogonial branch; cystocarps are enveloped by a pericarp.

I. *Champiaceae*

Plants are usually bushy; the branches are cylindrical or compressed, delicately membranous to quite soft; from an apical meristem, develop superficial small assimilatory cells; an inner cortex of large cells is present and a medullary cavity is traversed by longitudinal filaments, the filaments bear lateral secretory cells; tetrahedral sporangia are formed from cortical cells and lie just below the surface; spermatangia are borne on groups of surface cells of the small male plants; carpogenic branches are three to four-celled, each borne on an inner cortical cell; the auxiliary cell is secondarily derived from the supporting cell; after fertilization the gonimoblasts and in turn the large carposporangia are formed from a large fusion cell and the whole structure is covered by a prominent ostiolate pericarp.

1. *Champia compressa* Harvey, 1838 (Pl. 1A and B, Figs. 2A-C)

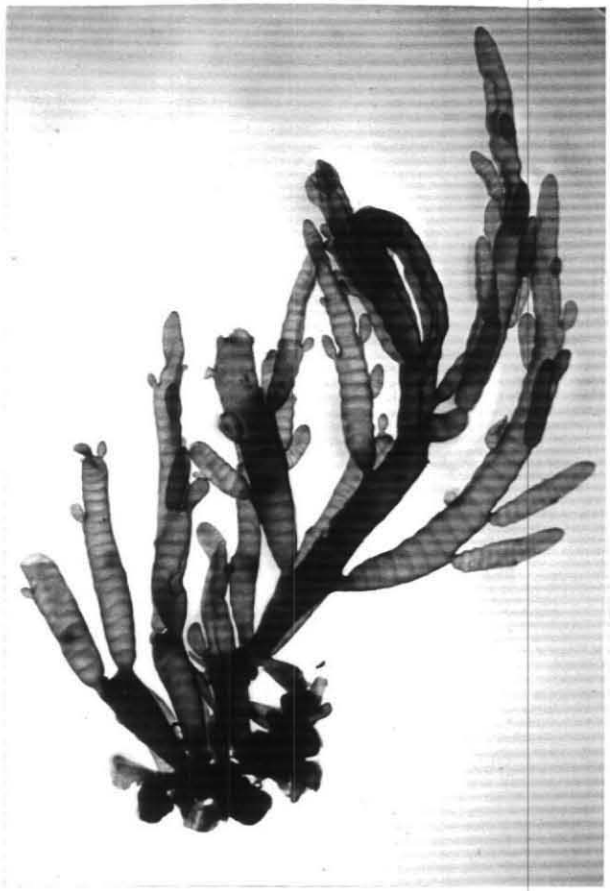
= *Gastridium zonatum* Suhr, 1834

Location: Shivrajnagar and Dwarka (Gujarat State)

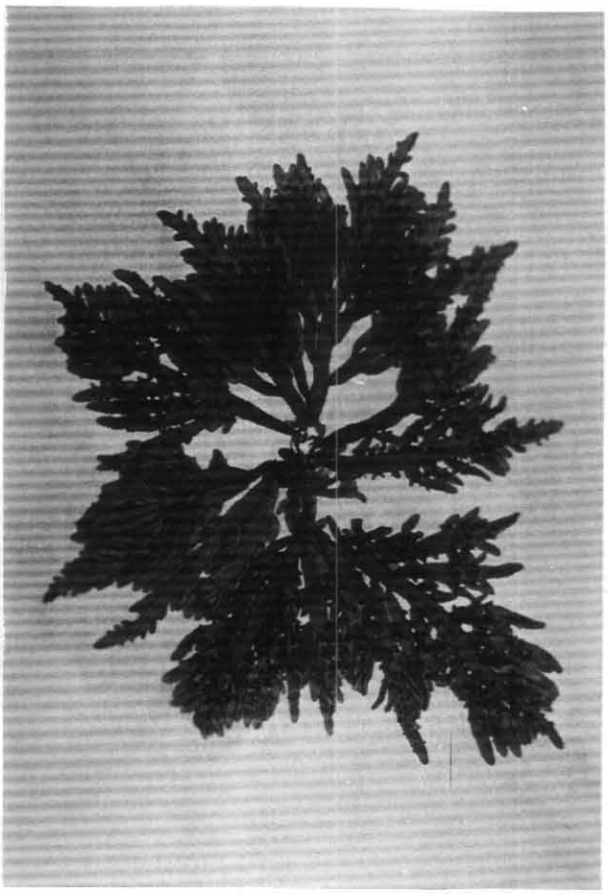
Plants grow attached to rocks near the low water mark. The plants are highly branched, small, upto 3cm high and 3 mm broad; branching irregular forming clusters. The thalli are highly mucilaginous and red in colour, the fronds are compressed to flattened. The

PLATE - 1A

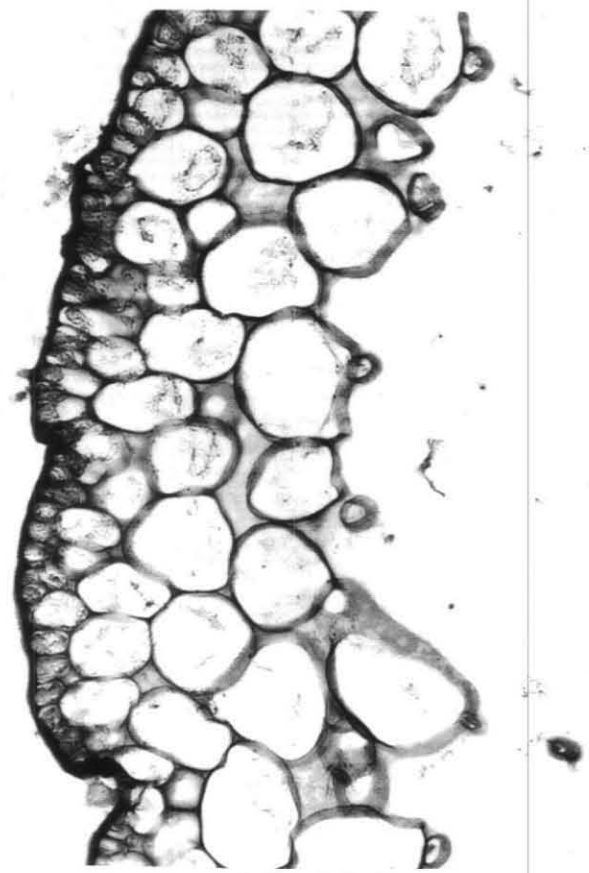
Champia compressa



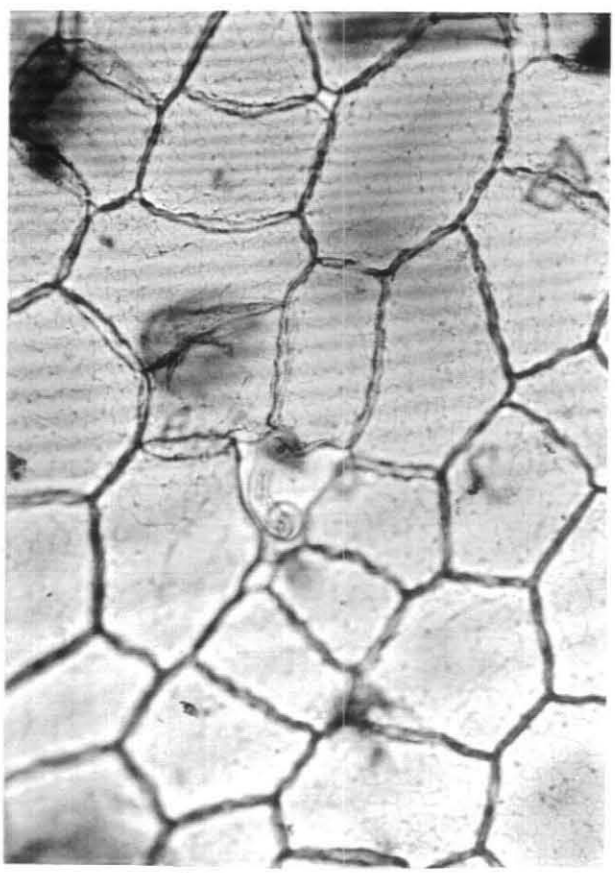
a. Tetraspororic plant



b. Cystocarpic plant



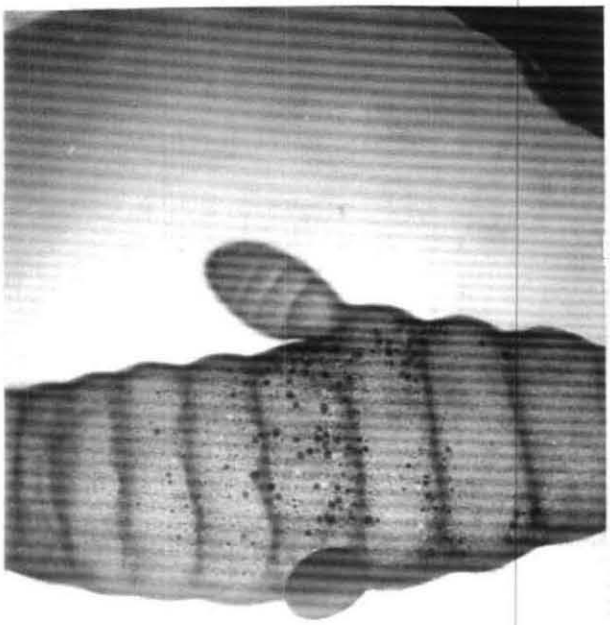
c. C.S. of thallus



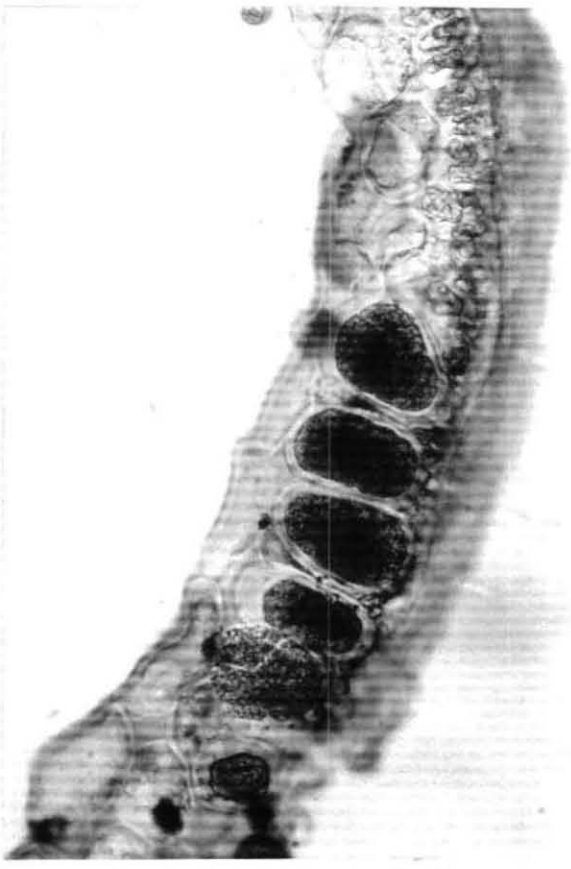
d. A portion of septum

PLATE - 1B

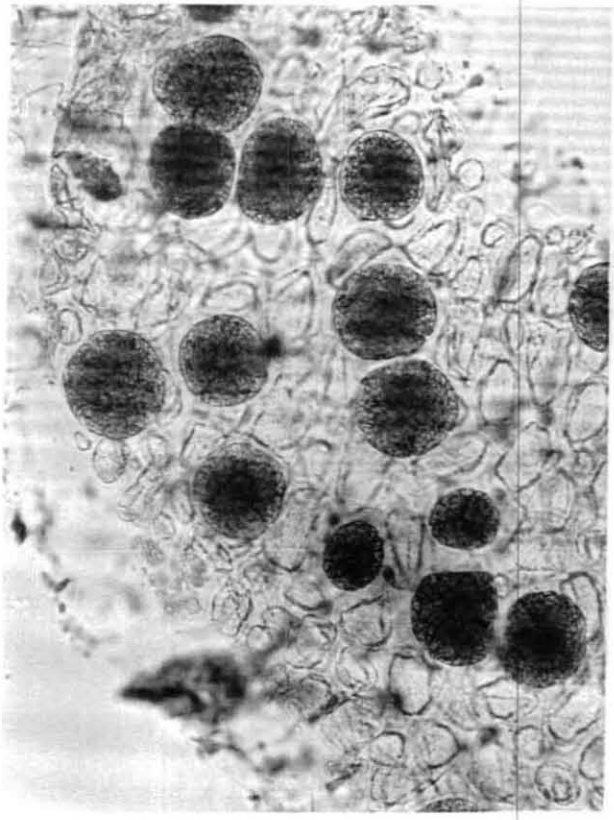
Champia compressa



e. A portion of tetrasporic plant



f. C.S. of tetrasporic thallus



g. Surface view of tetraspores

h. L.S. of cystocarp

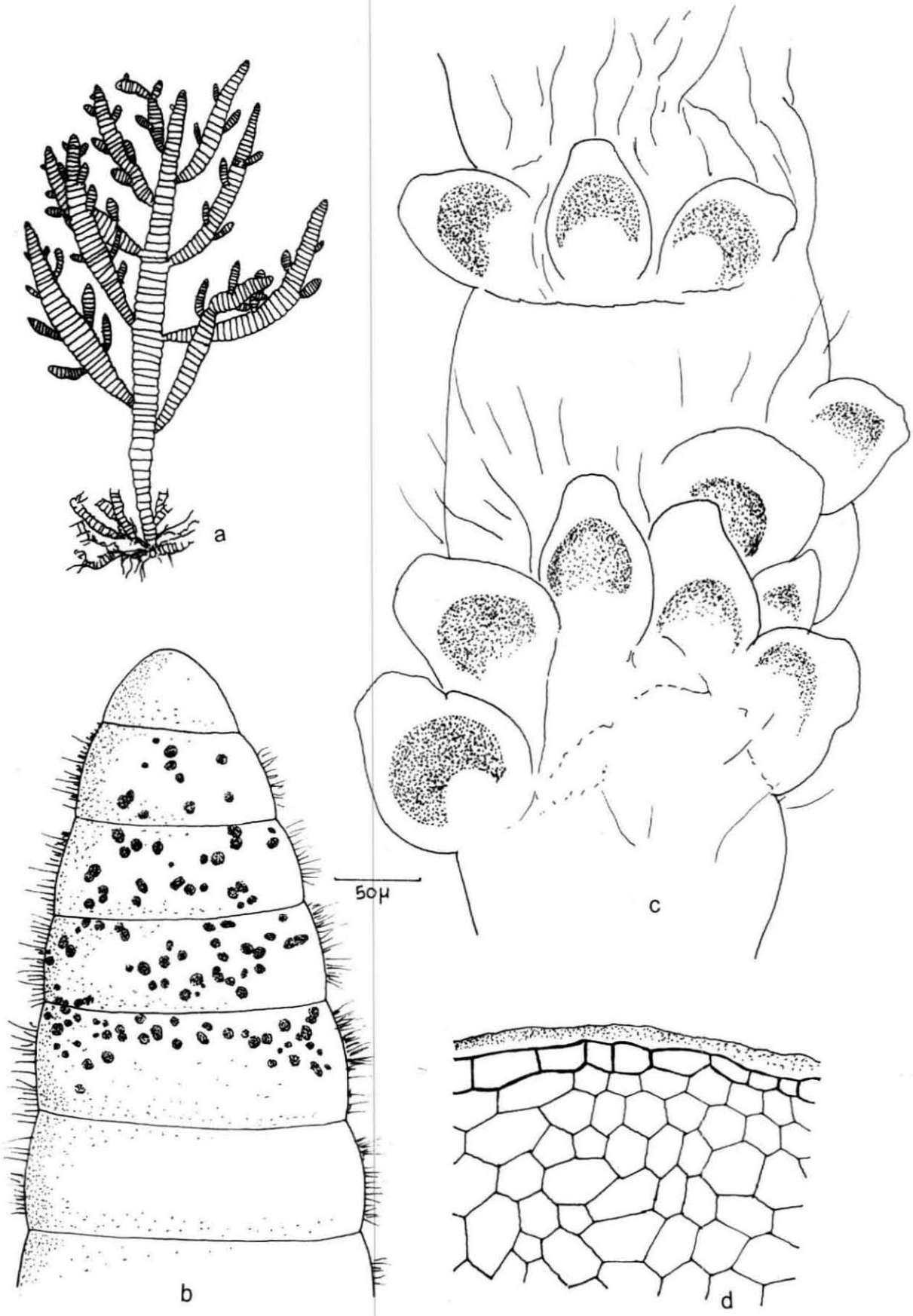
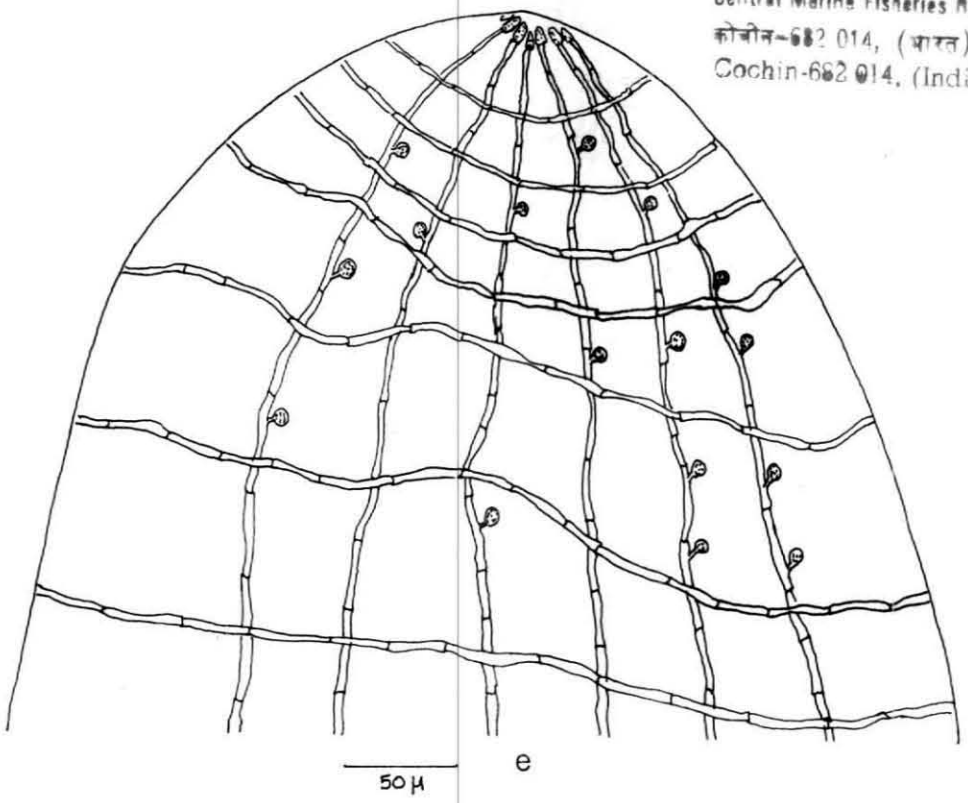
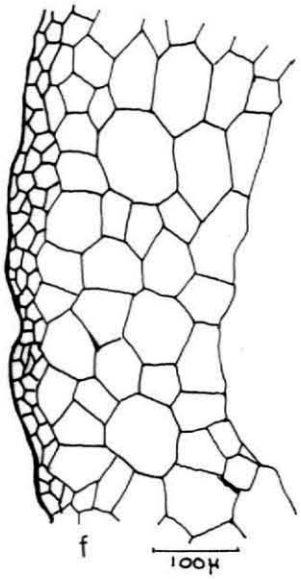
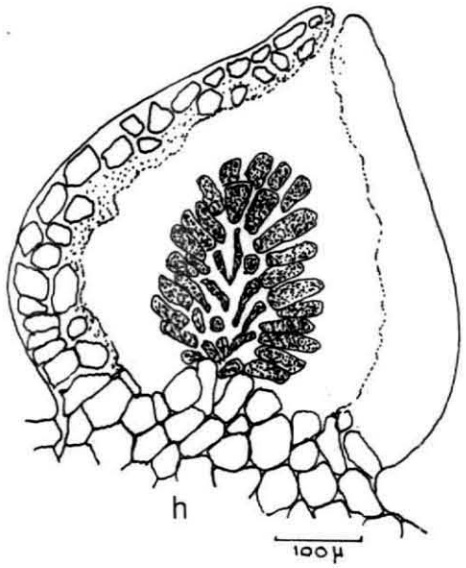


Fig. 2A. ***Champia compressa***

a. Habit b. A portion of tetrasporic plant c. A portion of carposporic plant
d. A portion of septum







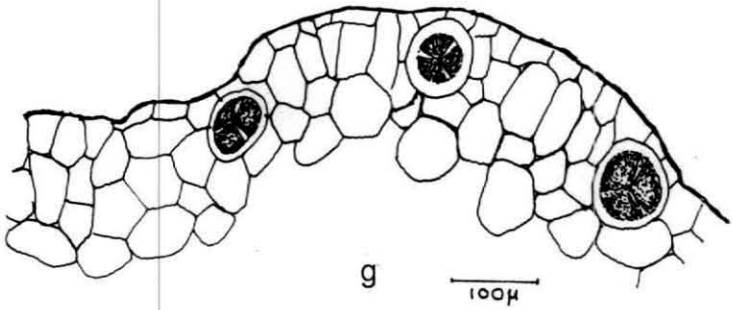


Fig. 2B. *Champia compressa*

e. L.S. of apex f. C.S. of thallus g. C.S of tetrasporic thallus

h. L.S. of cystocarp

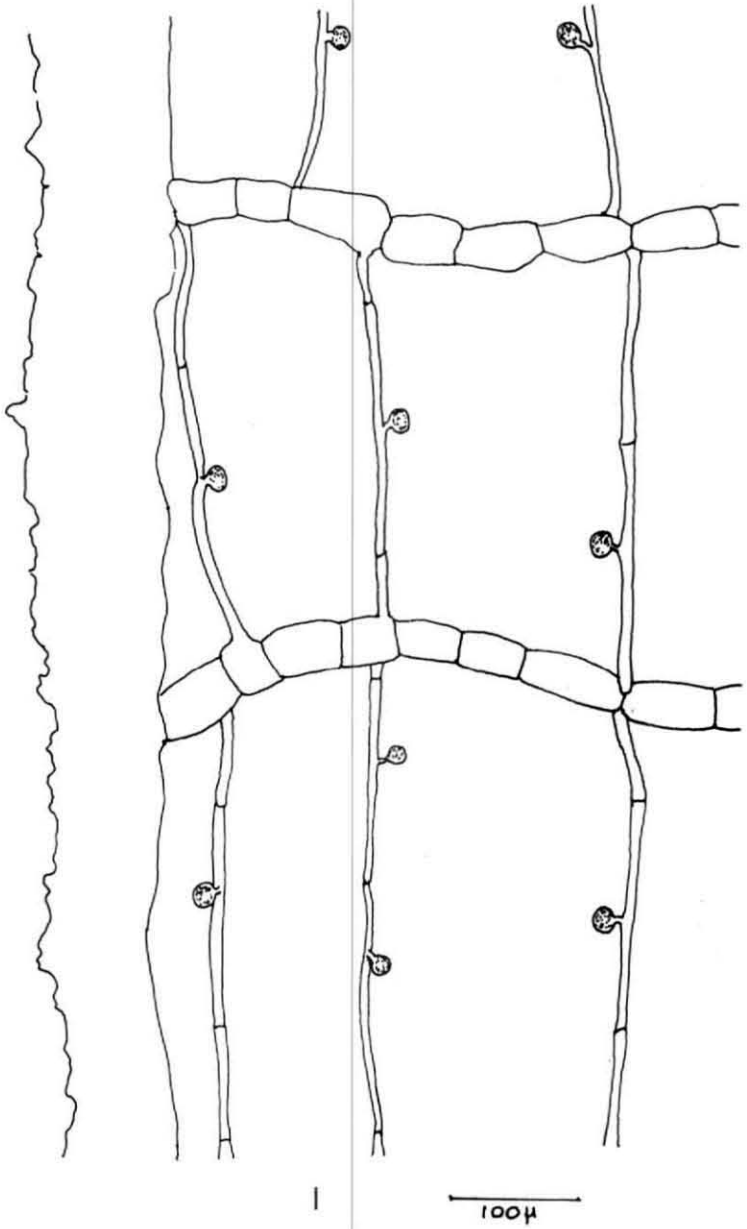


Fig. 2C. ***Champia compressa***

i. L.S. of thallus showing septum and origin of gland cells

barrel shaped segments are short, 1 - 1.5 mm long and 2 - 5.23 mm broad. A cross section of the thallus shows only one layered wall of more or less squarish cells, 50-60 μm long and 45-60 μm broad and with a thick mucilaginous sheath. A few smaller sub cortical cells, 35-40 μm long and 28-35 μm broad are seen here and there. The vertical filaments are mostly unbranched, 28-30 μm in diameter. Gland cells with dense contents are 15-20 μm in diameter.

Tetrasporangia are arranged in well marked transverse bands both on the main axis and branches. Tetrasporangia are ovoid and 80-100 μm long and 60-75 μm wide. Tetraspores are tetrahedrally arranged, pyramidal in shape and 50-70 μm in diameter. The cystocarpic plants are slightly larger than tetrasporic plants. Cystocarps urceolate, neck elongated with a distinct ostiole, more than five on each segment, 900-1300 μm long and 800-1150 μm broad, carpospores are pyriform in shape, produced in terminal carposporangia and measure about 76-80 μm long and 25-30 μm broad. Spermatangial plants are usually smaller than the tetrasporic plants, spermatangial sorus irregular in shape is found as white patches, spreading over the segments, 2-4 nm long and 1-2 mm broad. Spermatia cut off from the subcortical cells measure about 3-4.5 μm in diameter, spherical or ovoid in shape.

2. *Champia globulifera* Boergesen, 1937 (Pl. 2, Figs. 3A and B)

Location: Mandapam (Tamilnadu State)

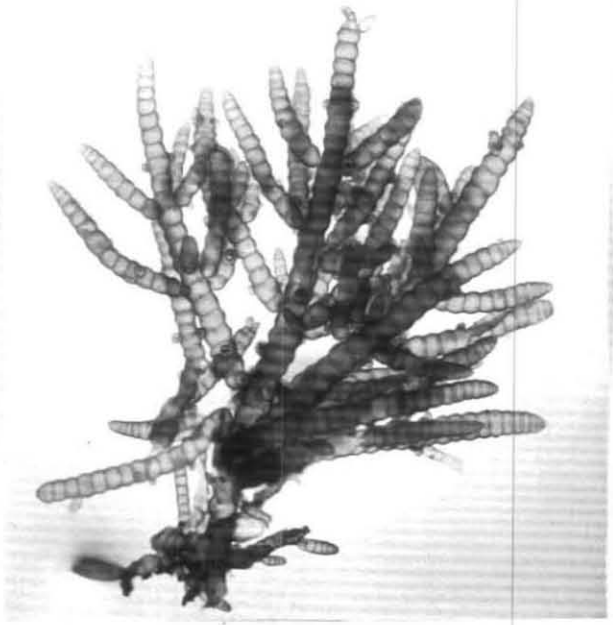
Plants grow attached to partially exposed rocks in the intertidal areas. Plants upto 6 cm height, form dense tufts, as several shoots arise from the basal disc and decumbent branches are able to form new discs, thus giving rise to new tufts. The plant is monopodial in growth and the branches are given out in all directions. They are either solitary or often opposite or verticillate and they are ramified again in the same way but to a lesser extent. The main shoots have a breadth of about 2 mm but the branches are a little less broad. The branches are narrowed at their base and taper slowly towards their upper ends. The apex is obtuse. The plant is clearly constricted at the diaphragms, the segments becoming barrel-shaped and about as long as broad, but becoming gradually shorter upwards.

A transverse section shows that the wall is composed of two layers of cells, inner layer of large cells 40-45 μm X 30-35 μm size, covered more or less completely by an outer layer composed of slightly smaller cells, 25-35 μm X 15 μm size.

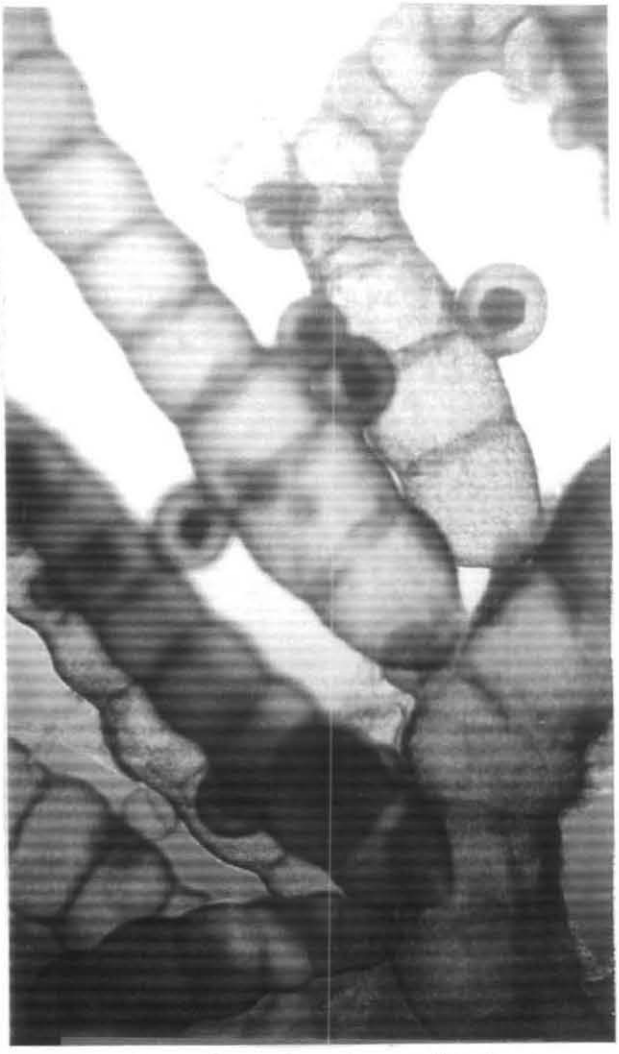
The cystocarps are nearly globose and rather large and measure about 1 mm long and 1 mm broad. They occur scattered on the thallus though often with a tendency to place

PLATE - 2

Champia globulifera

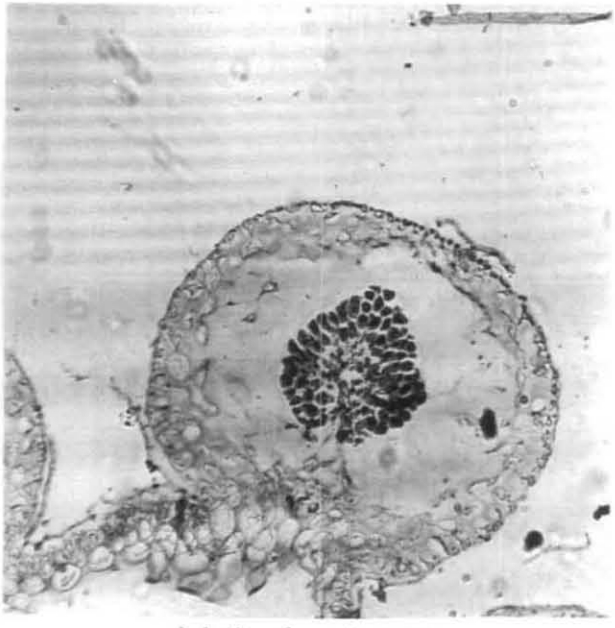


a. Habit



b. A portion of cystocarpic plant

c. A portion of tetrasporic plant



d. L.S. of cystocarp

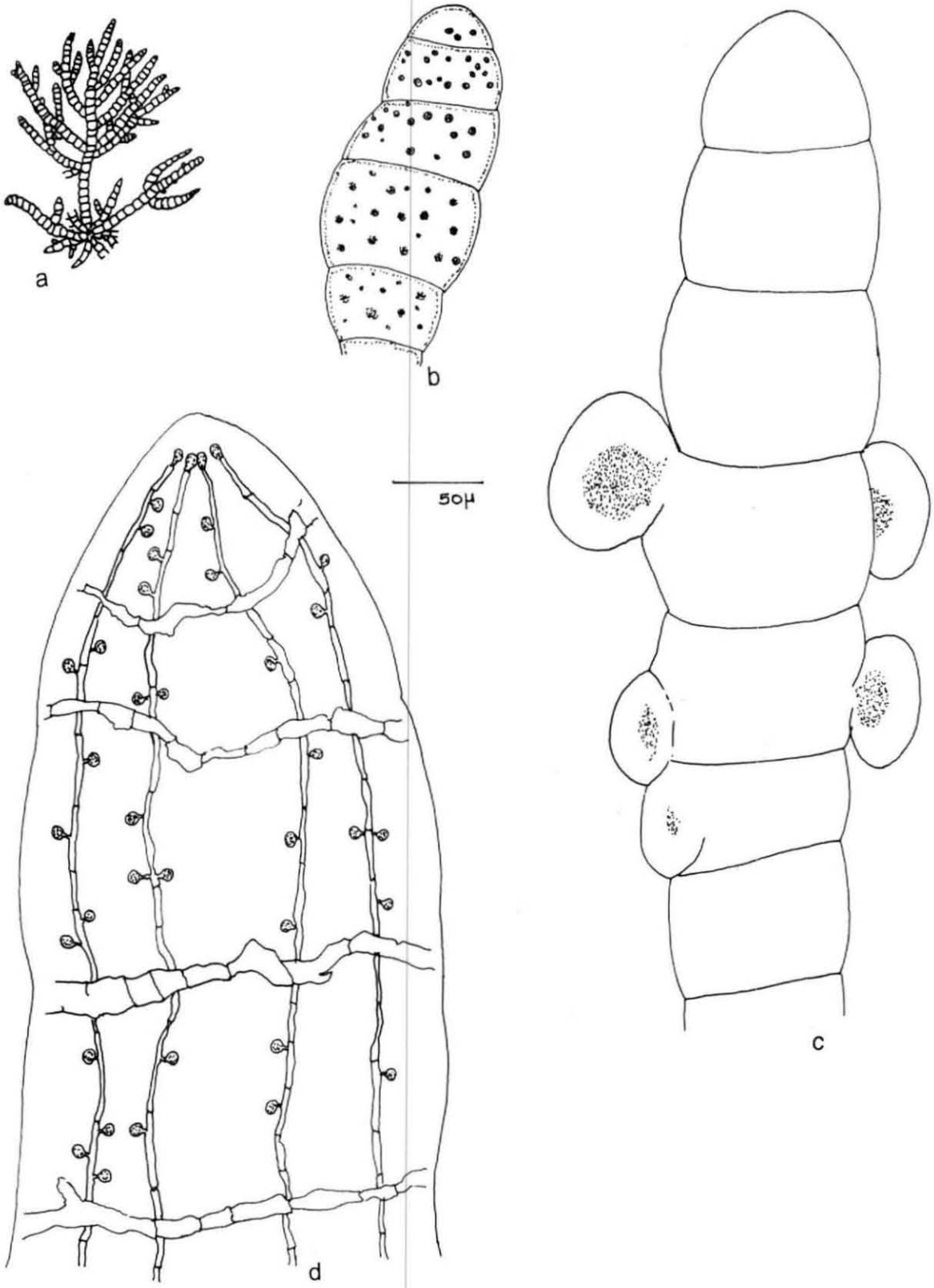
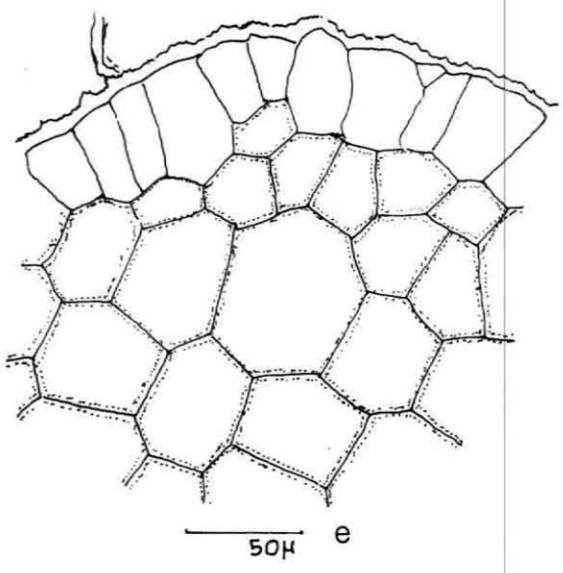
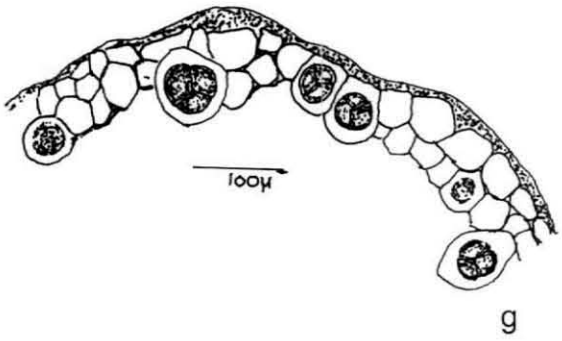


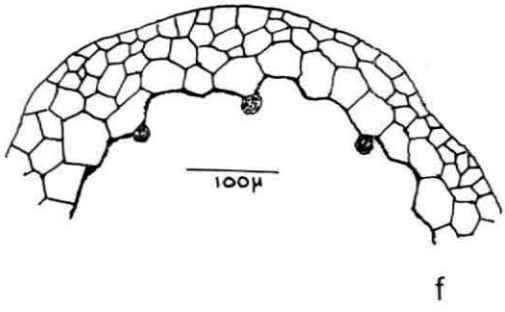
Fig. 3A. *Champia globulifera*

a. Habit b. A portion of tetrasporic plant c. A portion of carposporic plant

d. L.S. of apex







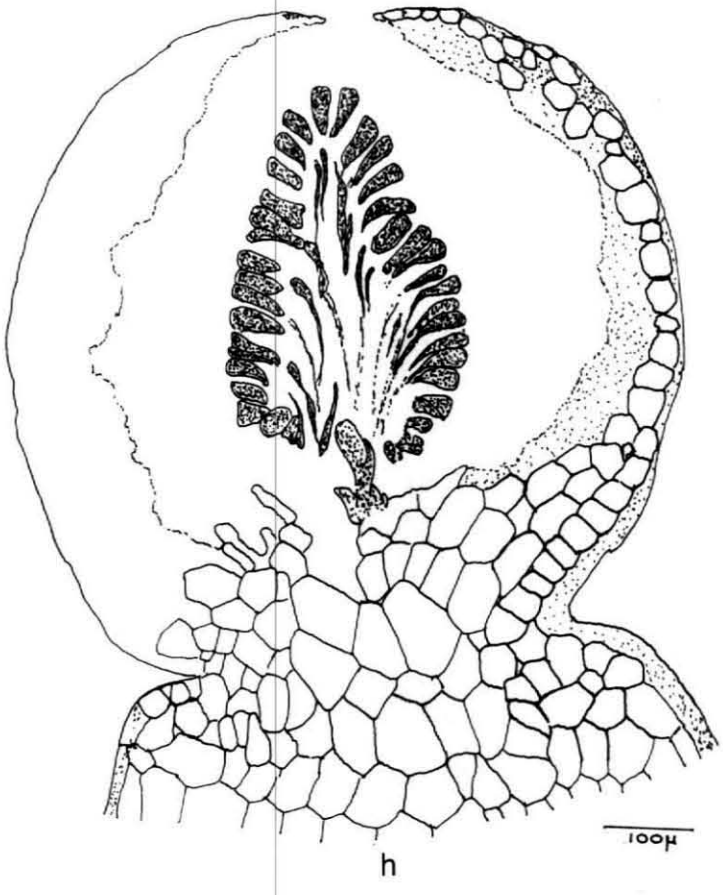


Fig. 3B. *Champia globulifera*

e. A portion of septum f. C.S. of thallus g. C.S. of tertasporic plant

h. L.S. of cystocarp

themselves in small groups round the constrictions. The tetrasporangia are found scattered in the walls of the branches with a tendency to be clustered near the constrictions, subglobose or spherical, about 1000 μm in diameter.

3. *Champia indica* Boergesen, 1933 (Pl. 3, Figs. 4A and B)

Location: Shivrajnagar and Dwarka (Gujarat State)

Plants grow near the lower water mark, attached to the rocks in moderately exposed localities. Erect plants are upto 15 cm high, pink or rose-red in colour. Branching is rich and the branchlets are arranged in a feather-like manner. The thallus is 2-3 mm thick with segments half as long as broad or shorter. In cross section, the thallus wall appears to be monostromatic with cells inside a thick pectinoid colourless matrix.

The thallus wall is composed of only one layer of roundish polygonal cells, about 50-75 μm long and 50-60 μm broad. Cortical cells are small with a diameter of 12 μm. The diaphragms are composed of one layer of polygonal cells. The breadth of the vertical filaments varies from 4 to 23 μm; they run in their interior of the joints and are ramified, sending out branches in all directions, some of them approaching the cells of the wall and running along these. Spherical gland cells are present here and there. The tetraspores lie scattered over the surface of the thallus. The cystocarps are relatively small, depressed - subspherical and about 500 μm high 600 μm broad.

4. *Champia parvula* (C. Agardh) Harvey, 1853 (Pl. 4, Figs. 5A and B)

= *Chondria parvula* C. Agardh, 1824

= *Chylocladia parvula* (C. Agardh) W. Hooker, 1833

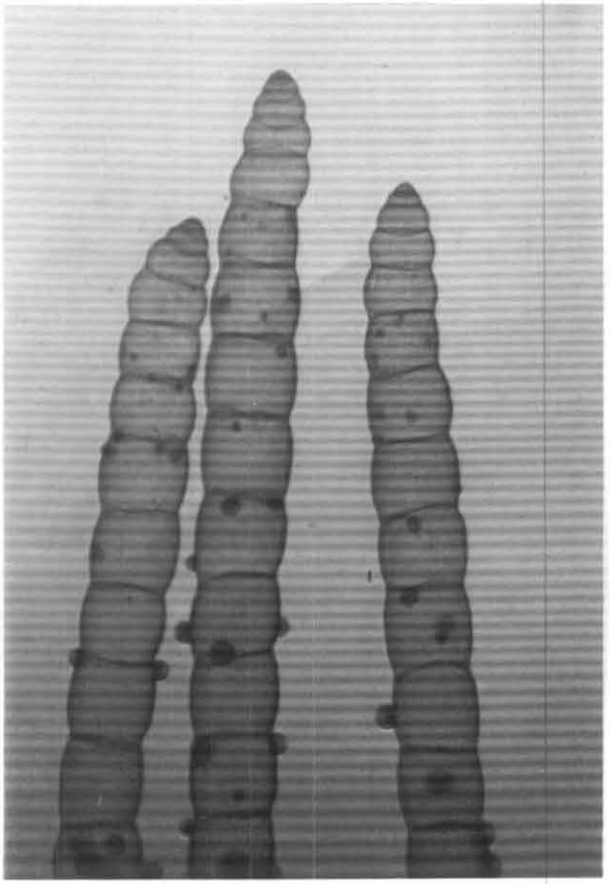
= *Lomentaria parvula* (C. Agardh) Zanardini, 1841

Location: Krusadai Island (Gulf of Mannar, Tamilnadu State).

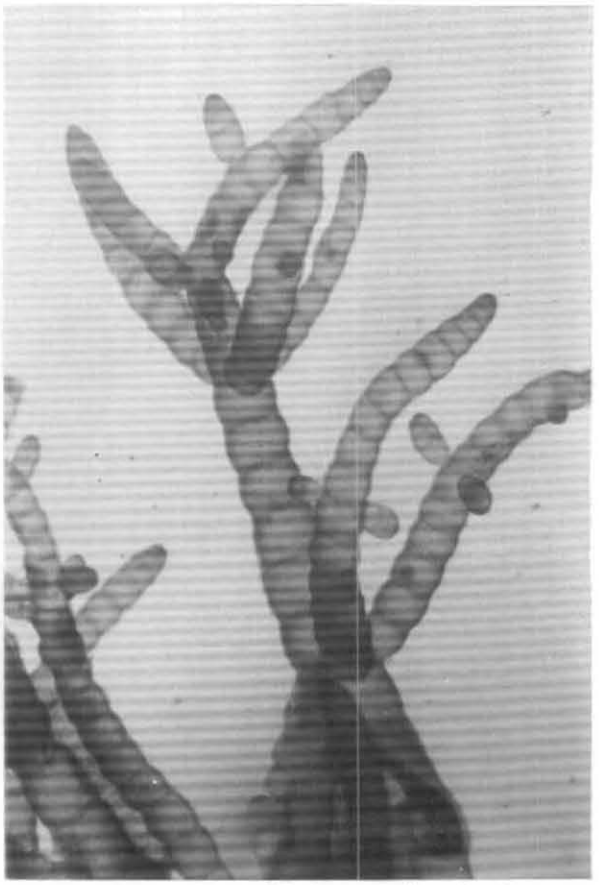
Plants epiphylic, thallus forming spherically, tufted intertangled mass, cylindrical, tender, gelatinous, branching three to four times, monopodial in growth, estipitate, attaching to substratum by means of discoid flat holdfast, 5-7 cm high, 1.5-2.0 mm wide at the broadest part; holdfat erecting a few to several fronds, 1.0-2.0 mm in diameter; frond articulated in cask-like rows at 1-2 mm intervals; main axis much narrow at base, broad in middle portion, attenuate upwards and obtuse to round at apex; branches irregular, verticillate, sometimes alternate or opposite, wide or patent, occurring at septa or inter-septa with less than 1 cm

PLATE - 3

Champia indica

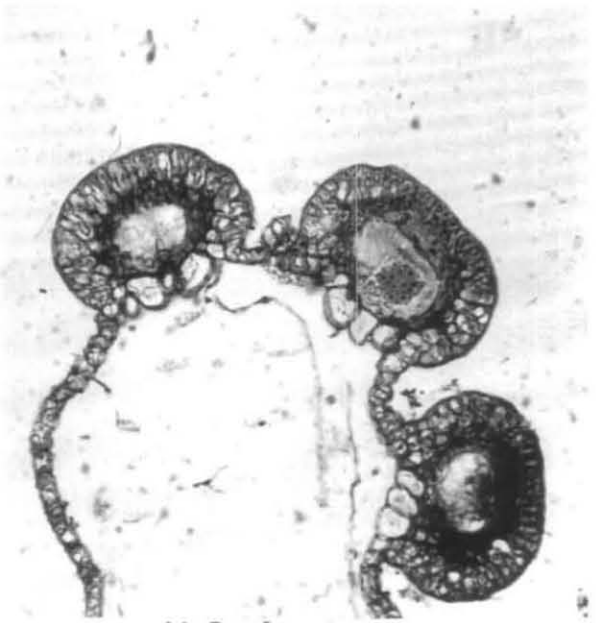


a. A portion of cystocarpic plant



b. A portion of tetrasporic plant

c. C. S. of tetrasporic thallus



d.L.S. of cystocarp

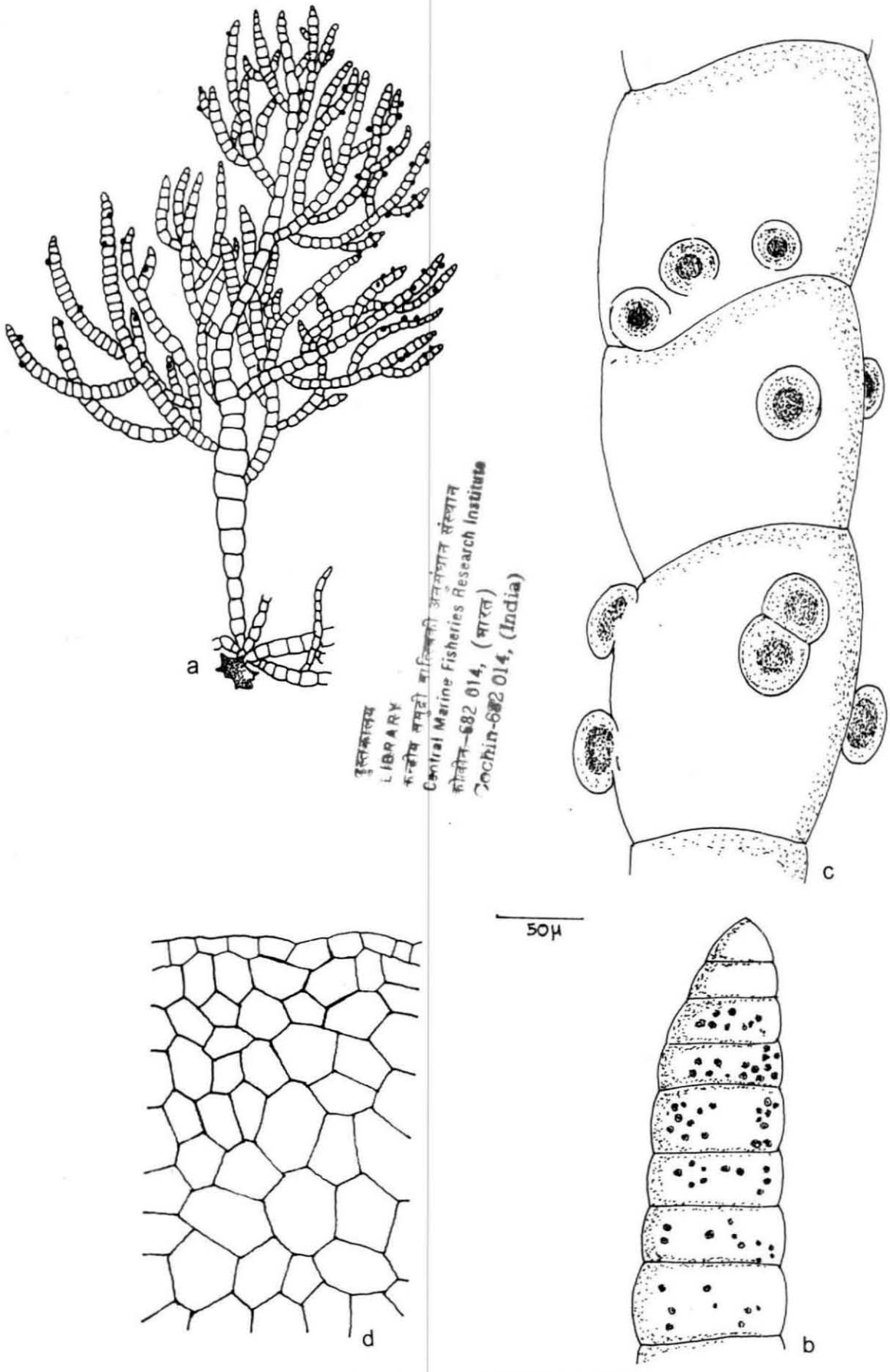


Fig. 4A. *Champia indica*

a. Habit b. A portion of tetrasporic plant c. A portion of carposporic plant
d. A portion of septum

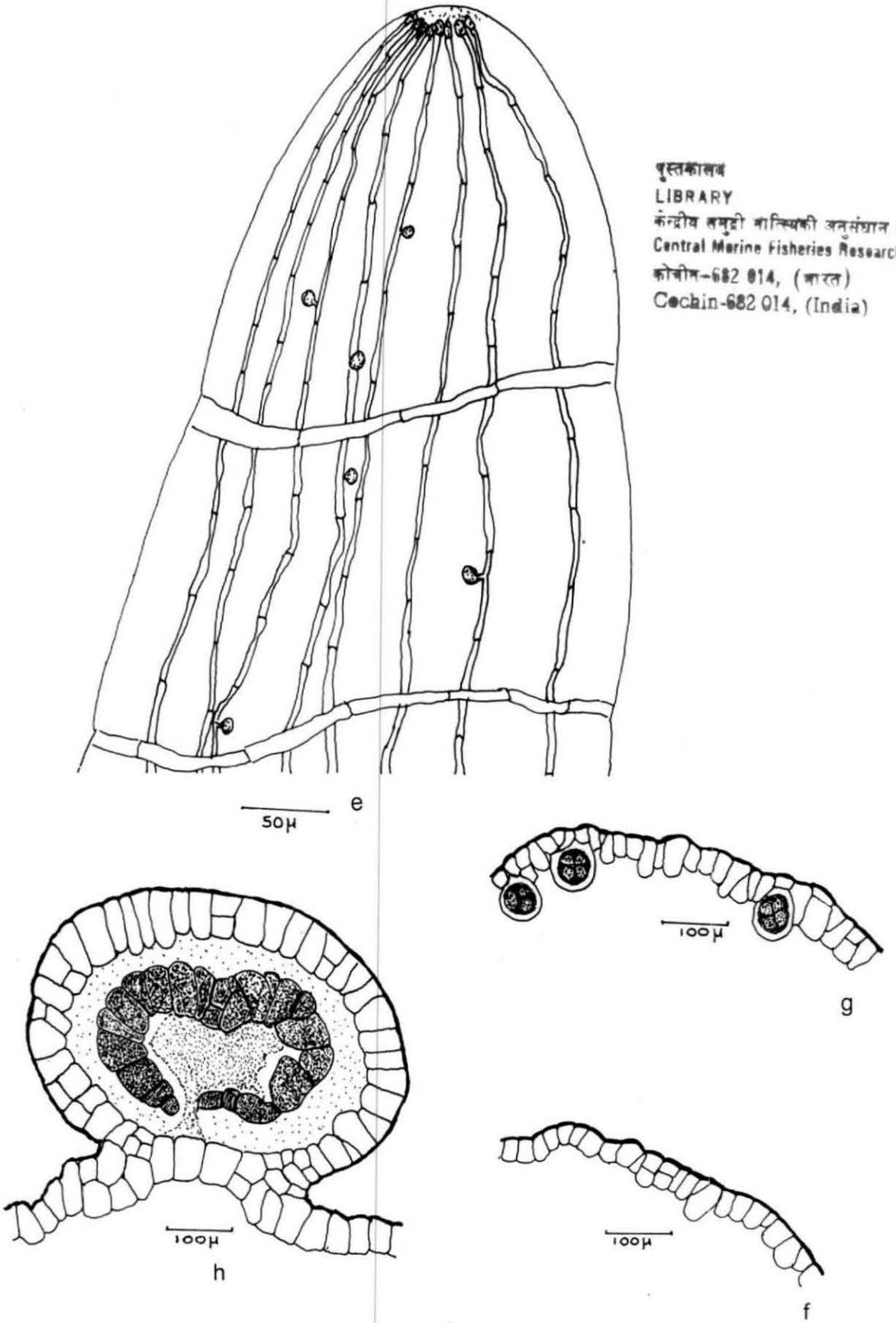


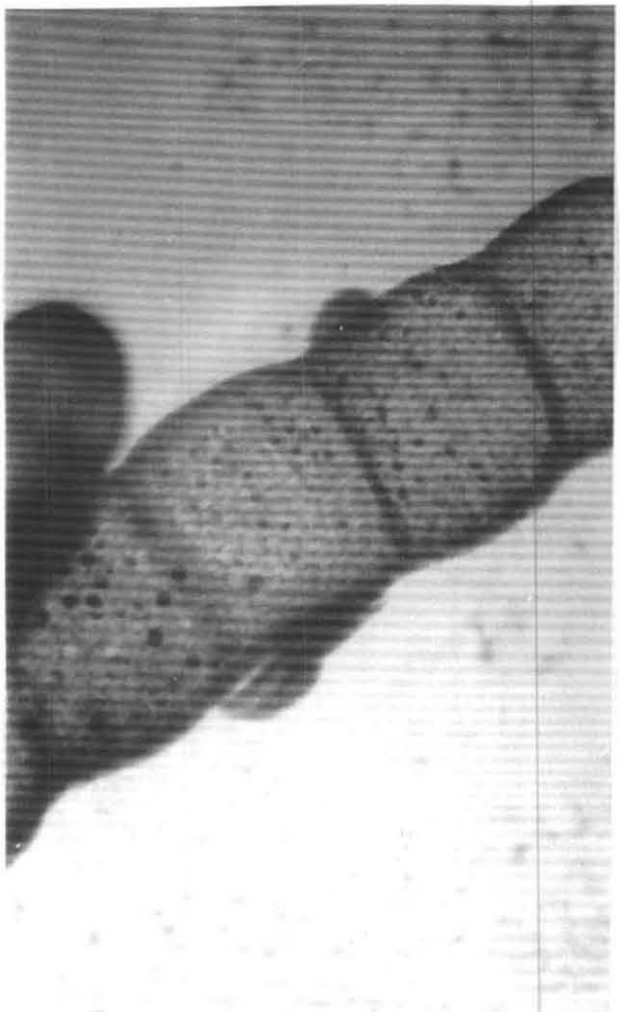
Fig. 4B. *Champia indica*

e. L.S. of apex f. C.S. of thallus g. C.S. of tertasporic plant

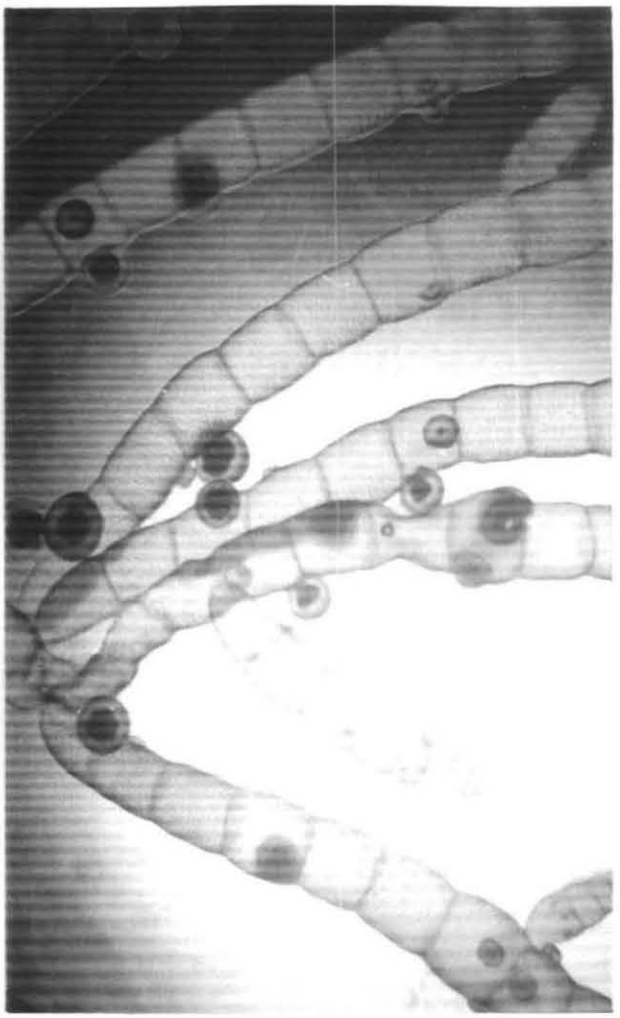
h. L.S. of cystocarp

Champia parvula

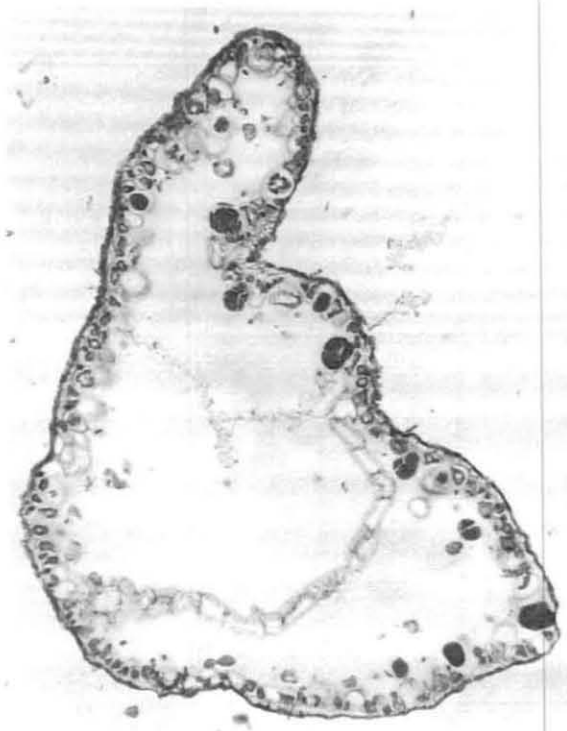
PLATE - 4



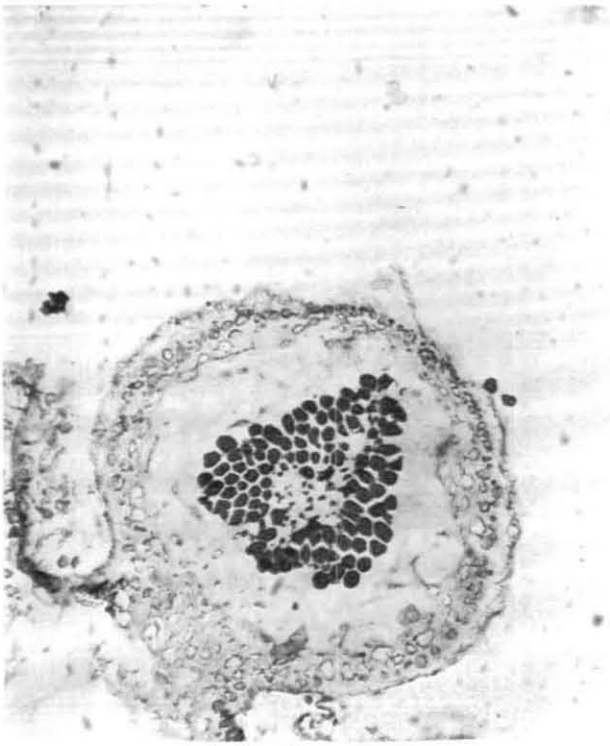
a. A portion of tetrasporic plant



b. A portion of cystocarpic plant



c. C. S. of tetrasporic thallus



d. L.S. of cystocarp

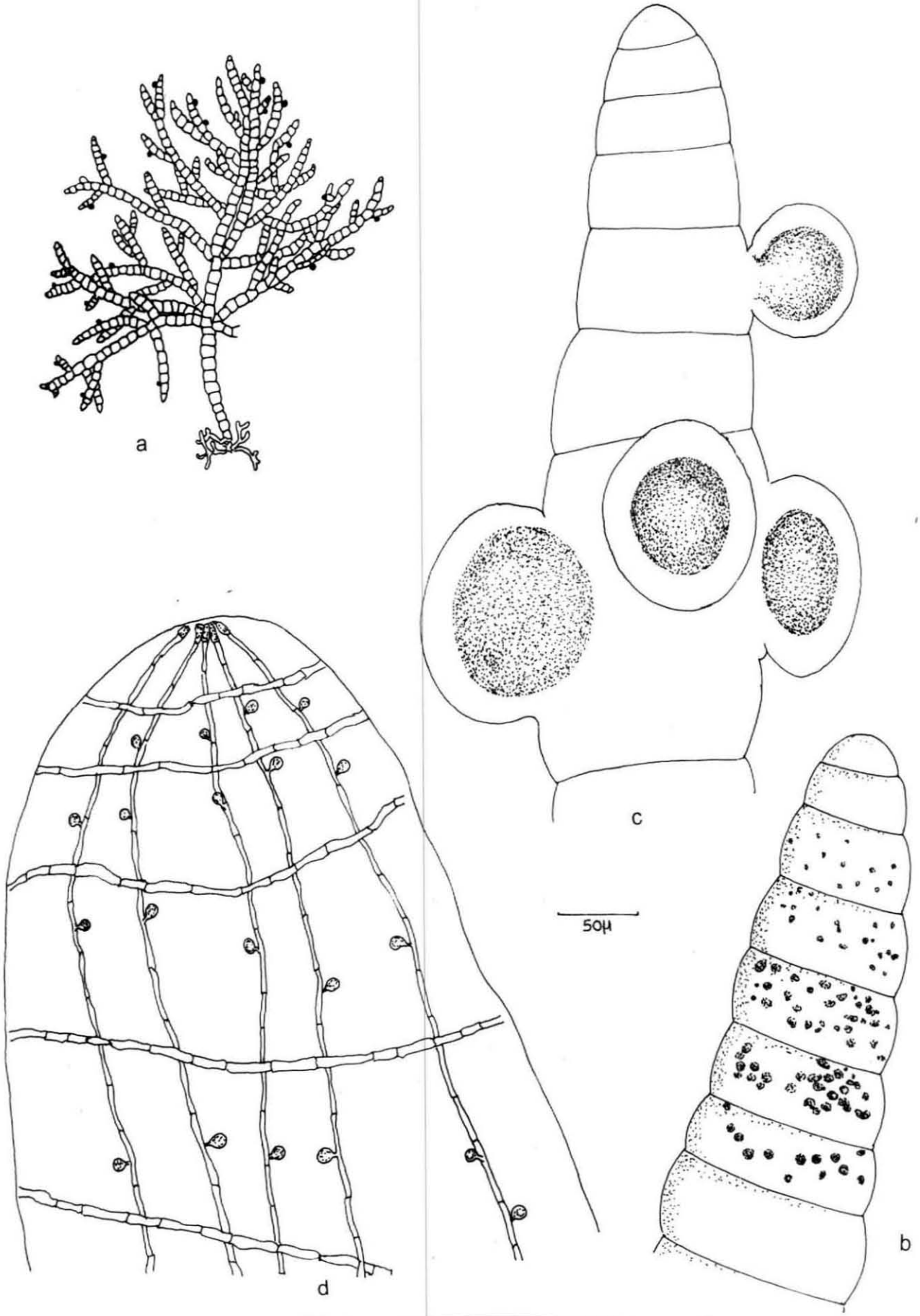


Fig. 5A. *Champia parvula*

a. Habit b. A portion of tetrasporic plant c. A portion of carposporic plant
d. L.S. of apex

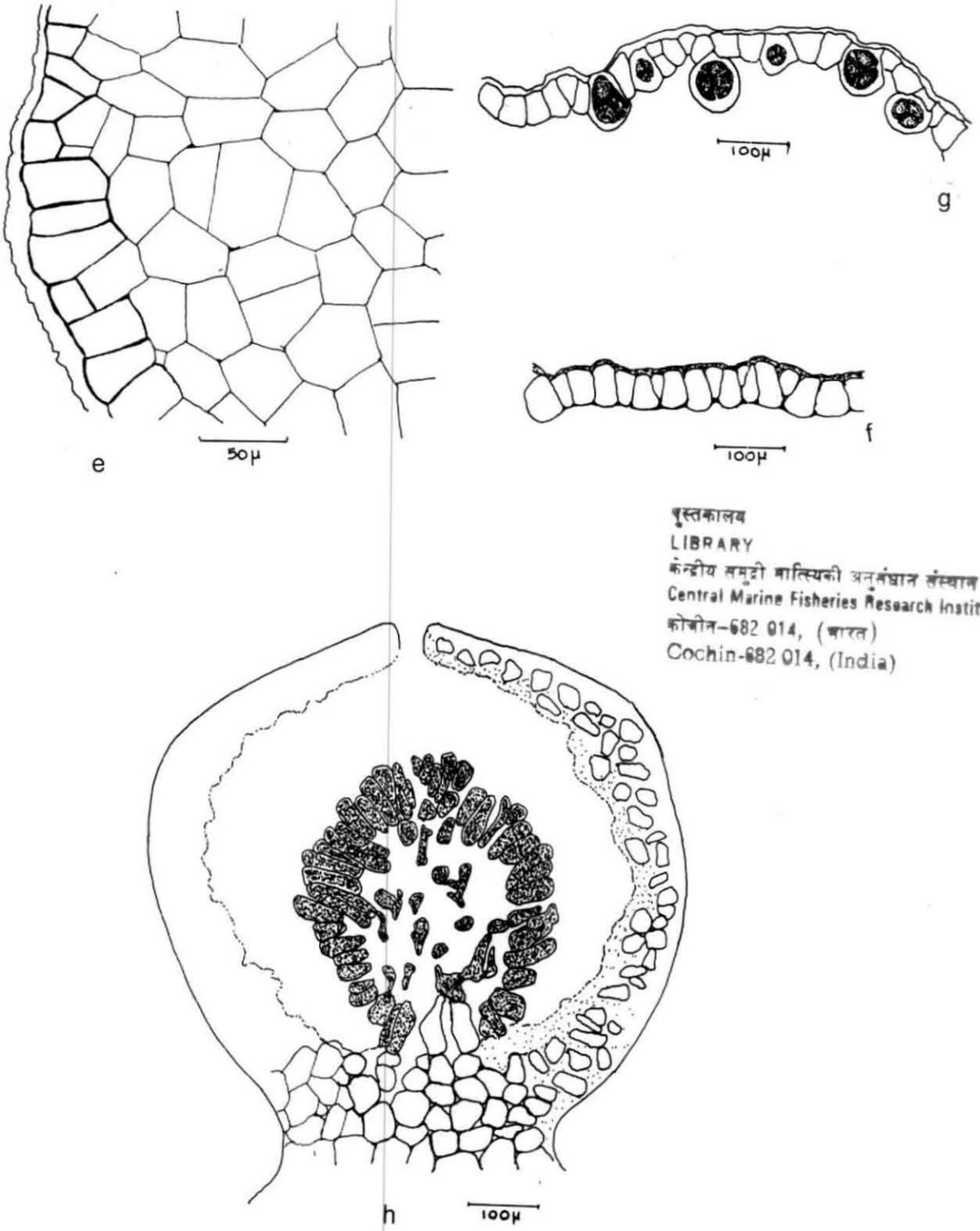


Fig. 5B. ***Champia parvula***

e. A portion of septum f. C.S. of thallus g. C.S. of tertasporic plant
h. L.S. of cystocarp

intervals, ultimate branchlets much constricted at base, 0.5 to 1.0 mm wide; rhizoids developing from frond, compressed; frond in section single layered with central cavity interrupted by diaphragms, 55-65 μm thick; cells polygonally angled, 28-35 μm high, 35-42 μm wide, 45-83 μm long cutting off small cells outwards; small cells round to polygonal, cutting off much smaller cells obliquely outwards, longitudinal, filaments attaching to large cell, running through frond; diaphragm single or sometimes partially two cell-rowed; gland cells attaching to filament inwards; unicellular hairs abundant; tetrasporongia occurring in sori, intercalary among large or small cells, ovoid, bulging inward to cavity, divided tetrahedrally; spermatangia occurring in sori, ellipitical, subterminal on mother cell, 6.8 μm long 4.3 μm wide; cystocarps abundant, solitary or aggregated, spherically elevated, sessile, with carpostome, 860-1100 μm high and wide; carpogonial branch four-celled, carposporangia round to polygonal, colour dark purple to brownish red, sometimes greenish purple.

5. *Gastroclonium iyengarii* K. Srinivasan, 1960 (Pl. 5, Figs. 6A and B)

Location: Okha (Gujarat State)

This alga grows in submerged situations, below low water mark, also in open bays, where there is much disturbance due to current and swell during high tides.

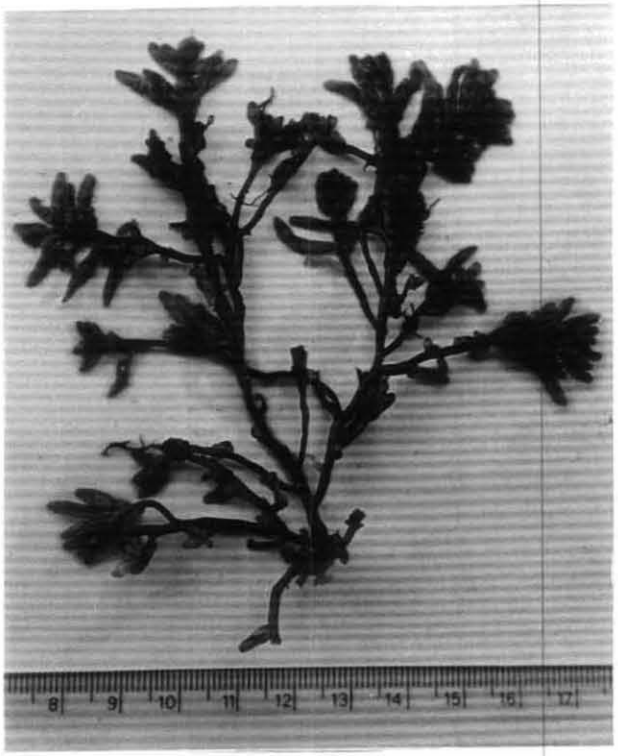
The alga has an erect shoot, bearing large number of linear oblong articulated structures in tufts near the extremetics of the shoots bearing them. The colour varies from red to pink while young and light red or purple with shade of light green when old.

Frond cartilaginous, erect, cylindrical,10-12 cm or more in height, 2 cm thick; branching pseudo-dichotomous, ramuli numerous, lateral in acropetal succession on frond, inflated, linear-oblong, segmented, 15-20 mm long and 2.5 to 3.5 mm broad; number of segments 11-20 in each ramulus; midsegments longer than the basal and distal segments; cavity inside the ramulus intercepted by diaphragm at intervals; axial filaments of ramuli, 16.5 to 30 μm across; bulb cells 23-33 μm x 20-26 μm.

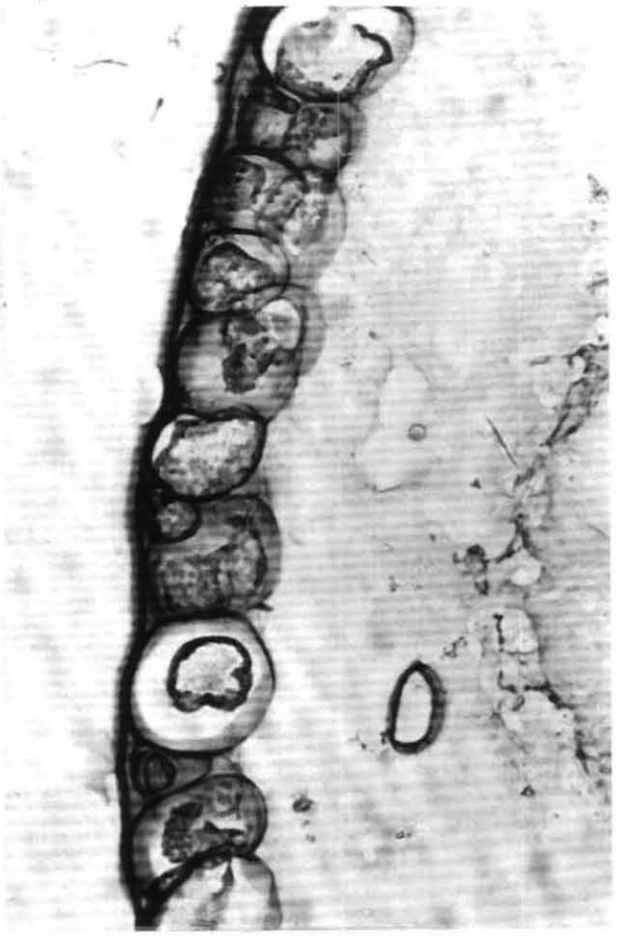
Tetrasporangia pyriform, 100 μm X 50 μm in size; tetraspores are formed by tetrahedral division; cystocarps are 800-1000 μm in diameter and approximately of the same height, urceolate with well defined ostioles.

PLATE - 5

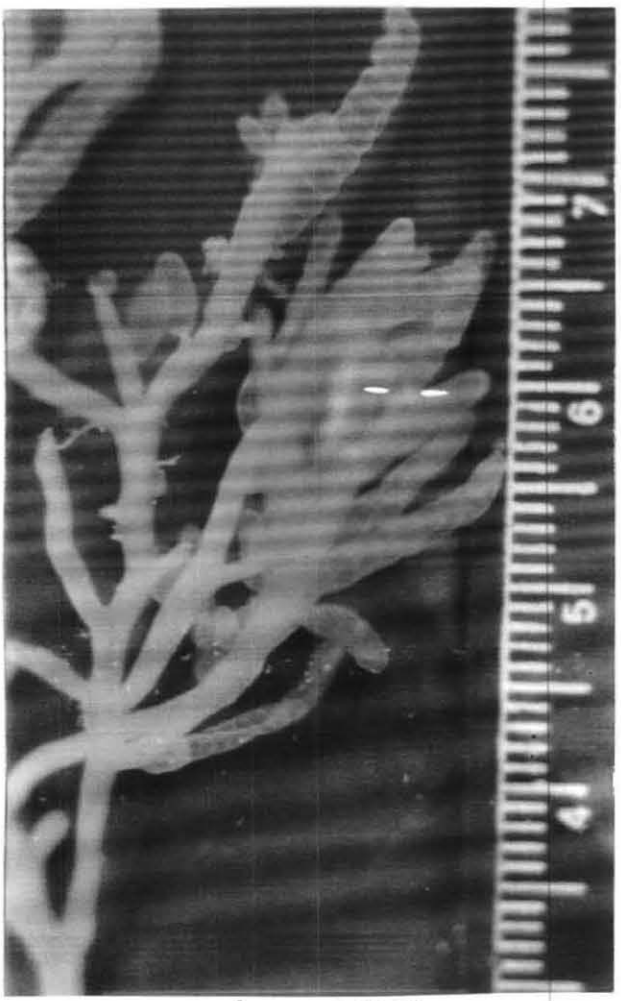
Gastraclonium iyengarii



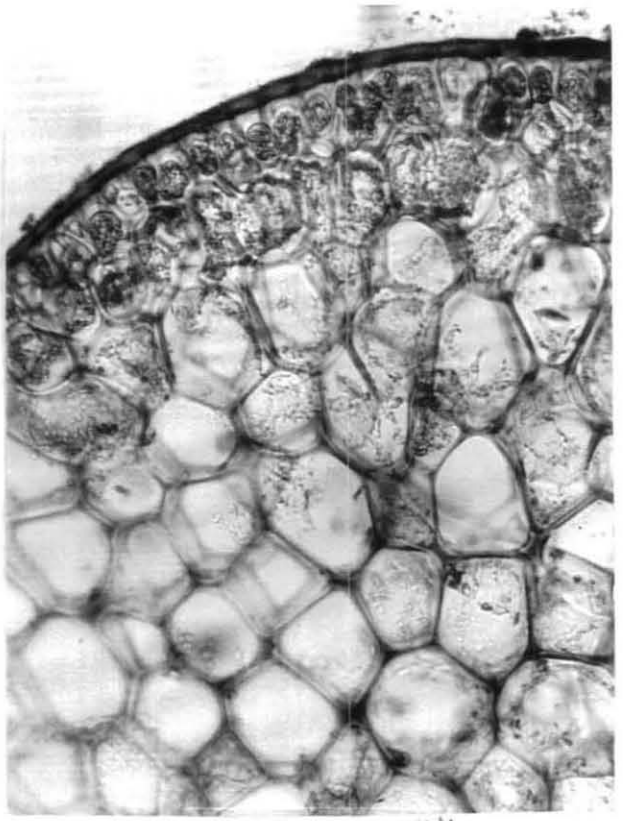
a. Habit



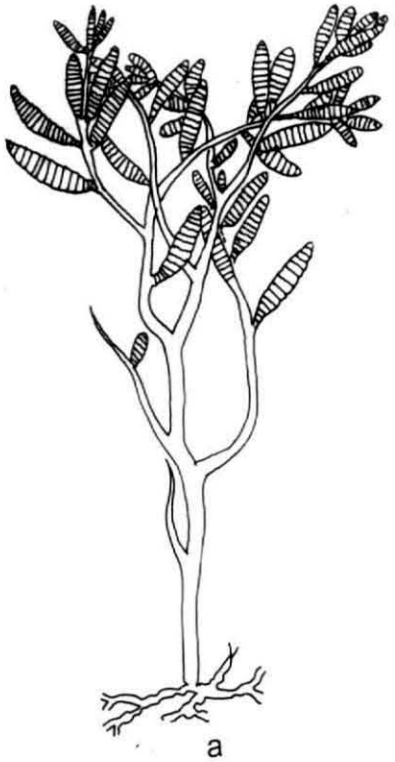
c. C.S. of segment

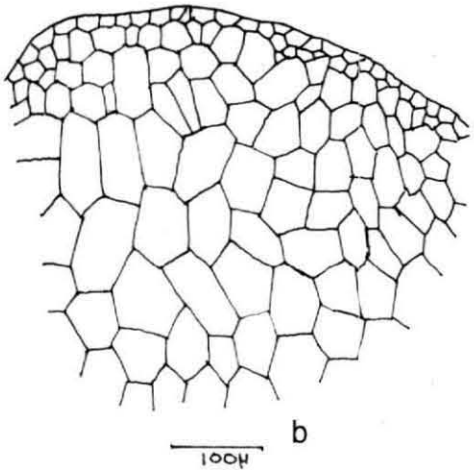


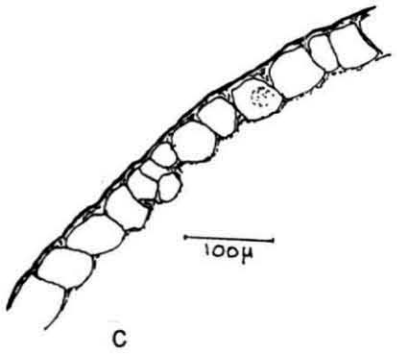
b. A portion of thallus



d. C.S. of ramuli







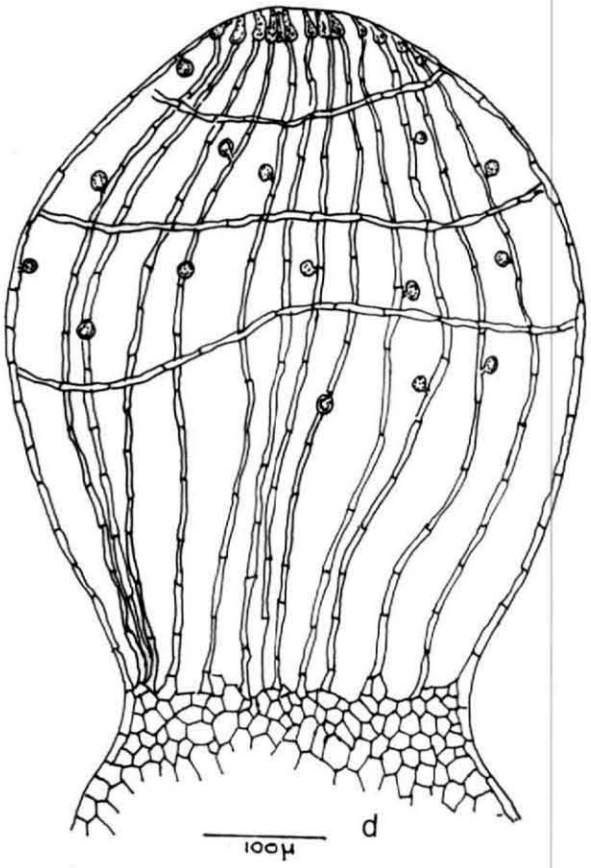


Fig. 6A. *Gastroclonium iyengarii*

a. Habit b. A portion of septum c. C.S. of thallus

d. L.S. of apex of ramuli

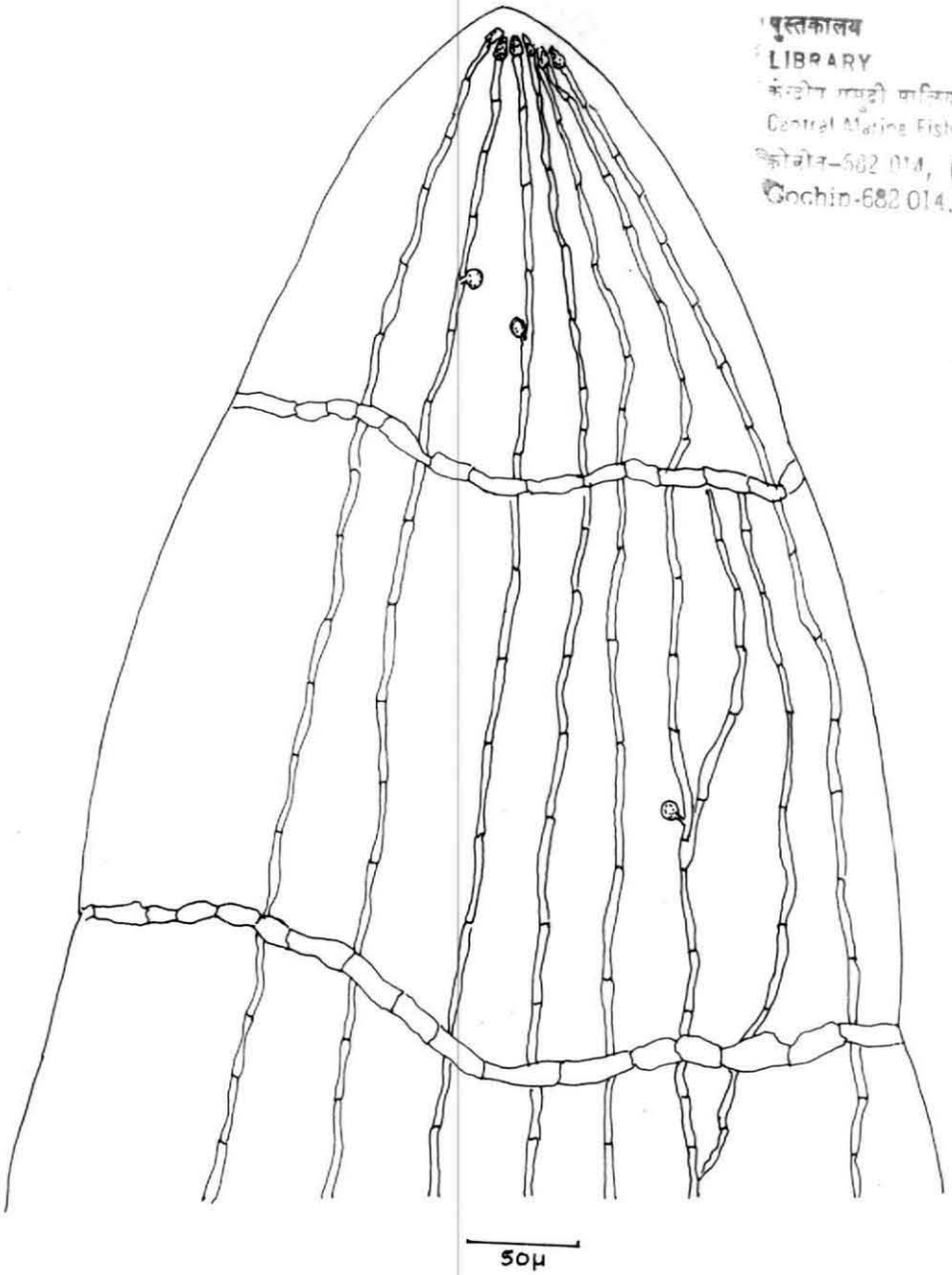


Fig. 6B. ***Gastroclonium iyengarii***

e. L.S. of apex of segment

II. Rhodymeniaceae

Plants erect or attached, nearly simple or somewhat freely divided, the divisions flat and subdichotomous or subcylindrical and radially branched, solid or hollow, soft to tough-membranous; developing from an apical meristem, the innermost cells large, forming a parenchymatous medulla; the surface cells small, often in short radial series and containing chromatophores; sporangia sometimes in sori, tetrapartite, formed between these superficial cells; carpogonial branches three-celled, the supporting cells cut off an auxiliary mother cell before fertilisation; gonimoblasts extensively branched, most of the cells forming rather small carpospores, the whole structure eventually enveloped by a loose pericarp.

1. ***Botryocladia leptopoda*** **(J. Agardh) Kylin, 1931 (Pl. 6, Figs. 7A and B)**

= *Chrysemenia uvaria* J. Agardh var. *leptopoda* J. Agardh, 1876

= *Chrysemenia leptopoda* (J. Agardh) Weber-van-Bosse, 1928

Location: Off Manoli Island (Gulf of Mannar, Tamilnadu State)

This alga occurs in deep water areas of 5 to 15 m depth. In the Gulf of Mannar area, this alga grows luxuriantly with a harvestable quantity.

Thallus upto 50 cm long, cylindrical, 2-2.5 mm broad, highly branched, branches irregular, densely covered with hollow vesicles, 2-4 mm in diameter, oblong or rounded, swollen, broader at the upper end, constricted near the base; main thallus is composed of a central axis of large rounded cells, 50-130 μm in diameter, surrounded by a cortex of small cells, 4-6 μm in diameter. In longitudinal section, the central cells are vertically elongated with small rounded gland cells upon and in between them, wall of the vesicle 50-60 μm thick, composed of a layer of large polygonal cells, 40-50 μm in diameter, abutting the cavity of the vesicle, there are one or two layers of small rounded cortical cells, 4-6 μm in diameter. A single gland cell is, as a rule, present in the middle of each large cell. Conceptacles partly immersed in the frond, hemispherical or urceolate; tetrasporangia scattered in the peripheral cells, cruciate. Plants gelatinous and adhere firmly to paper on drying.

2. ***Coelarthrum opuntia*** **(Endlicher) Boergesen, 1937 (Pl. 7, Fig. 8)**

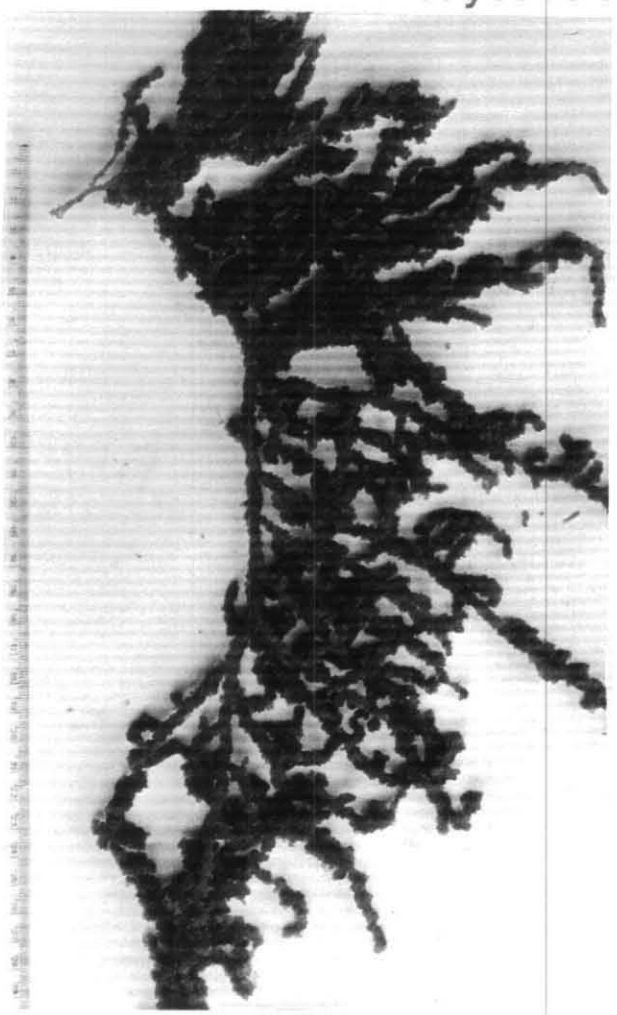
= *Chondria opuntia* J. Agardh, 1841,

= *Chrysemenia opuntia* Endlicher, 1843

= *Gastroclonium opuntia* (Endlicher) Kuetzing, 1849

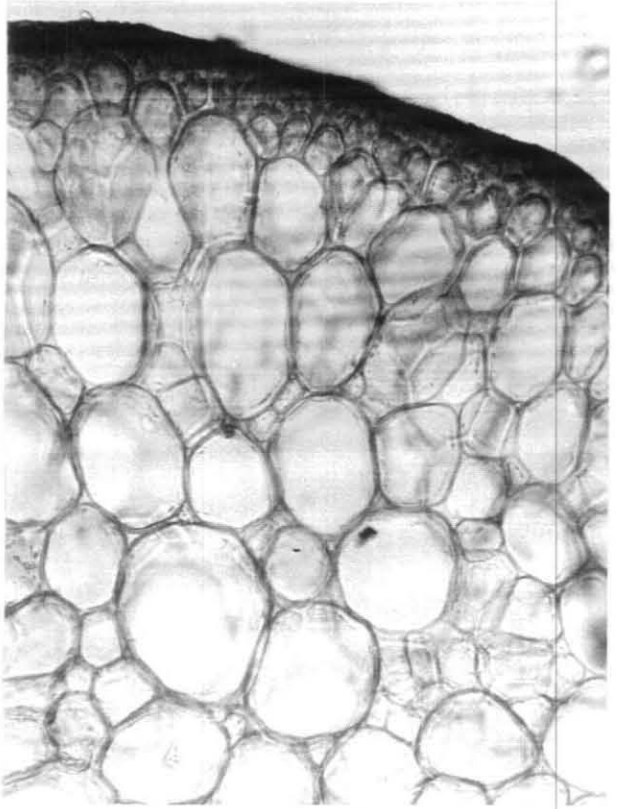
= *Sedoidea opuntia* (Endlicher) Kuntze, 1891

Botryocladia leptopoda



a. Habit

b. A portion of cystocarpic plant



c. c.s. of stem

L.S. of cystocarp

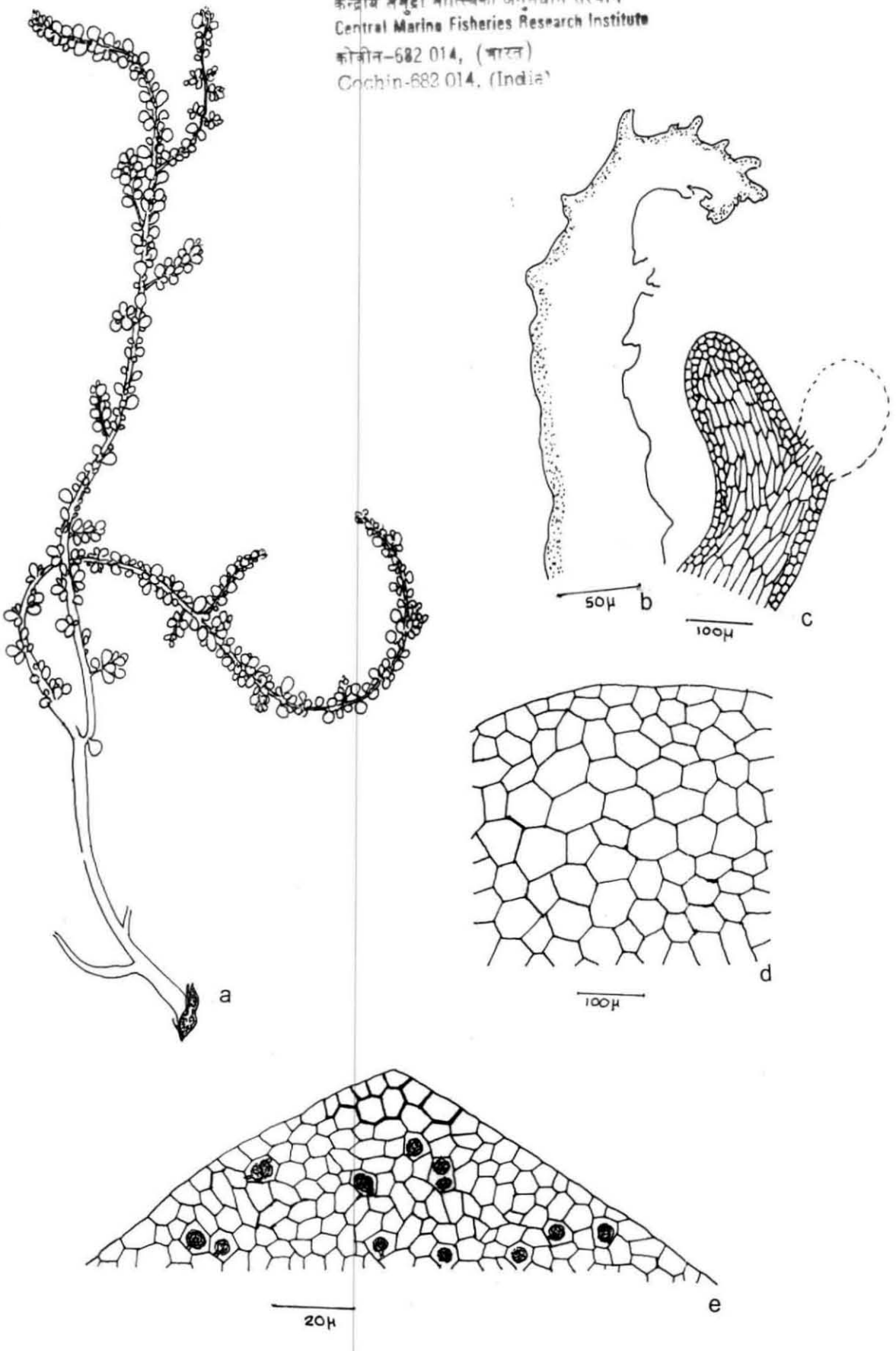


Fig. 7A. *Botryocladia leptopoda*

a. Habit b. Apex of stem c. L.S. of stem apex
d. A portion of septum e. L.S. of vesicle apex

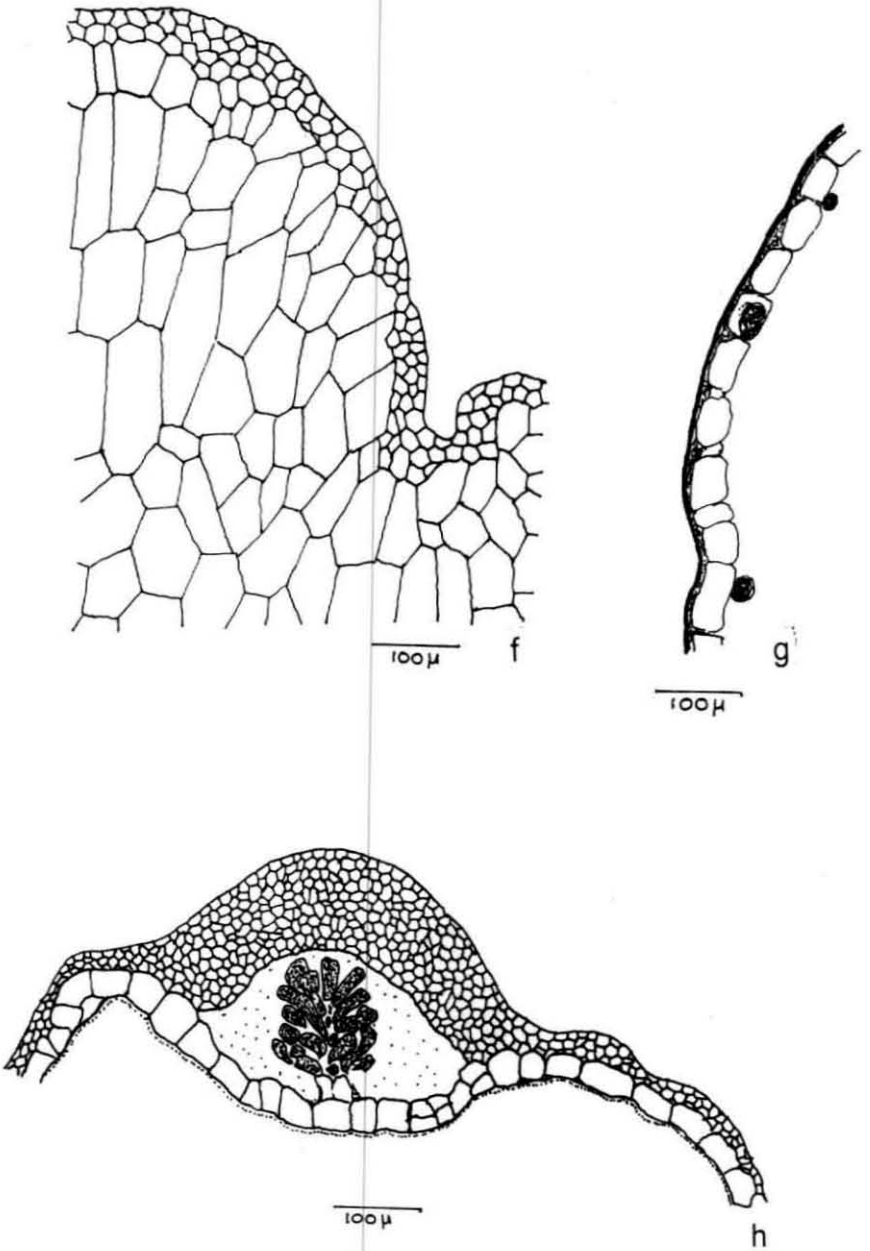
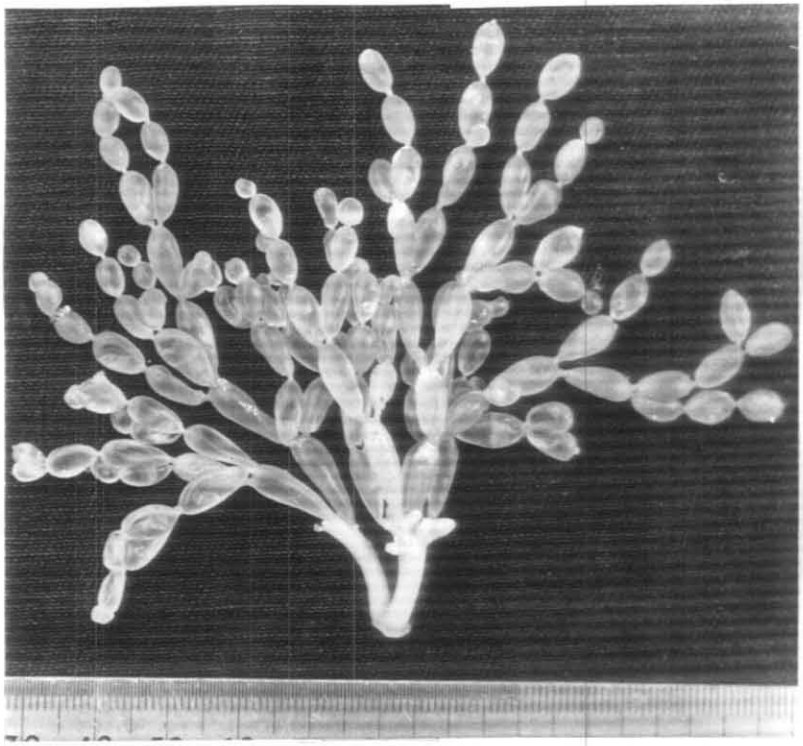


Fig. 7B. *Botryocladia leptopoda*

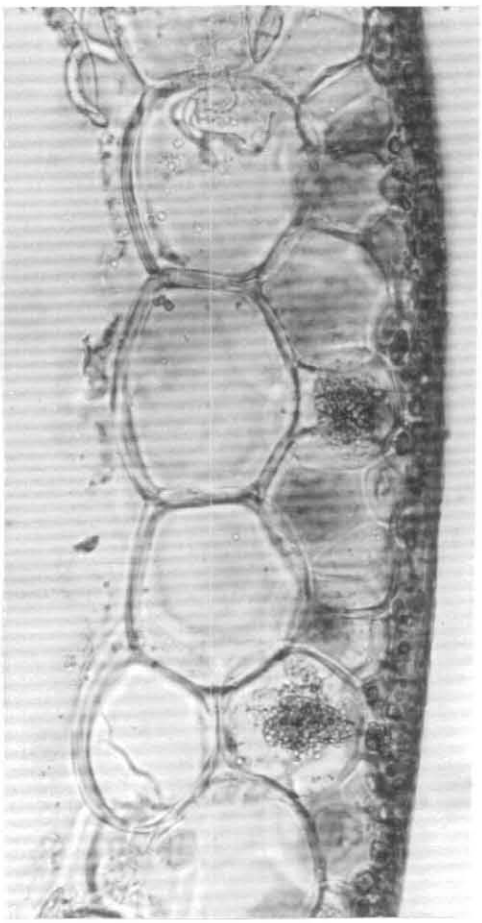
f. C.S. of stem g. C.S. of vesicle h. L.S. of cystocarp

PLATE - 7

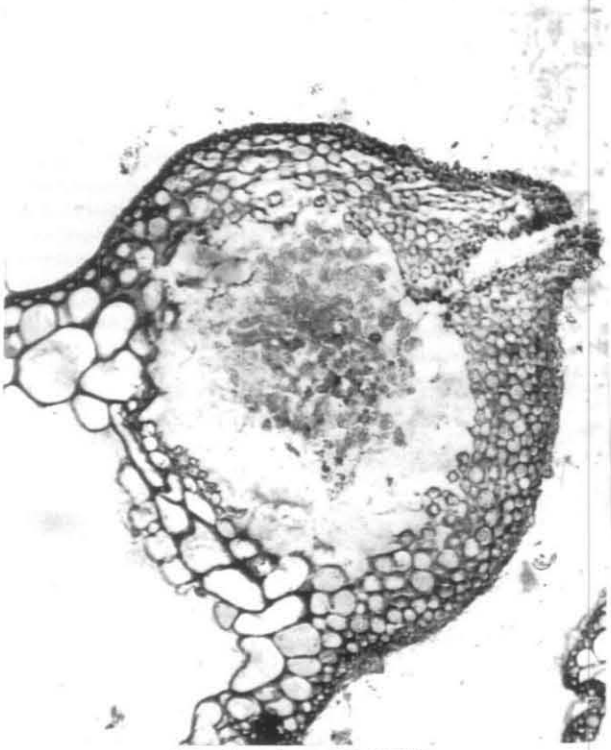
Coelarthrum opuntia



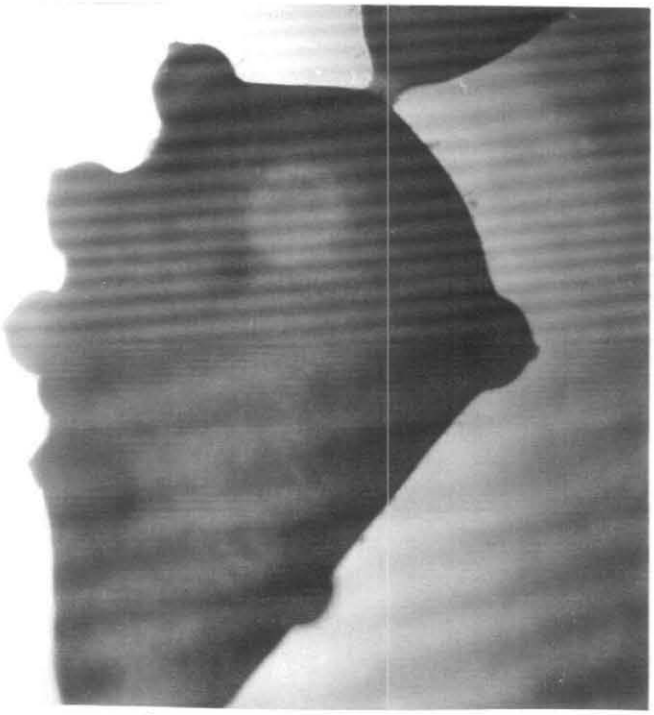
a. Habit



b. C.S. of segment



d. L.S. of cystocarp



c. A segment with cystocarps

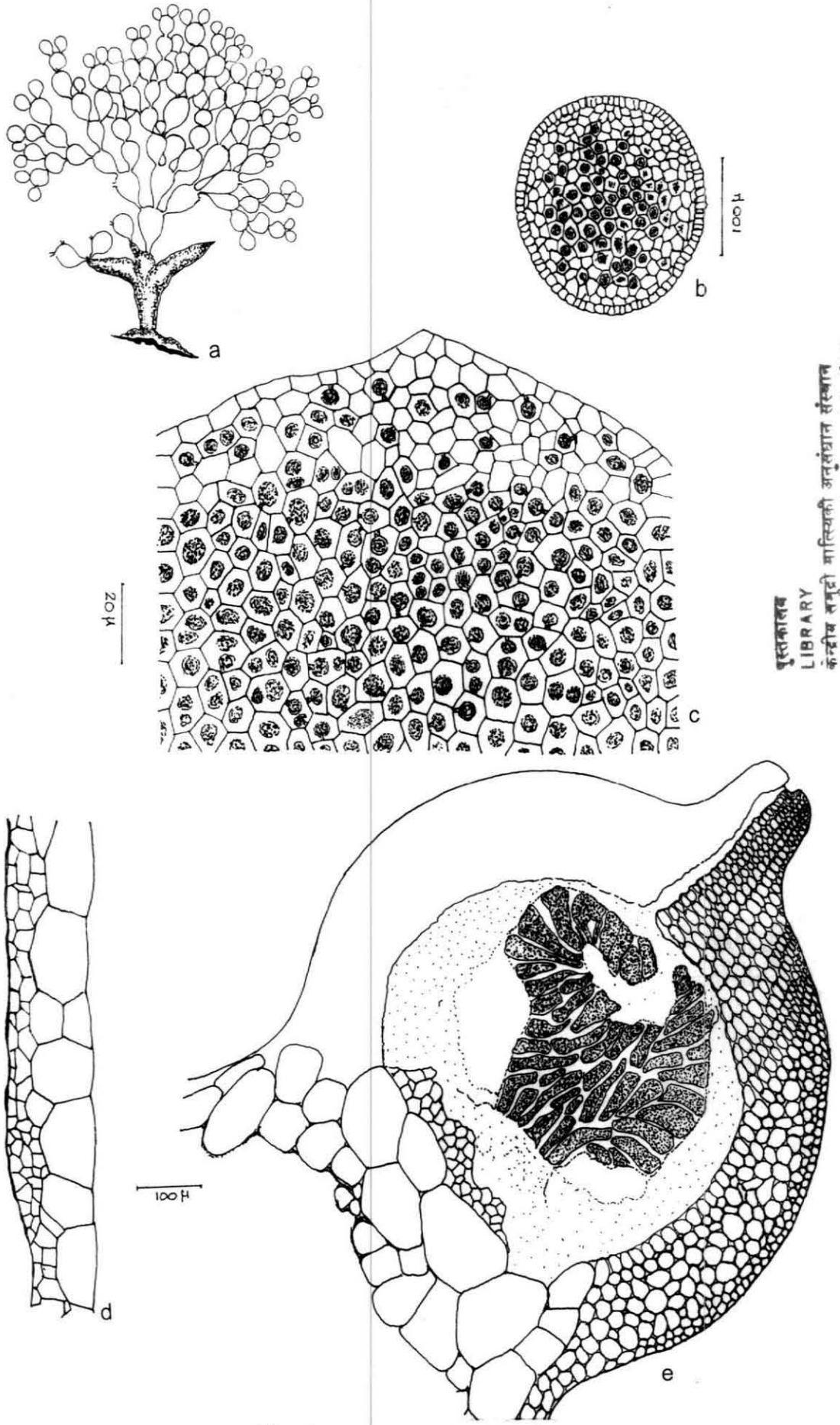


Fig. 8. *Coelarthrum opuntia*

a. Habit b. Septum c. L.S. of segment

d. C.S. of segment e. L.S. of cystocarp

Location: Off Manoli Island (Gulf of Mannar, Tamilnadu State)

This alga was collected from 8 m depth off Manoli Island. Plants 8-10 cm high, attached by stolons; segments broader, 6-8 mm wide, 1-1.7 cm long, oblong or only slightly cuneate; walls of segments three layered, inner layer cells, 200 μm X 150-175 μm, the middle layer with slightly smaller cells, the outer layer with small rounded cells, 8-14 μm in diameter. On the wall of the large cells facing the cavity of the inflated joints of the thallus, gland cells occur on irregularly shaped or stellate pedicel cells. Cystocarps hemispherical, with an apical pore, scattered upon the thallus; tetrsporangia in cortical cells, cruciate. The colour of the plant is bright red; plants adhere firmly to paper. Stoloniferous branches are given off from some of the solid articulations.

2. ***Gelidiopsis variabilis*** **(J. Agardh) Schmitz, 1895 (Pl. 8, Fig. 9)**
   = ***Acrocarpus gracilis*** **Kuetzing, 1849**
   = ***Gelidium variabile*** **J. Agardh, 1851**
   = ***Gelidium acrocarpum*** **Hauck, 1888 (1886-1889)**
   = ***Gelidiopsis gracilis*** **(Kuetzing) Feldmann, 1931**
   = ***Ceratodictyon variabile*** **(J. Agardh) Norris, 1987**

Location: Pudumadam (Tamilnadu State)

Thallus erect, basal area associated with sponge; frond 7-10 cm in height, cylindrical, filiform; the primary axis, erect, sparsely branched from below; branches simple, cylindrical with obtuse apex, patent. Cystocarps ovoid, minute, sessile on the upper branches, sometimes densely aggregated. Tetrasporangia occur in the rounded apical portions of the branches.

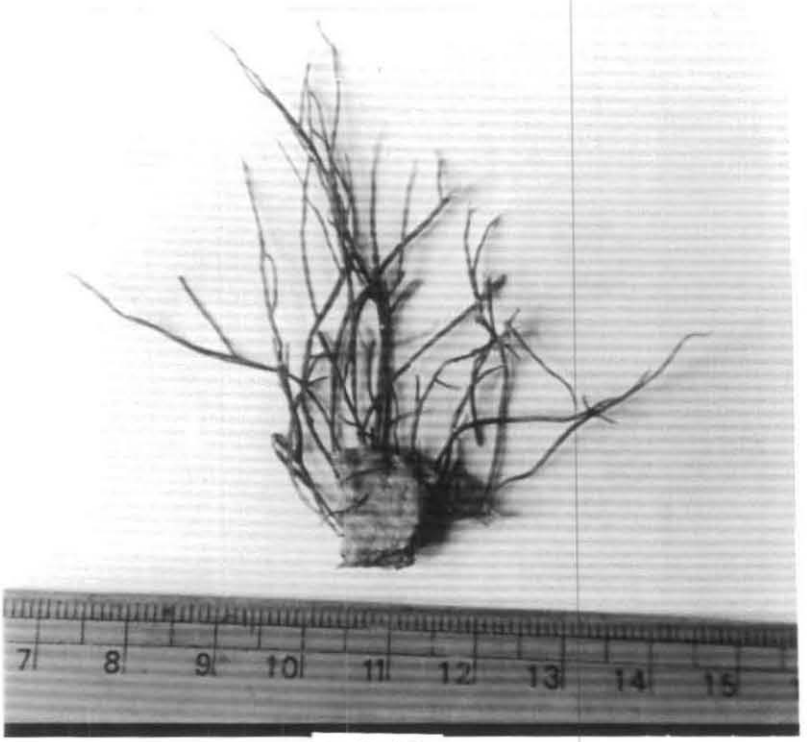
3. ***Rhodymenia sonderi*** **P. Silva, 1996 (Pl. 8, Fig. 10)**
   = ***Rhodymenia australis*** **Sonder, 1845**
   = ***Sphaerococcus australis*** **Kuetzing, 1849**
   = ***Acropeltis australis*** **J. Agardh, 1849**

Location: Manapad and Kanyakumari (Tamilnadu State)

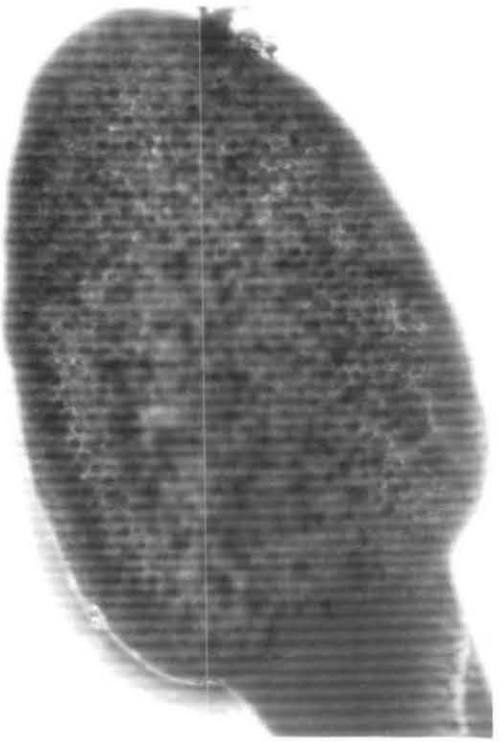
Plants attached to rocks by discoid holdfast. Plants erect, dichotomously divided, upto 15cm; colour dark red to rose purple; turning brownish when dry, consistency firm and gelatinous; erect blades stipitate, the lower portions cuneate and 5-10 mm wide, the upper

PLATE - 8

Gelidiopsis variabilis



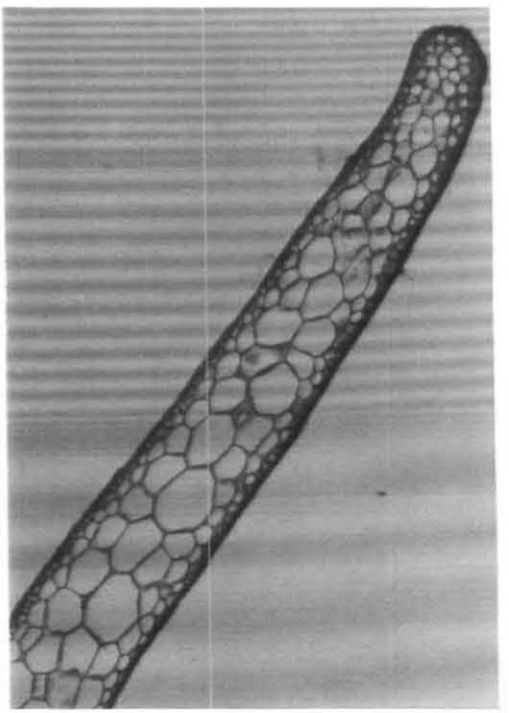
a. Habit



b. Tetrasporangium – enlarged view

Rhodymenia sonderi

c. Habit



d. C.S. of thallus

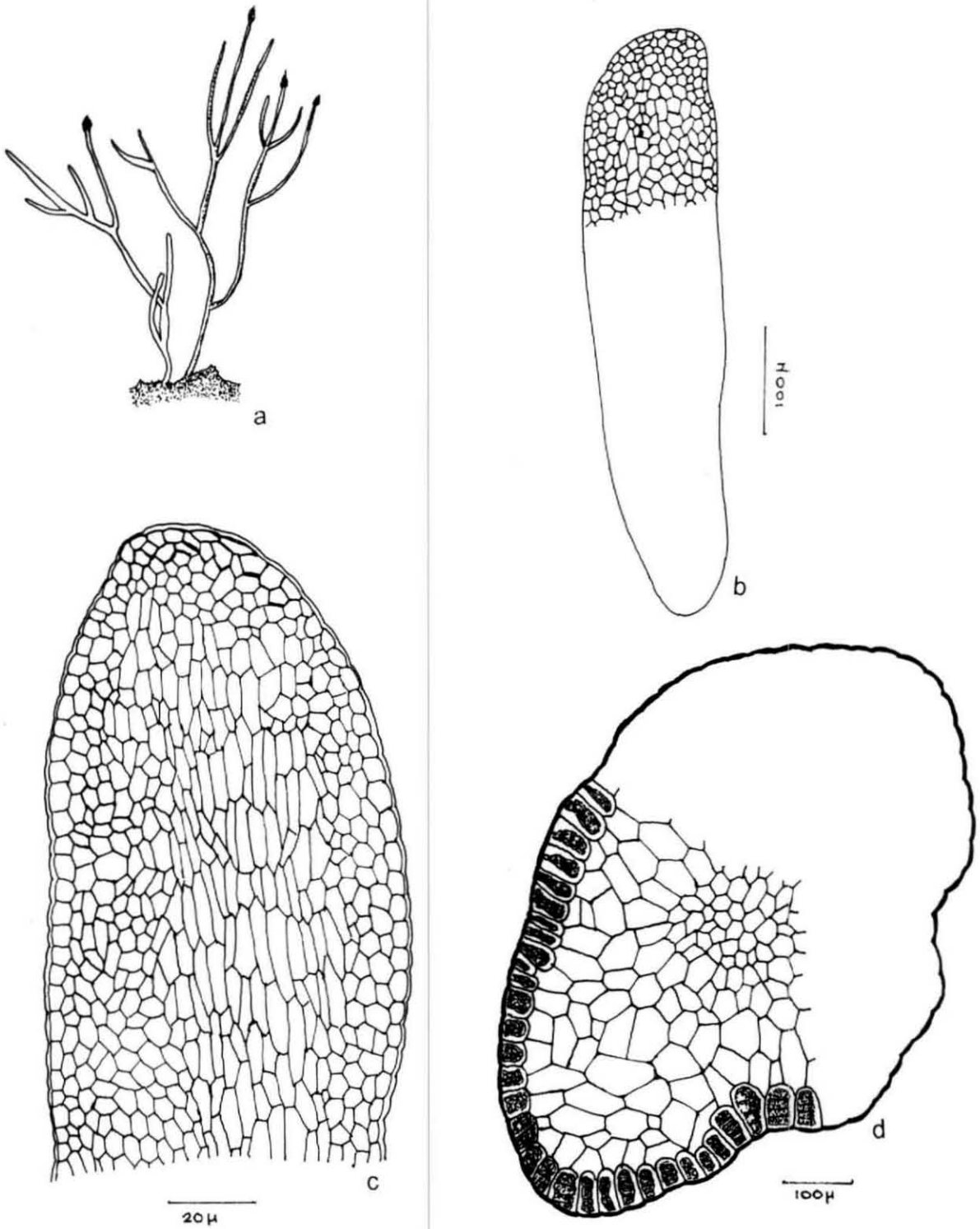
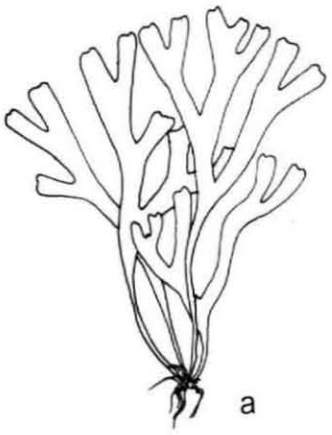
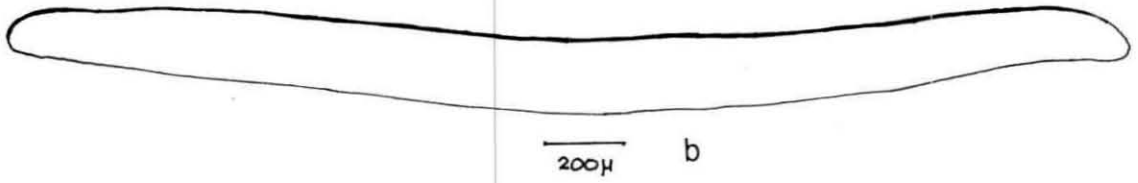


Fig. 9. ***Gelidiopsis variabilis***

a. Habit b. C.S. of thallus c. L.S. apex d. C.S. of tetrasporangium





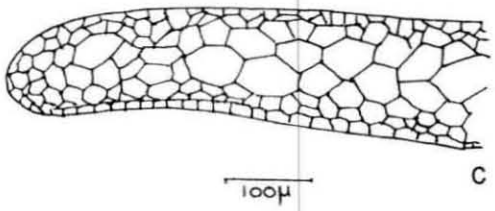


Fig. 10. *Rhodymenia sonderi*

a. Habit b & c. C.S. of thallus

portions linear and 2-3 mm wide, apical part subflabelliform and fastigiate; angle between furcations acute; axils somewhat rounded; margin of blades entire, rarely with short obovate proliferations; fronds slightly thickened at the margins and more or less subcanaliculate or concave on one side. Cystocarps hemispherical, protruding and slightly constricted at base; several and scattered over the younger portions of the blade, upto 0.5 mm in diameter, with a thick wall and prominent ostiole. Tetrasporangia in shield shaped nemathecioid sori situated just below apices, subspherical to pyriform, cruciately divided.

Studies on the vegetative structures and reproductive organs of the nine Indian species revealed that these species agree well with the descriptions given for the same species reported from other countries. There are no marked differences either in the morphology or anatomy of the species reported from India and other countries.

The apical cells in *Champia* spp have been observed. Bliding (1928) and Lee (1978) have reported 17 apical cells in *Champia parvula*. During the present study only 8 apical cells were counted in *Champia globulifera* and *C. parvula* whereas 16 apical cells were noticed in *C.indica* and 23 apical cells in *C.compressa*. The apical cell is triangular of which upper angle is directed to the apical centre. These apical cells cut off large cells perpendicularly to the surface, which become longitudinally elongate oblong later.

The longitudinal filaments developed in central cavity of the thallus are attached to large cells and anchor at the diaphragm. In branch apex, the filament initials are cut off periclinally towards the cavity from the cells nearer to the apical cells. They are elongated longitudinally and transform into filaments later. The filament is frequently branched dichotomously or connected with the adjacent ones. The diaphragm at the septum is single rowed with thin walled hyaline cells. It is connected both to large cells and filaments. The central portion is slightly thicker than the margin. The diaphragm originates from inner large cells near the apex.

The branch is developed by periclinal divisions of a few large cells. Then, the divided superficial cells become the apex of the new branch, while the divided inner cells remain as a basal septum after the branch is developed.

The gland cells are developed solitarily on the filaments inwards (Davis, 1892, Bliding, 1928, Inagaki, 1934). They appear more often in the upper portion of brnches and are round to ellipical in shape bearing ne to three nuclei. A large gland cell is about 15 μm in diameter.

The longitudinal filaments developed in central cavity of the thallus are attached to the large cells and anchor at the diaphragm. In branch apex, the filament initials are cut off periclinally towards the cavity from the cells nearer to the apical cells. They are elongated longitudinally and transform into filaments later. The filament is frequently branched dichotomously or connected with the adjacent ones. The diaphragm at the septum has a single row of thin walled hyaline cells and the diaphragm is connected to both large cells and filaments.

Ecological studies on *Champia globulifera*

Results obtained on seasonal changes in growth and fruiting in *Champia globulifera* are presented below. Data collected on the environmental and hydrological parameters at the collection locality in Mandapam are presented in Fig. 11. The air temperature varied from 28.3 (February) to 32.5°C (May) and the seawater temperature varied from 27.9 (February) to 32.0°C (May). The dissolved oxygen content ranged from 3.61 (March) to 5.43 ml/l (August). Salinity ranged from 29.23 (February) to 36.0‰ (June). The phosphate concentration in seawater varied from 0.11 (October) to 0.28 µg at./l (November) whereas the silicate varied from 1.25 (May) to 31.40 µg at./l (January). Nitrite concentration ranged from 0.02 in June to 1.25 µg at./l in March and Nitrate concentration ranged from 1.00 to 3.64 µg at./l in October and September respectively.

Studies on the Growth on *Champia globulifera*

Data obtained for one year from April 1997 to March 1998 on seasonal variation in the mean height of the erect fronds, standard deviation and minimum and maximum and height are presented in Fig. 12A. The percentage of vegetative, tetrasporic and cystocarpic plants in the population is presented in Fig. 12B.

Populations of *C. globulifera* occurred in Mandapam only for 10 months during the study period from April to January. *C. globulifera* grows attached to the surface of the rocks at the edge of the sea. During low tides, the plants get exposed for a few hours. The plants are normally within 3 cm height and the maximum height was recorded was 5.15 cm in June. Boergesen (1937) reported a maximum height of 6 cm. The plant forms dense tufts, as several shoots arise from the basal disc and decumbent branches are able to form new discs, thus giving rise to new tufts. The plant is monopodial in growth and the branches are given in all directions.

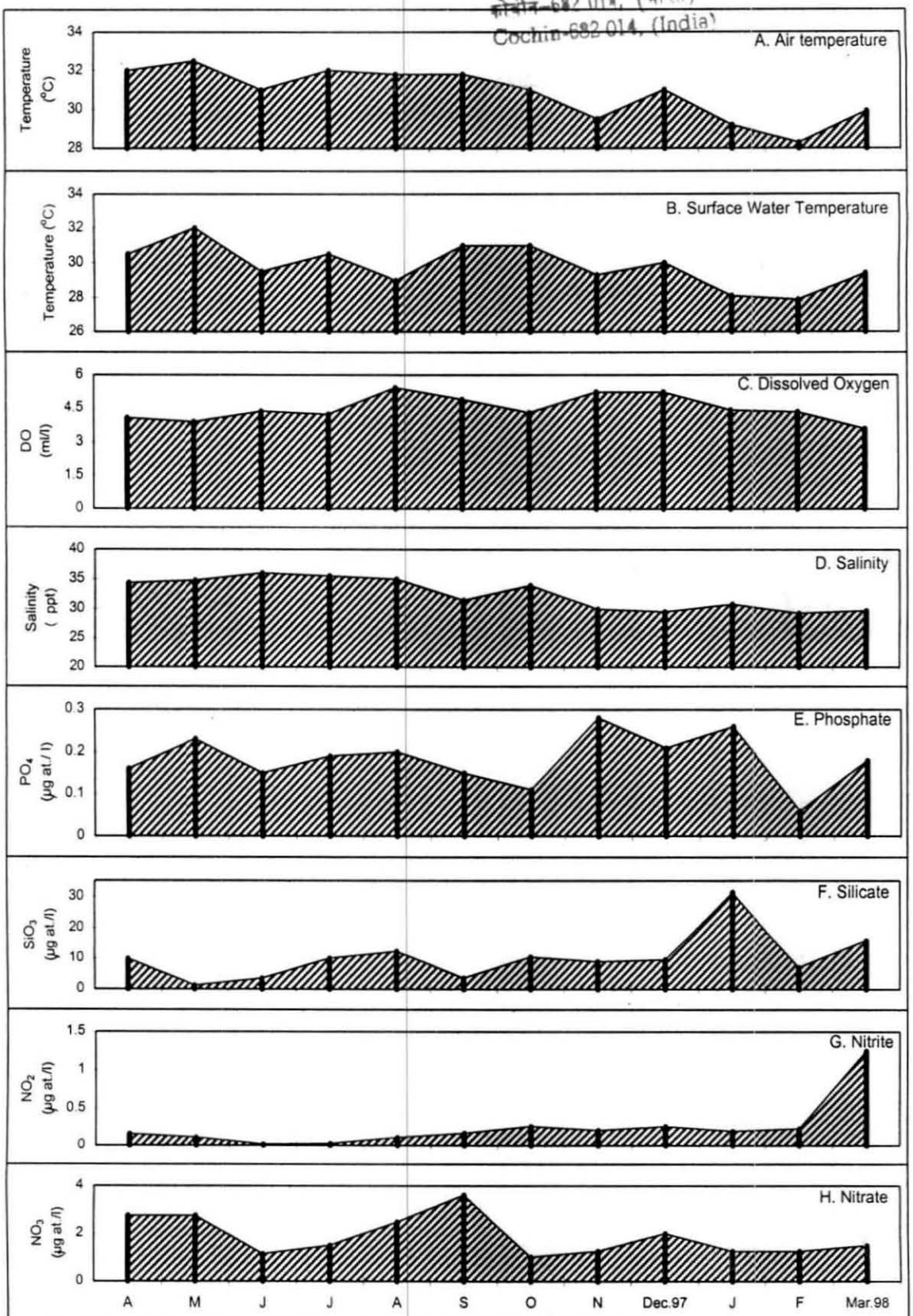


Fig.11(A-H). Monthly variations in hydrological parameters recorded at Mandapam during April 97 to March 98

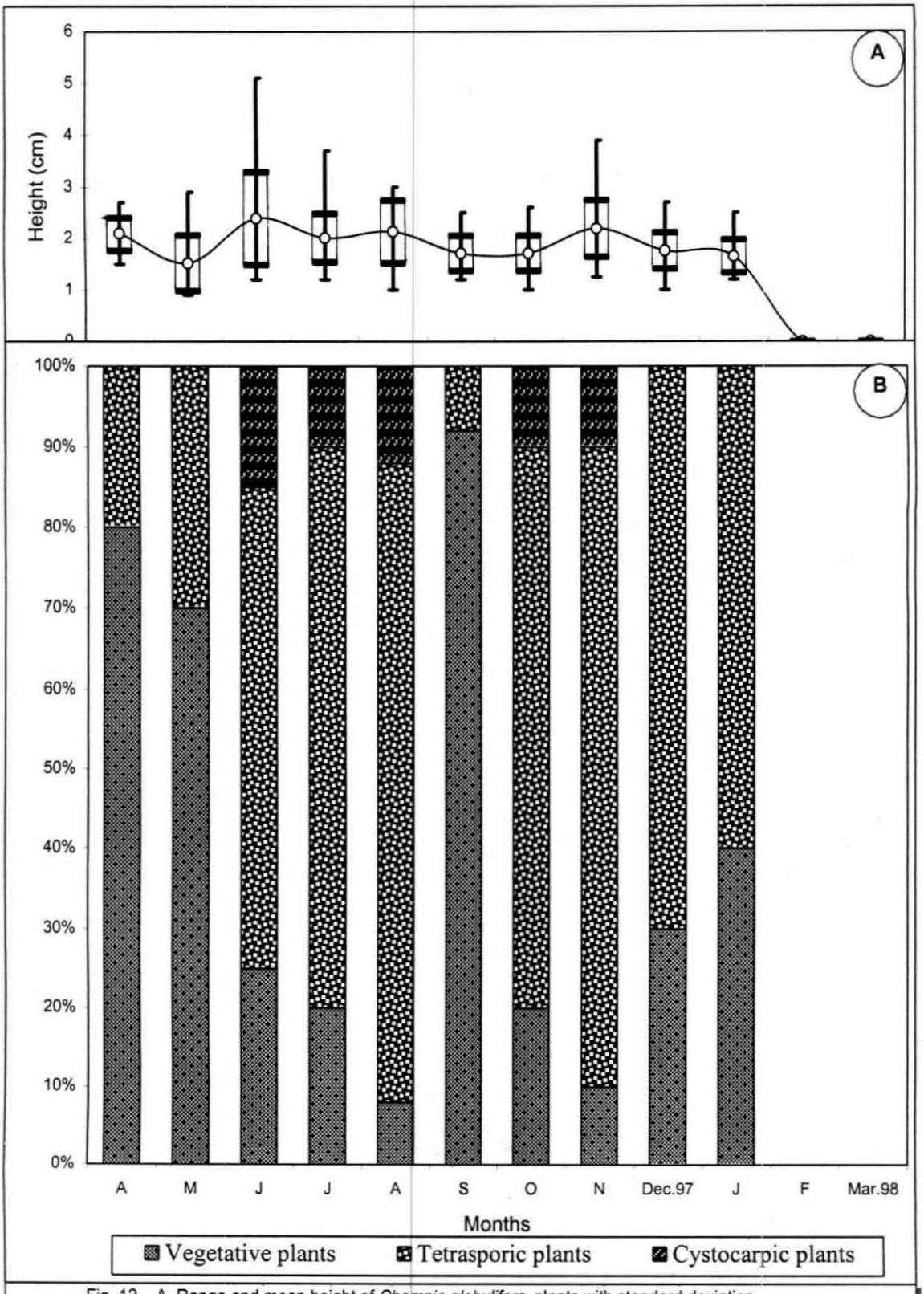


Fig. 12. A. Range and mean height of *Champia globulifera* plants with standard deviation
B. Percentage ocuurence of diffenrent sexual plants of *C. globulifera*

Two peaks with maximum height of plants could be seen in June and November. Tetrasporic plants were abundant and occurred during all 10 months of the growth period whereas the cystocarpic plants were less in number and found during five months of study only i.e. June to August and October - November. Vegetative plants occurred during all the ten months. Male plants were not found in the collections during the one year period.

Simple correlation analysis made between the hydrological parameters and growth of *Champia globulifera* (Table 1) showed a singificant positive correlation with air temperature and salinity. This indicates that increase in air temperature ($r = 0.557$; $P<0.05$) and salinity of the seawater ($r = 600$; $P<0.05$) are favourable for the growth of *Champia globulifera*.

Table.1. Simple correlation co-efficient(r) values for hydrological parameters and height of *Champia globulifera*.

Parameter	Air temp.	S. W. temp.	DO	Salinity	PO_4	SiO_3	NO_2	NO_3	Pl. height
Air temp	1.000								
SWT	0.819***	1.000							
DO	-0.006	-0.220	1.000						
Salinity	0.737**	0.471	-0.162	1.000					
PO_4	0.101	0.028	0.277	-0.061	1.000				
SiO_3	-0.454	-0.568*	-0.041	-0.308	0.363	1.000			
NO_2	-0.337	-0.157	-0.417	-0.509	-0.031	0.285	1.000		
NO_3	0.645*	0.516	0.163	0.150	0.057	-0.365	-0.162	1.000	
Pl. height	0.557*	0.320	0.477	0.600*	0.424	-0.124	-0.703**	0.171	1.000

* P< 0.05 level ** P< 0.01 level *** P< 0.001 level

SUMMARY

The order Rhodymenials consists of rather distinctive groups of algae in three families viz. Champiaceae, Lomentariaceae and Rhodymeniaceae. The members of Rhodymeniales occur in all tropical and temperate waters. A total of 35 genera and 185 species have been reported so far. In the order, Rhodymeniales, Rhodymeniaceae and Champiaceae are represented in the Indian flora with 12 and 8 species respectively.

Studies on the vegetative structure and reproductive organs of the members belonging to Champiaceae and Rhodymeniaceae have been carried out by several authors in different countries. However, only very few studies have been made so far on Indian Rhodymeniales which are rather limited to their distribution and description. Hence, studies on the vegetative structure and reproductive organs of nine species viz. *Champia compressa, C. globulifera, C. indica, C.parvula, Gastroclonium iyengarii* of Champiaceae and *Botryocladia leptopoda, Coelarthrum opuntia, Gelidiopsis variabilis* and *Rhodymenia sonderi* of Rhodymeniaceae collected from the Gulf of Mannar region in Tamil Nadu State and Okhamandal coast in Gujarat State have been made and the results obtained are presented.

Plants were collected from the intertidal region and also from shallow waters upto 6.0 m depth. Liquid specimens were prepared with 5% formalin for microtomy. Herbarium was also prepared.

Parts of the specimens with important stages were cut into small bits (1.0 to 1.5 cm long) for sectioning with microtome. Tertiary Butyl Alcohol method was used for dehydration and infiltration.

Studies on the vegetative structures and reproductive organs of the nine Indian species revealed that these species agree well with the descriptions given for these species from other countries. Observations were made on the apical cells, disphragm and gland cells of the members of Champiaceae. The apical cell is triangular and its upper angle is directed to the apical centre. These apical cells cut off the large cells perpendicular to the surface, which become longitudinally elongated and oblong later.

The branch is developed by periclinal divisions of a few large cells. Then, the divided superficial cells become the apex of the new branch, while the divided inner cells remain as a basal septum after the branch is developed. The gland cells are developed solitarily on the

filament inwards. They appear more often in the upper portion of branches and are round to elliptical in shape bearing one to three nuclei, with a maximum size of 15 μm in diameter. The longitudinal filaments developed in central cavity of the thallus are attached to the large cells and anchor at the diaphragm. In branch apex, the filament initials are cut periclinally towards the cavity from the cells nearer to the apical cells. They are elongated longitudinally and transform into filaments later. The filament is frequently branched dichotomously or connected with the adjacent ones. The diaphragm at the septum has a single row of thin walled hyaline cells and the diaphragm is connected to both large cells and filaments.

Ecological study was made on *Champia globulifera* from Mandapam of Gulf of Mannar for a period of one year (April 1997 to March 1998). Data on environmental and hydrological parameters were also collected from the collection site. Simple correlation analysis made between hydrological parameters and growth of *Champia globulifera* showed a significant positive correlation with air temperature and salinity.

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